Arthroscopic Correction of the Critical Shoulder Angle Through Lateral Acromioplasty: A Safe Adjunct to Rotator Cuff Repair

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Purpose: To investigate whether arthroscopic lateral acromioplasty reliably decreases the critical shoulder angle (CSA) and whether it is associated with damage to the deltoid or other complications. Methods: Patients undergoing arthroscopic rotator cuff repair (RCR) with lateral but without anterior acromioplasty for degenerative, full-thickness rotator cuff tears and a CSA of 34° or greater were retrospectively reviewed. Patients with traumatic or irreparable rotator cuff tears, osteoarthritis, or previous surgery were excluded. Clinical and radiographic outcomes were assessed at a minimum of 12 months’ follow-up. Results: We reviewed 49 consecutive patients (mean age, 56 years; age range, 39-76 years) at a mean of 30 months (range, 12-47 months). There were 7 RCR failures (14%). The mean CSA was reduced from 37.5° preoperatively (95% confidence interval [CI], 36.7°-38.3°) to 33.9° postoperatively (95% CI, 33.3°-34.6°; P < .001). There were no cases of dehiscence, increases in fatty infiltration, or significant atrophy of the deltoid. Scarring at the deltoid origin was noted in 18 patients (37%). The mean absolute and relative Constant scores increased from 59 points (95% CI, 54-64 points) to 74 points (95% CI, 70-78 points) and from 66% (95% CI, 61%-71%) to 80% (95% CI, 74%-86%) (P < .001 for all 3 improvements). The postoperative CSA was significantly larger in failed than in healed repairs (P = .026). Patients with a healed RCR and a CSA corrected to 33° or less (n = 22) had 25% more abduction strength than patients with a healed cuff and a CSA corrected to 35° or greater (n = 14, P = .04). Conclusions: Arthroscopic lateral acromioplasty performed in addition to arthroscopic RCR can reduce the CSA without significantly compromising the deltoid origin, deltoid muscle, or function. It is not associated with any additional complications of arthroscopic RCR. Insufficiently corrected, abnormally large CSAs are associated either with a higher retear rate or with inferior strength of abduction if the tears heal. Level of Evidence: Level IV, case series, treatment study.

The critical shoulder angle (CSA), defined as the angle between the plane of the glenoid fossa and a line connecting the inferior glenoid rim with the most lateral extension of the acromion on true anteroposterior radiographs, has been identified as one of the most important anatomic predictors of the development of degenerative rotator cuff disease. A CSA of more than 34° is associated with rotator cuff tears (RCTs). A CSA of 30° or less is a strong predictor of the absence of RCTs but is predictive of primary osteoarthritis. Experimentally, a large CSA leads to high loads on the supraspinatus (SSP) during abduction. Because reducing the CSA substantially decreases the load on the SSP, it is rational to hypothesize that reduction of an increased CSA could assist in preventing RCTs or retears. Preliminary investigations studied the effect of arthroscopic lateral acromioplasty on the CSA and the deltoid in vitro. The safety and efficacy of an in vivo CSA correction have not been reported. The purpose of this study was to investigate whether arthroscopic lateral acromioplasty as an adjunct to rotator cuff repair...
(RCR) reliably allows a large CSA to be decreased and whether it is associated with damage to the deltoid or other complications of arthroscopic RCR. We hypothesized that arthroscopic lateral acromioplasty would reliably decrease a large CSA and that it would not jeopardize the deltoid origin or cause additional complications of arthroscopic RCR.

**Methods**

The inclusion criteria were a minimum follow-up period of 12 months; a unilateral, degenerative full-thickness RCT diagnosed by magnetic resonance (MR) arthrography and corroborated during surgery; a CSA of 34° or greater; and complete preoperative clinical, radiographic, and MR arthrographic documentation. Patients with radiographic signs of advanced osteoarthritic changes or superior glenoid rim wear, traumatic RCTs, previous surgery, adhesive capsulitis, inflammatory disease, or crystal arthropathy were excluded, as were those with massive, irreparable RCTs. A degenerative RCT was defined as an RCT resulting from multifactorial causes other than trauma. Irreparability of the rotator cuff was considered if patients had chronic pseudoparalysis of active anterior flexion, if the acromiohumeral distance was less than 7 mm on a true anteroposterior radiograph, and/or if fatty infiltration of the rotator cuff muscles was greater than stage 2 according to the classification of Goutallier et al. For this retrospective review, all patients gave written consent and institutional review board approval was obtained (Ethical Committee Zurich; KEK-ZH-Nr 2014-0476).

**Surgical Indications and Technique**

The indications for surgery were weakness with or without shoulder pain, which did not respond to conservative treatment; an MRI-verified full-thickness RCT; and a CSA of at least 34° measured on a true anteroposterior radiograph. All patients were operated on in the beach-chair position under interscalene anesthesia by the senior surgeon (C.G.) or under his direct supervision. Through a posterior arthroscopic viewing portal, a standardized intra-articular examination confirmed the full-thickness RCT. The footprint was cleaned with a full-radius resector, introduced through an anterolateral portal. A biceps tenotomy was performed by use of a straight lateral portal, a standardized intra-articular examination confirmed the full-thickness RCT. The footprint was cleaned with a full-radius resector, introduced through an anterolateral portal. A biceps tenotomy was performed by use of a straight lateral portal. For an infraspinatus (ISP) tear and/or subscapularis (SSC) tear, 1 or 2 additional double-loaded metallic anchors (6.5 mm; Karl Storz) that were separated by at least 1 cm and introduced at the junction between the humeral head cartilage and the footprint at an angle of approximately 45° to the surface through the anterolateral portal by use of a straight lateral viewing portal. For an infraspinatus (ISP) tear and/or subscapularis (SSC) tear, 1 or 2 additional double-loaded anchors were used for each tendon. No. 2 nonabsorbable sutures were passed through the tendon by use of a First-Pass device (Smith & Nephew, Memphis, TN), and the single stitches were tied on top of the tendon with sliding knots. The postoperative protocol was identical to that used before performing lateral acromioplasty and consisted of wearing an abduction brace, which stabilized the arm in 30° of scapular-plane abduction for 4 to 6 weeks according to the tension necessary to perform the SSP repair. Passive range-of-motion exercises, involving abduction and elevation, were carried out from day 2. At 6 weeks, active-assisted exercises for elevation were instituted, and active unrestricted movements were allowed at 12 weeks.

Clinically, passive glenohumeral abduction and external rotation in the neutral position were measured with a handheld goniometer in the sitting patient. If postoperative passive glenohumeral abduction was limited for more than 8 but less than 12 weeks and passive external rotation of the adducted arm was pain free, prolonged postoperative stiffness was diagnosed. Adhesive capsulitis was diagnosed if passive glenohumeral abduction was limited for more than 12 weeks and passive external rotation of the adducted arm remained painful. In addition, active anterior flexion, abduction, and external rotation with the arm at the side were measured. Abduction strength, according to Constant and Murley, was measured as previously...
described with a validated electronic dynamometer (Isobex; Cursor, Bern, Switzerland). Absolute and relative Constant scores, the Subjective Shoulder Value, and the pain level (0-15 points, with 15 indicating no pain) were assessed by an examiner (L.E.) different from the operating surgeon. The minimal clinically important difference (MCID) for the Constant score was defined as 10.4 points. At final follow-up, patients subjectively rated their satisfaction with the result as excellent, good, fair, or unsatisfactory. Clinical assessment of the integrity of the deltoid included palpation of the origin of the deltoid muscle or recording of any pain on contraction of the deltoid with the arm in a neutral position.

Measurement of the preoperative and postoperative CSA was conducted on true anteroposterior radiographs according to the method described by Moor et al. (Fig 1), with scapular malrotation inferior to 20° of internal rotation or extension and inferior to 20° of external rotation or flexion. This method has been validated as an interobserver- and intraobserver-independent method for conventional radiographs of the quality used in our study. In addition, preoperative and postoperative lateral and axillary views were routinely obtained and excluded os acromiale, fracture of the acromion, and heterotopic ossification. All patients underwent magnetic resonance imaging (MRI) at final follow-up because repeat MR arthrography did not receive institutional review board clearance. On MRI, the deltoid origin was evaluated for dehiscence, scarring, and thickness; the muscle, for thickness and fatty infiltration. Dehiscence was defined as any discontinuity of any part of the deltoid origin on the acromion depicted as an area of no signal intensity on all sequences (T1-weighted, T2-weighted, and proton density fat saturation images). Scarring of the deltoid was defined as an area of low signal intensity in the intramuscular tissue on all sequences (T1-weighted, T2-weighted, and proton density fat saturation images; Fig 2). The thickness of the deltoid origin was measured in 4 zones on T2-weighted scans in the scapular plane (Fig 3). Fatty infiltration was identified on transverse T1-weighted images at the level of the coracoid tip and graded according to Fuchs et al. Atrophy of the deltoid was measured by comparing the preoperative and postoperative muscle belly thickness of the anterior, middle, and posterior deltoid on transverse T2-weighted MRI scans at the level of the coracoid tip (Fig 4).

At final follow-up, fatty infiltration, atrophy of the SSP according to the tangent sign, preoperative mediolateral retraction of the SSP tendon stump and

**Fig 1.** Correction of the critical shoulder angle (CSA) measured on true anteroposterior radiographs before and after lateral acromioplasty. (A) The depicted preoperative CSA of 39° is typically associated with degenerative rotator cuff disease. (B) The CSA was corrected to 33°. This angle lies within the favorable range in which the CSA is associated with neither osteoarthritis nor rotator cuff disease.
muscle, mediolateral length of the tendon stump, preoperative anteroposterior global tear extension, and postoperative repair integrity were recorded on MRI. Muscle retraction was defined as the distance from the lateral edge of the humeral articular surface (transition of the cartilage and the SSP footprint) to the myotendinous junction. The myotendinous junction was defined as the most lateral point at which inserting muscle fibers on the central tendon could be detected. Global tear extension was measured in the T2-weighted parasagittal plane through the center of the humeral head. The exact degree of anterior (SSC) and posterior (ISP and teres minor) tear extension was defined as the angle between the remaining anterior and posterior rotator cuff attachments. Integrity of the repair was defined as continuous rotator cuff attachment of the repaired tendon on all sequences.

All imaging studies were analyzed by consensus readout of 2 authors (C.G. and L.E.) who were blinded to the names of the patients and the clinical outcome. All unintended, unexpected perioperative local and systemic events potentially in relation with the treatment were recorded as complications.

**Statistical Analysis**

The statistical analysis was carried out by a professional biostatistician. Normal distribution of data was tested according to the Shapiro-Wilk test. Dependent samples were compared by use of a paired \( t \) test for normally distributed data and by the Wilcoxon signed rank test for non-normally distributed data. Independent samples were compared by an unpaired \( t \) test if data were normally distributed and by the Mann-Whitney \( U \) test if data were not normally distributed. For comparison of categorical data, the \( \chi^2 \) test and Fisher exact test (if \( n < 5 \)) were used. Correlations were assessed with the Pearson correlation coefficient (parametric measures) or Spearman rank correlation coefficient (nonparametric measures). All \( P \) values were 2 tailed, and the \( \alpha \) level was set to .05. The 95% confidence intervals (CIs) were included for most results.

**Results**

From January 2012 to December 2014, 59 patients (41 men and 18 women) with a mean age of 57 years (range, 39-76 years) underwent arthroscopic RCR with concomitant lateral acromioplasty for a unilateral, degenerative full-thickness RCT and a CSA of at least 34\(^\circ\). Of these patients, 9 (15\%) were not available for review and 1 (2\%) had died.

The mean age of the remaining patients, 36 men and 13 women, was 56 years (range, 39-76 years). Their demographic characteristics are summarized in Table 1. Of the patients, 21 (43\%) had a single-tendon tear, 24 (49\%) had a 2-tendon tear, and 4 (8\%) had a 3-tendon...
In 17 patients (35%) only the SSP tendon was affected, and in 4 patients (8%) only the SSC tendon was affected. The SSP tear extended into the SSC tendon in 22 cases (45%) and into the ISP tendon in another 2 cases (4%). All 3 tendons were involved in 4 shoulders (8%). The mean preoperative SSP tendon stump retraction was 12 mm (range, 3-38 mm; 95% CI, 9-15 mm); mean muscle retraction, 27 mm (range, 13-48 mm; 95% CI, 23-30 mm); mean length of the tendon stump, 15 mm (range, 7-22 mm; 95% CI, 13-16 mm); and mean anteroposterior global tear extension, 108° (range, 41°-226°; 95% CI, 91°-126°) (Table 2).

**Clinical Outcome**

Clinical outcomes are summarized in Table 3. At a mean follow-up of 30 months (range, 12-47 months), the mean absolute and relative Constant scores had improved from 59 points (range, 10-92 points; 95% CI, 54-64 points) to 74 points (range, 37-92 points; 95% CI, 70-78 points; \( P < .001 \)) and from 66% (range, 12%-96%; 95% CI, 61%-71%) to 83% (range, 49%-100%; 95% CI, 79%-87%; \( P < .001 \)), respectively. This improvement exceeded the defined MCID. The average pain level improved from 8 points preoperatively to 12 points postoperatively (\( P < .001 \)). The mean Subjective Shoulder Value increased from 45% (range, 5%-85%; 95% CI, 39%-50%) to 80% (range, 20%-100%; 95% CI, 74%-86%; \( P < .001 \)). Active anterior shoulder flexion and abduction increased from 135° to 151° (\( P = .005 \)) and from 130° to 150° (\( P = .002 \)), respectively. Of the patients, 33 (67%) rated their results as excellent, 6 (12%) as good, 6 (12%) as fair, and 4 (8%) as unsatisfactory.

![Fig 3](image1.png)

Fig 3. Measurement of the thickness of the proximal deltoid origin on magnetic resonance imaging scans in the scapular plane. (A) The proximal deltoid origin was divided into 4 zones: anterior acromion (Z 1), anterior third of the lateral acromial border (Z 2), middle third of the lateral acromial border (Z 3), and posterior third of the lateral acromial border (Z 4). (B) Magnetic resonance imaging scan after arthroscopic lateral acromioplasty. The minimal thickness of the deltoid origin (A) in each zone was determined by measuring the length perpendicular to the deltoid fibers.

![Fig 4](image2.png)

Fig 4. Measurement of the thickness of the muscle belly of the anterior, middle, and posterior deltoid (arrows counterclockwise starting from the top) on a transverse magnetic resonance imaging scan with the arm at the side in neutral rotation. At the level of the coracoid tip, the anterior and posterior deltoid volume was measured along a section of line B, which is parallel to the glenoid plane (line A) and passes through the center of the humeral head. The middle deltoid muscle volume was measured along a section of line C, which is perpendicular to line A and also passes through the center of the humeral head.
Mean abduction strength improved from 8 points preoperatively (range, 0-25 points; 95% CI, 6-9 points) to 10 points postoperatively (range, 0-19 points; 95% CI, 9-11 points; \(P = 0.003\)). The 22 patients with a healed RCR and a CSA corrected to 33\(^\circ\)/C14 or less had 25% more abduction strength (mean, 12 points; range, 2-19 points; 95% CI, 8-12 points) than the 14 shoulders with a healed cuff and a CSA corrected to 35\(^\circ\)/C14 or greater (mean, 9 points; range, 3-14 points; 95% CI, 8-13 points; \(P = 0.04\)). Clinical evaluation of the integrity of the deltoid muscle did not show any deformity nor did patients report pain.

**Radiographic Outcome**

At final follow-up at a mean of 30 months (range, 12-47 months), neither acromial fractures nor heterotopic ossification was observed. The mean CSA was reduced from 37.5\(^\circ\) preoperatively (range, 34\(^\circ\)-44\(^\circ\); 95% CI, 36.7\(^\circ\)-38.3\(^\circ\)) to 33.9\(^\circ\) postoperatively (range, 30\(^\circ\)-38\(^\circ\); 95% CI, 33.3\(^\circ\)-34.6\(^\circ\); \(P < 0.001\)) (Table 2).

In terms of safety of the procedure, there were no cases of dehiscence of the deltoid origin or increases in the amount of deltoid fatty infiltration postoperatively (Table 2). Postoperative scarring at the deltoid origin was found in 18 patients (37%). The mean longitudinal length of the deltoid scar was 8 mm (range, 5-16 mm; 95% CI, 6.5-9.6 mm). The mean preoperative and postoperative thicknesses of the proximal deltoid in zones 1 to 4 and of the muscle belly are depicted in Table 4. Overall, no significant thinning of the deltoid origin was observed postoperatively. The relative postoperative decrease in thickness was 4%, 4%, 2%, and 2% in zone 1, zone 2, zone 3, and zone 4, respectively. Although not significant, the mean muscle belly thickness of the anterior (2%), middle (3%), and posterior (4%) deltoid was increased postoperatively.

Mean fatty infiltration of the cuff muscles progressed in the SSP (from 0.7 to 1.0, \(P = 0.009\)), ISP (from 0.4 to 0.8, \(P < 0.001\)), and SSC (from 0.3 to 0.6, \(P < 0.001\)) (Table 2). Preoperatively, there were 7 positive tangent signs (14%); postoperatively, there were 8 positive tangent signs, 4 of which occurred in shoulders with a failed SSP repair.

The repair failure rate was 14% (\(n = 7\)), with 2 failures of an isolated SSP repair; 4 failures of a 2-tendon repair, involving the SSP and SSC in 3 patients and the SSP and ISP in 1 patient; and 1 failure of a 3-tendon repair. Failed repairs were significantly associated with more preoperative SSP tendon stump retraction (20 mm [range, 6-38 mm; 95% CI, 11-30 mm] vs 9 mm

### Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>49</td>
</tr>
<tr>
<td>Age, mean (range), yr</td>
<td>56 (39-76)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>36 (73)</td>
</tr>
<tr>
<td>Surgery on dominant side, n (%)</td>
<td>41 (84)</td>
</tr>
<tr>
<td>Smokers, n (%)</td>
<td>15 (31)</td>
</tr>
<tr>
<td>Type 2 diabetes mellitus, n (%)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Laborer, n (%)</td>
<td>23 (47)</td>
</tr>
</tbody>
</table>

### Table 2. Preoperative and Postoperative Radiographic and MRI Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>(P) Value</th>
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</thead>
<tbody>
<tr>
<td>Radiography</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSA, (^\circ)</td>
<td>37.5 (34-44)</td>
<td>33.9 (30-38)</td>
<td>(&lt;0.001)*</td>
</tr>
<tr>
<td>Acromion fracture, n (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Heterotopic ossification, n (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>MRI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deltoid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dehiscence, n (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Scarring, n (%)</td>
<td>0 (0)</td>
<td>18 (37)</td>
<td></td>
</tr>
<tr>
<td>Longitudinal length, mm</td>
<td></td>
<td>8 (5-16)</td>
<td></td>
</tr>
<tr>
<td>FI, n (%)</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Rotator cuff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSP FI</td>
<td>0.7 (0-2)</td>
<td>1.0 (0-4)</td>
<td>(0.009)*</td>
</tr>
<tr>
<td>ISP FI</td>
<td>0.4 (0-2)</td>
<td>0.8 (0-3)</td>
<td>(&lt;0.001)*</td>
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<tr>
<td>TM FI</td>
<td>0.1 (0-2)</td>
<td>0.2 (0-3)</td>
<td>(0.058)</td>
</tr>
<tr>
<td>SSC FI</td>
<td>0.3 (0-2)</td>
<td>0.6 (0-4)</td>
<td>(&lt;0.001)*</td>
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<tr>
<td>SSP atrophy, n (%)</td>
<td>7 (14)</td>
<td>8 (16)</td>
<td></td>
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<tr>
<td>Preoperative SSP tendon stump retraction, mm</td>
<td>12 (3-38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative SSP muscle retraction, mm</td>
<td>27 (13-48)</td>
<td></td>
<td></td>
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<tr>
<td>Preoperative SSP tendon length, mm</td>
<td>15 (7-22)</td>
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<tr>
<td>Preoperative anteroposterior global tear extension, (^\circ)</td>
<td>108 (41-226)</td>
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</tr>
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</table>

**NOTE.** Data are presented as mean (range) unless otherwise indicated.

CSA, critical shoulder angle; FI, fatty infiltration; ISP, infraspinatus; MRI, magnetic resonance imaging; SSC, subscapularis; SSP, supraspinatus; TM, teres minor.

*Significant difference between preoperative and postoperative results.

Descriptive analysis only.
On T2-weighted magnetic resonance imaging scans in the scapular plane, the proximal deltoid origin was divided into 4 zones: anterior (zone 1), anterior third of the lateral acromial border (zone 2), middle third of the lateral acromial border (zone 3), and posterior third of the lateral acromial border (zone 4). Measurement of muscle belly thickness on T2-weighted transverse magnetic resonance imaging scans was conducted on the anterior, middle, and posterior deltid at the level of the coracoid tip.

Table 3. Preoperative and Postoperative Functional Scores, Pain Levels, Subjective Shoulder Values, Range-of-Motion Values, and Patient Outcome Satisfaction Ratings

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Range (95% CI)</td>
</tr>
<tr>
<td>Constant score</td>
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</tr>
<tr>
<td>Absolute, points</td>
<td>59</td>
<td>10-92 (54-64)</td>
</tr>
<tr>
<td>Relative, %</td>
<td>66</td>
<td>12-96 (61-71)</td>
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<tr>
<td>Pain, points</td>
<td>8</td>
<td>0-15 (7-9)</td>
</tr>
<tr>
<td>Abduction strength, points</td>
<td>8</td>
<td>0-25 (6-9)</td>
</tr>
<tr>
<td>Subjective Shoulder Value, %</td>
<td>45</td>
<td>5-85 (39-50)</td>
</tr>
<tr>
<td>Active range of motion, °</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior flexion</td>
<td>135</td>
<td>30-180 (124-146)</td>
</tr>
<tr>
<td>Abduction</td>
<td>130</td>
<td>30-180 (119-142)</td>
</tr>
<tr>
<td>External rotation</td>
<td>51</td>
<td>5-90 (45-56)</td>
</tr>
<tr>
<td>Satisfaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>33 (67)</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>6 (12)</td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>6 (12)</td>
<td></td>
</tr>
<tr>
<td>Unsatisfactory</td>
<td>4 (8)</td>
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CI, confidence interval.

*Significant difference between preoperative and postoperative results.

Descriptive analysis with absolute and relative values only.

Table 4. Preoperative and Postoperative Thickness of Proximal Deltoid Origin and Muscle Belly

<table>
<thead>
<tr>
<th>Area</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>Discrepancy, %</th>
<th>P Value</th>
</tr>
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<tbody>
<tr>
<td>Mean, mm</td>
<td>Range (95% CI)</td>
<td>Mean, mm</td>
<td>Range (95% CI)</td>
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<tr>
<td>Zone 1</td>
<td>6.0</td>
<td>3.1-11.1 (5.5-6.6)</td>
<td>5.8</td>
<td>3.1-10.9 (5.3-6.4)</td>
</tr>
<tr>
<td>Zone 2</td>
<td>6.5</td>
<td>3.3-11.4 (6.0-7.0)</td>
<td>6.2</td>
<td>3.2-11.0 (5.7-6.8)</td>
</tr>
<tr>
<td>Zone 3</td>
<td>7.2</td>
<td>3.9-11.4 (6.7-7.8)</td>
<td>7.1</td>
<td>3.9-11.7 (6.7-7.6)</td>
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<tr>
<td>Zone 4</td>
<td>8.0</td>
<td>3.6-11.3 (7.6-8.5)</td>
<td>7.8</td>
<td>4.3-11.8 (7.4-8.3)</td>
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<tr>
<td>Anterior</td>
<td>18.8</td>
<td>9.6-26.0 (17.7-19.9)</td>
<td>19.2</td>
<td>9.2-31.5 (17.9-20.5)</td>
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<tr>
<td>Middle</td>
<td>10.3</td>
<td>6.0-23.6 (9.4-11.2)</td>
<td>10.7</td>
<td>4.3-26.4 (9.7-11.6)</td>
</tr>
<tr>
<td>Posterior</td>
<td>28.0</td>
<td>13.6-45.0 (25.8-30.1)</td>
<td>29.0</td>
<td>15.7-40.7 (27.2-30.9)</td>
</tr>
</tbody>
</table>

NOTE. On T2-weighted magnetic resonance imaging scans in the scapular plane, the proximal deltid origin was divided into 4 zones: anterior acromion (zone 1), anterior third of the lateral acromial border (zone 2), middle third of the lateral acromial border (zone 3), and posterior third of the lateral acromial border (zone 4). Measurement of muscle belly thickness on T2-weighted transverse magnetic resonance imaging scans was conducted on the anterior, middle, and posterior deltid at the level of the coracoid tip.

CI, confidence interval.

Postoperative decrease in mean thickness of the proximal deltid origin in zones 1 through 4 and muscle belly of the anterior, middle, and posterior deltid.
more, active abduction (125.060). Improvement clearly exceeded the de
muscle.14,15
without signi
arthroscopic lateral acromioplasty can be performed
liminary in vitro studies, which had suggested that
problems. The results thereby con
or by studying clinical symptoms attributable to deltoid
ss transfers the SSP load to the deltoid, allowing protec-
to the deltoid, whether studied with advanced imaging

Discussion

In this study, reduction of a CSA was safely possible
with arthroscopic lateral acromioplasty. It did not
significantly damage the deltoid origin or muscle or
generate other complications. The procedure was
associated with a clinical outcome of RCR, which is at
least comparable to that of other RCR techniques re-
ported.37,38 The ultimate strength for abduction in
healed repairs was greater if the CSA was reduced to
33° or below and the repairs, which had failed to heal,
had larger (preoperative and) postoperative CSAs.
These data are compatible with the experimental
finding that reduction of an abnormally large CSA
transfers the SSP load to the deltoid, allowing protec-
tion of the SSP and generation of more abduction
power by more effective use of the deltoid.6,12,13

This mechanism, however, can only be effective if the
deltoid muscle is not compromised by a procedure that
reduces the CSA. This study shows that lateral acro-
mioplasty can be performed without significant damage
to the deltoid, whether studied with advanced imaging
or by studying clinical symptoms attributable to deltoid
problems. The results thereby confirm in vivo the pre-
liminary in vitro studies, which had suggested that
arthroscopic lateral acromioplasty can be performed
without significant risk to the deltoid origin and
muscle.14,15

Although the mean correction of the CSA to 33.9°
was approximately as desired, the correction obtained
was not satisfactory in each case. The exact amount of
required lateral resection was not precisely measured at
the beginning of this study, and a technique to allow
resection of the precise amount of the lateral acromion
was not in place. We now plan to go to 33°, measure
the amount of resection to be performed on true
anteroposterior radiographs, translate the distance to
the undersurface of the acromion with a calibrated
probe, and mark it with electrocautery. In addition, we
use the MR images to determine the angle between the
lateral border of the acromion and the glenoid fossa,
which allows us to estimate whether more of the
anterior acromion or more of the posterior acromion
has to be removed to correct the CSA more precisely.
This has more recently helped us to prevent insuf-
icient resection. Currently, we aim at a normal CSA that is
epidemiologically associated with neither osteoarthritis
nor rotator cuff disease, but we are aware that the ideal
CSA to aim for is not yet established. The fact that
insufficient CSA reduction was associated with a higher
rate of nonhealing and with lower abduction strength if
the repairs had healed suggests that CSA reduction has
to be performed quantitatively.

Anterior acromioplasty effectively relieves pain39 but
does not prevent the development of RCTs.40 It does
not have an experimental rationale and addresses
acromial changes, which are now considered to be due
to rotator cuff weakness and tearing.31,42 Conversely,
lateral acromial shortening does reduce the load on the
SSP during scapular-plane elevation at the expense of
higher loading of the deltoid and thereby has the
potential to assist in preventing chronic overload of the
SSP tendon.

Limitations

This study does not attempt to prove the need for or
superiority of lateral acromioplasty over RCR with or
without anterior acromioplasty. It tested the safety of a
biomechanically sound and clinically potentially bene-

fic adjunct to RCR. Although a minimal follow-up
period of 12 months may be criticized, we believe this
period and the mean follow-up period of 30 months are
largely sufficient to study the integrity of the deltoid
origin and muscle after acromioplasty. In addition, the
structural cuff retear rate is unlikely to change between
1 and 2 years postoperatively.

Limitations of this study include the retrospective
design and its associated bias, a missing control group,
and a single RCR technique. There was also no a priori
power analysis, and the sample size is limited for
meaningful subgroup analyses such as the differences
between the healed and failed RCR groups. Because
this is a phase 1 study of lateral acromioplasty with all
available patients included, we believe that, with the
information provided, it is ethically justified and
scientifically warranted to conduct further prospective,
randomized studies comparing the results of RCR with
and without lateral acromioplasty. Another limitation is
the certain heterogeneity in terms of tendons involved
leading to selection bias, which could affect the out-
comes and the ability to compare our results with those
of previous studies. On the basis of our strict inclusion

(85%; range, 49%-100%; 95% CI, 79%-89%; P = .060). Improvement clearly exceeded the defined
MCID. The mean final Subjective Shoulder Value was
significantly inferior in the patients with failed repairs
(69%; range, 20%-98%; 95% CI, 37%-94%) compared with those with healed repairs (88%; range,
30%-100%; 95% CI, 74%-89%; P = .025). Furthermore, active abduction (125° [range, 75°-170°; 95% CI,
90°-162°] vs 154° [range, 80°-180°; 95% CI, 145°-
162°] for healed repairs; P = .022) and abduction
strength (6 points [range, 0-9 points; 95% CI, 1-9
points] vs 10 points [range, 3-18 points; 95% CI, 9-12
points) for healed repairs; P = .022) were significantly
inferior in the patients with failed repairs.

Complications

There were no intraoperative complications. There
were no executed or planned revisions. Some
prolonged postoperative stiffness occurred in 11
patients (22%).
and exclusion criteria, the impact of this potential bias is limited.

Conclusions

Arthroscopic lateral acromioplasty performed in addition to arthroscopic RCR can reduce the CSA without significantly compromising the deltoid origin, deltoid muscle, or function. It is not associated with any additional complications of arthroscopic RCR. Insufficiently corrected, abnormally large CSAs are associated either with a higher retear rate or with inferior strength of abduction if the tears heal.

References

9. Spieg UJ, Horan MP, Smith SW, Ho CP, Millett PJ. The critical shoulder angle is associated with rotator cuff tears and shoulder osteoarthritis and is better assessed with radiographs over MRI. Knee Surg Sports Traumatol Arthrosc 2016;24:2244-2251.