The Effects of Arthroscopic Lateral Acromioplasty on the Critical Shoulder Angle and the Anterolateral Deltoid Origin: An Anatomic Cadaveric Study

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Purpose: To investigate if (1) an anterolateral acromioplasty and (2) a lateral acromion resection alter the critical shoulder angle (CSA) without affecting the deltoid origin. **Methods:** First, the native CSAs of 10 human cadaveric shoulders (6 male and 4 female specimens; mean age, 54.2 years) were determined with the use of fluoroscopy. Setup allowed for consistent repetitive measurements. Next, a standard arthroscopic anterolateral acromioplasty was performed to create a type 1 acromion, and the CSA was reassessed fluoroscopically. Afterward, a lateral acromioplasty was performed with a 5-mm lateral acromion resection using a 5-mm burr, and the CSA was measured again. The native CSA was compared with (1) the CSA after acromioplasty and (2) the CSA after acromioplasty and lateral acromion resection using a paired *t* test. Finally, the acromial deltoid attachment was evaluated anatomically for damage to the anterolateral origin. **Results:** The mean native CSA (34.3° ± 2.1°) was reduced significantly by acromioplasty (33.1° ± 2.0°, $P < .001$) and further reduced by lateral acromion resection (31.5° ± 1.7°, $P < .001$). Anterolateral acromioplasty reduced the CSA by a mean of 1.4° (95% confidence interval boundaries, 0.8° and 1.9°), and in combination with lateral acromion resection, the CSA was reduced by a mean of 2.8° (95% confidence interval boundaries, 2.1° and 3.5°). In all specimens (5 of 5) with a presurgery CSA of 35° or greater, the CSA was reduced to the range of 30° to 35° by the combination of both techniques. However, in 2 specimens with a CSA of approximately 32°, the CSA was reduced to less than 30°. The acromial deltoid attachment was found to be well preserved in all specimens. **Conclusions:** Arthroscopic anterolateral acromioplasty and a 5-mm lateral acromion resection each reduced the CSA significantly and did not damage the deltoid origin. **Clinical Relevance:** The combination of both techniques could potentially be used in clinical practice to reduce a CSA greater than 35° to the desired range of 30° to 35°.

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Symptomatic rotator cuff tears (RCTs) are common.[1,2] Degenerative, nontraumatic RCTs result from multifactorial causes that are not fully understood.[3,4] The scapular bony morphology, however, has been identified to play a major role in the formation of atraumatic RCTs.[5-13] A large lateral acromion extension, as indicated by the acromion index, and an increased glenoid inclination are each associated with full-thickness RCTs.[5,10-13] The critical shoulder angle (CSA) is a radiologic parameter that combines the measurements of inclination of the glenoid and the lateral extension of the acromion (the acromion index).[6] A CSA greater than 35° is associated with RCTs, and a CSA smaller than 30° is associated with glenohumeral osteoarthritis.[6,14,15] The "favorable" range of the CSA seems to exist between 30° and 35°.

The effect a standard anterolateral acromioplasty has on the CSA is unknown, and the literature lacks potential techniques to reduce the CSA surgically. The aims of this study were therefore to investigate if (1) a standard anterolateral acromioplasty and (2) a lateral acromion resection alter the CSA without affecting the deltoid origin. It was hypothesized that a standard anterolateral

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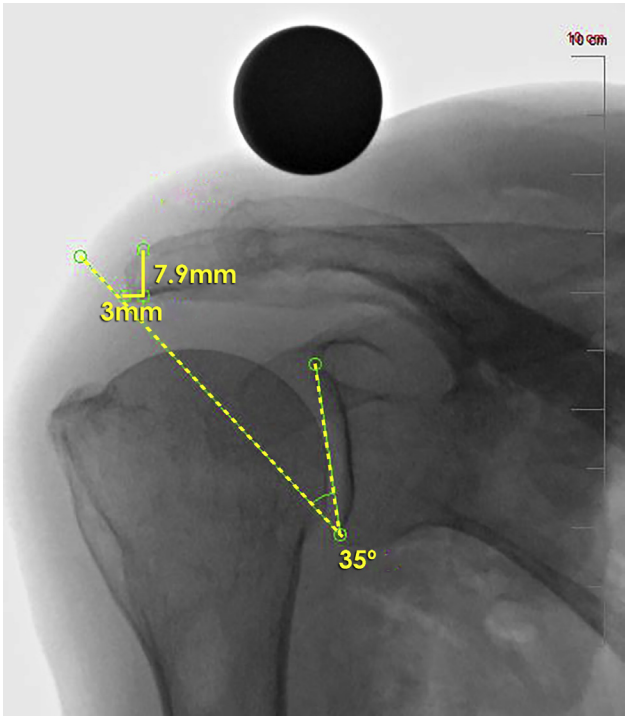

Fig 1. Preoperative true anteroposterior fluoroscopy showing critical shoulder angle (35°) and acromial thickness (7.9 mm) measurements in a 63-year-old female specimen (right shoulder).

acromioplasty alone would not significantly alter the CSA but an additional lateral acromion resection would and that both procedures could be executed without damaging the acromial deltoid attachment.

Methods

A total of 10 fresh-frozen human shoulder cadaveric specimens (mean age, 54 years [range, 29 to 64 years]; 6 male and 4 female specimens) with no history of rotator cuff injury, surgery, or other definitive shoulder injury were included in the final analysis of this study. Each specimen was thawed at room temperature for 24 hours and rigidly mounted to a shoulder surgical tower by clamping of the scapula. The native CSA of each human cadaveric specimen was determined with fluoroscopy (Fig 1) using a mobile C-arm. The surgical tower and C-arm positions were recorded to ensure consistency among subsequent measurements. Next, a standard arthroscopic anterolateral acromioplasty was performed using a modified cutting-block technique to create a Bigliani type 1 acromion (Fig 2), and the CSA was reassessed fluoroscopically (Fig 3). Similar to clinical practice, the acromioplasty varied from individual to individual depending on the anatomy of the anterolateral acromion. In each case (before and after standard anterolateral acromioplasty), both the CSA

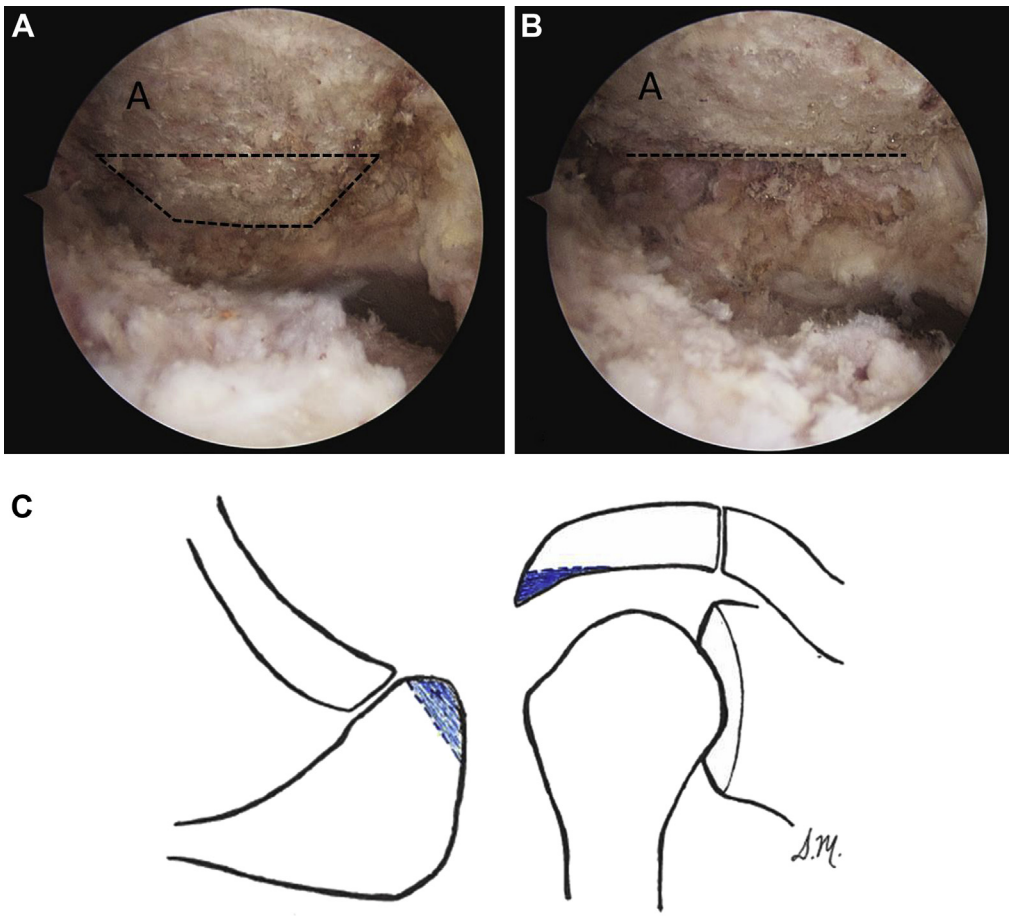

Fig 2. Standard anterolateral acromioplasty. Shoulder arthroscopy of the subacromial space through a posterior viewing portal in a 63-year-old female specimen (right shoulder) (A) before standard anterolateral acromioplasty (in which the dotted line indicates the area to be resected) and (B) after standard anterolateral acromioplasty (in which the dotted line indicates the resection line after acromioplasty). (C) View from undersurface (left) and anteroposterior view (right). Blue hatching indicates the area of anterolateral acromioplasty. (A, acromion.)

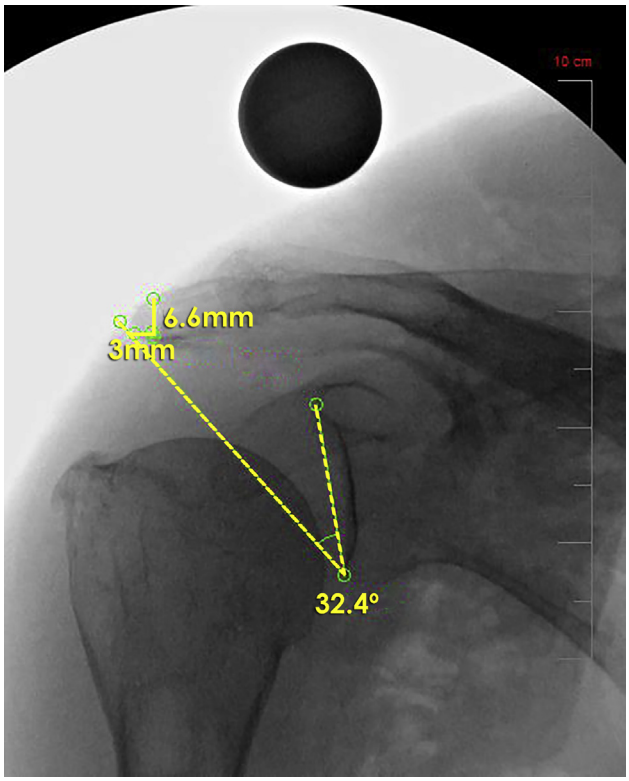

Fig 3. True anteroposterior fluoroscopy after standard anterolateral acromioplasty showing critical shoulder angle (32.4°) and acromial thickness (6.6 mm) measurements in a 63-year-old female specimen (right shoulder).

and acromion thickness were measured with PACS OrthoCase Imaging software (Merge Healthcare, Chicago, IL). A 1-inch radiopaque sphere was included directly in the imaging plane and used to calibrate the measurements (Fig 1). The CSA was measured according to the technique described by Moor et al.[6] The measurement of the lateral acromion thickness was implemented 3 mm medial to the most lateral extension (Fig 3).

By use of a 5-mm burr, a lateral acromioplasty was performed next with a 5-mm lateral acromion resection (Fig 4), and the CSA and acromion thickness were assessed once more fluoroscopically (Fig 5). After the lateral acromion resection, the native CSA was compared with (1) the CSA after standard anterolateral acromioplasty and (2) the CSA after acromioplasty and lateral acromion resection. In addition, the effect both surgical steps had on the lateral acromion thickness was evaluated. To assess the inter-rater agreement, all measurements were performed independently by 2 investigators (J.C.K. and D.C.M.).

After completion of all surgical procedures by a single orthopaedic surgeon (J.C.K.), each shoulder was dissected by an independent research assistant (D.C.M.) and the acromial deltoid attachment was assessed anatomically to evaluate any damage to the anterolateral origin. For each specimen, it was recorded whether (1) the inner deltoid sheath was damaged and (2) the deltoid origin was detached.

For statistical analysis, R version 3.2.0 (R Foundation for Statistical Computing, Vienna, Austria) was used. With the assumption of a repeated-measures design and $\alpha = .05$, 10 shoulders were analyzed to be sufficient to detect an effect size of $d = 1$ with 80% statistical power. Comparisons to the native shoulder for the acromioplasty and lateral resection states were made with a paired t test. Lateral acromial thickness was likewise compared using a paired t test. P values were adjusted for multiplicity using the Holm method. The inter-rater agreement was tested with the absolute-agreement version of the intraclass correlation coefficient (ICC).

Results

The mean native CSA (34.3° ± 2.1°) was reduced significantly by standard anterolateral acromioplasty (mean CSA, 33.1° ± 2.0°; $P < .001$) and was further reduced by lateral acromioplasty (i.e., lateral acromion resection; mean CSA, 31.5° ± 1.7°; $P < .001$) (Fig 6). Anterolateral acromioplasty reduced the CSA by a mean of 1.4° (95% confidence interval [CI] boundaries, 0.8° and 1.9°), and in combination with lateral acromion resection, the CSA was reduced by a mean of 2.8° (95% CI boundaries, 2.1° and 3.5°).

In all specimens (5 of 5) with a presurgery, native CSA of 35° or greater, the CSA was reduced to the desired range of 30° to 35° by the combination of a standard anterolateral acromioplasty and a 5-mm lateral acromion resection. However, in 2 specimens with a CSA of approximately 32°, the CSA was reduced to less than 30°. The lateral acromion thickness was reduced ($P < .001$) from a mean of 7.5 ± 1.3 mm initially to a mean of 5.0 ± 0.9 mm after both surgical steps. On average, two-thirds of the original acromion thickness remained after the procedure. The inner deltoid sheath and the acromial deltoid attachment were found to be well preserved in all 10 specimens (Fig 7). The interobserver reliability was high, with an ICC of 0.94 (95% CI boundaries, 0.82 and 0.98) for measurements of the CSA and an ICC of 0.97 (95% CI boundaries, 0.94 and 0.99) for measurements of the acromial thickness.

Discussion

Both the standard anterolateral acromioplasty alone and the standard anterolateral acromioplasty with additional lateral acromion resection reduced the CSA significantly. However, only the combination of both procedures reduced a CSA greater than 35° to the favorable range of 30° to 35°. In 2 specimens with a CSA of approximately 32°, the CSA was reduced to less than 30°. As expected, the deltoid inner sheath and acromial deltoid origin remained undamaged in all cases.

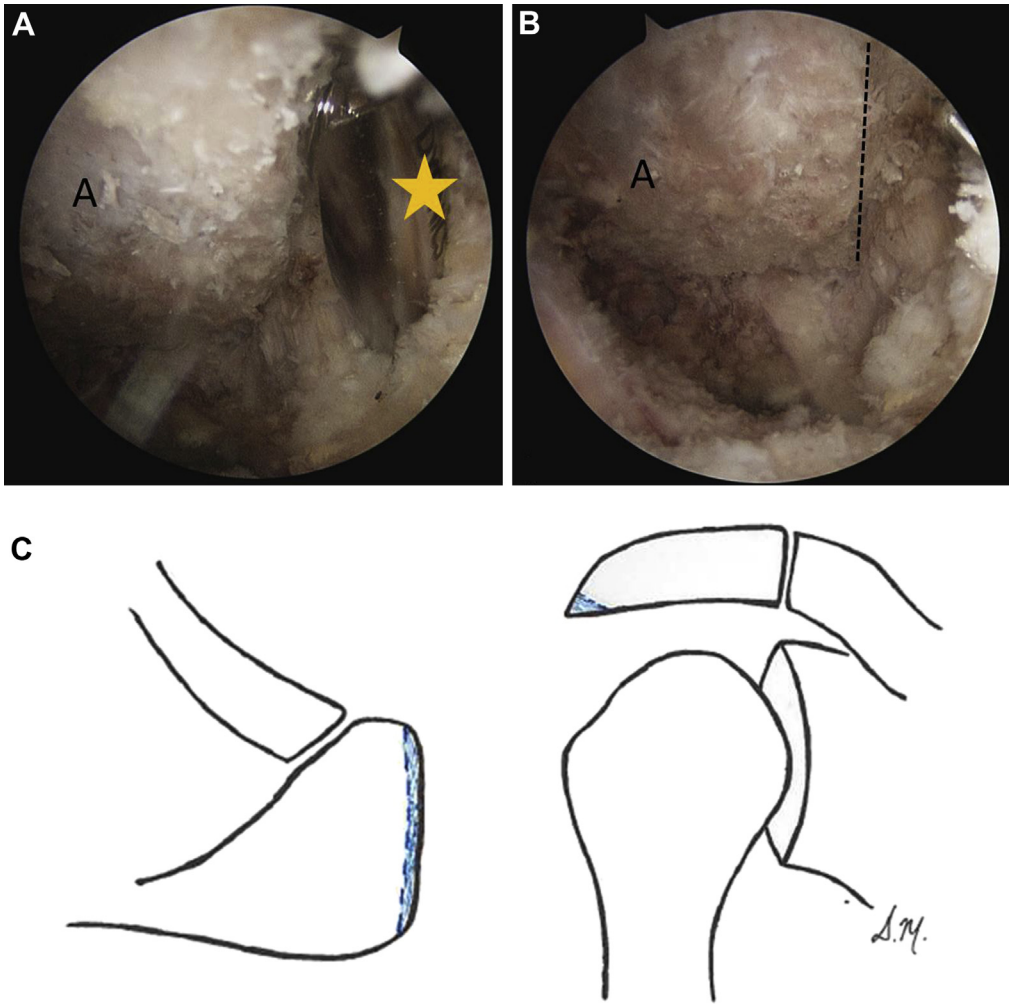

Fig 4. Lateral acromion resection. Shoulder arthroscopy of the subacromial space through a posterior viewing portal in a 63-year-old female specimen (right shoulder): (A) lateral acromion resection with 5-mm burr (star) and (B) after lateral resection (in which the dotted line indicates the resection line). (C) View from undersurface (left) and anteroposterior view (right). Blue hatching indicates the area of 5-mm lateral acromion resection. (A, acromion.)

The introduction of the CSA by Moor et al.[6] was helpful to identify patients at risk of an RCT (CSA >35°) or glenohumeral osteoarthritis (CSA <30°). Yet, the possible consequences in clinical practice have only been of a theoretical nature thus far. As such, 2 primary questions are currently unanswered. First, it is unknown whether the reduction of a CSA greater than 35° in patients with clinically symptomatic subacromial impingement could reduce the risk of development of a degenerative RCT. Second, it is unknown whether a reduction of the CSA in patients with a degenerative RCT associated with a large CSA could protect these patients from a future retear of the rotator cuff or help improve clinical outcomes.

The only evidence in the current literature that supports an influence of the postoperative CSA on clinical outcomes was published by Gerber et al.[16] in the context of long-term results after latissimus dorsi tendon transfer for treatment of irreparable posterosuperior RCTs. They observed inferior functional results in shoulders with a larger postoperative CSA. With findings similar to these results, Ames et al.[17] reported that patients with a larger acromial index had more disability as recorded by the Quick Disabilities of the Arm, Shoulder and Hand outcome measure and poorer physical health as measured by the Short Form 12 Physical Component Summary score. However, the effect of a postoperative CSA greater than 35° on midterm or long-term functional outcomes and on retear rates of rotator cuff repair remains unknown.

The results of this study show that a 5-mm full-width lateral acromion resection is arthroscopically feasible without damaging the acromial deltoid origin and reduces the CSA significantly. Furthermore, the combination of arthroscopic standard anterolateral acromioplasty and arthroscopic lateral acromion resection could potentially be used in clinical practice to reduce a CSA greater than 35° to the favorable range of 30° to 35°, which may lower the risk of primary RCTs or decrease retears after rotator cuff repair. The results of 2 specimens show that it is possible to reduce the CSA below 30°, possibly with a higher risk of

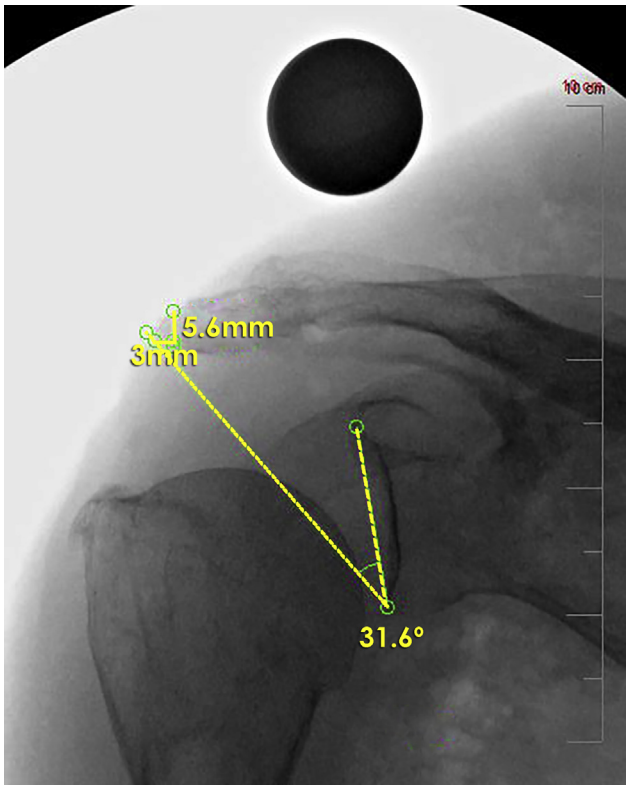

Fig 5. True anteroposterior fluoroscopy after lateral acromion resection showing critical shoulder angle (31.6°) and acromial thickness (5.6 mm) measurements in a 63-year-old female specimen (right shoulder).

Fig 7. Anatomic dissection showing undamaged acromial deltoid attachment (star) after arthroscopic lateral acromion resection (arrows).

glenohumeral osteoarthritis. This finding must be considered in clinical practice to avoid over-correction of the CSA. Future investigations should solely focus on patients with a CSA greater than 35° to determine to what extent a lateral acromion resection is needed to reduce the CSA to the desired range.

Preservation of the deltoid origin is of great importance in this context. Partial detachment of the deltoid has been observed after open and arthroscopic repair of large to massive RCTs.[18] In cases of chronic RCTs, the structural integrity of the deltoid seems to be weakened by overuse.[19] The major portion of the anterolateral fibers of the deltoid originates from the superior acromion.[20] Nonetheless, the anterior parts of the deltoid have fibers attaching to the anterior edge of the acromion.[20] As shown in this study, the deltoid inner sheath and the deltoid acromial attachment can be preserved if the standard anterolateral acromioplasty and the lateral acromion resection are carried out from the undersurface of the acromion and the anterolateral parts of the acromion are resected cautiously. The reduction of acromial thickness is another aspect to be considered as a potential risk factor for complications. However, acromion stress fractures associated with cuff tear arthropathy or reverse shoulder arthroplasty usually involve larger fragments than just the very lateral edge.[21,22] With a growing amount of lateral acromion resection, the mechanics and therefore the strength of the deltoid muscle may be changed, similar to the effect a medialized center of rotation has in reverse shoulder arthroplasty.[23] The maximum possible amount of lateral acromion resection, though, is limited by the given anatomic circumstances of the acromial deltoid attachment.

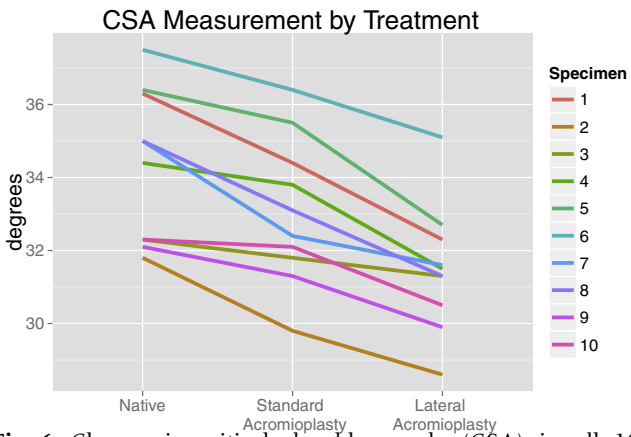

Fig 6. Change in critical shoulder angle (CSA) in all 10 specimens.

The significant effect of CSA reduction produced by standard anterolateral acromioplasty alone was

unanticipated. Nevertheless, the average amount of CSA reduction by standard anterolateral acromioplasty was minimal (1.4°) and would only bring patients with a CSA of up to 36.4° to the desired favorable range of 30° to 35°. This small of a change in CSA after standard anterolateral acromioplasty may not be clinically significant. Recently, the authors of a systematic review of 4 randomized controlled trials that reported on patients who underwent rotator cuff repair with or without acromioplasty found that results in the literature do not support the routine use of partial acromioplasty in the surgical treatment of rotator cuff disease.[24] However, arthroscopic subacromial decompression with acromioplasty was found to reduce the prevalence of RCTs in impingement patients over the long-term.[25] A more differentiated evaluation of the effect of standard anterolateral acromioplasty relating to various anatomic acromial conditions should be the subject of future clinical investigations.

Limitations

In this study, 5 of 10 specimens had a native CSA below 35°. This may be considered a limitation of the study because a reduction of the CSA only seems reasonable in cases with a native CSA greater than 35°. Nevertheless, even for those with a native CSA below 35°, both the standard anterolateral acromioplasty and the lateral acromion resection did not macroscopically damage the deltoid attachment. Insertion of the deltoid on the lateral acromion might have anatomic variability. Histologic appraisal of the violated deltoid insertion could have been useful to assess the extent of damage. In addition, there might be potential surgeon skill bias, as well as bias by the person investigating the deltoid integrity. Another limitation is that the influence that a thinned acromion has on the structural stability remains unknown. Furthermore, the CSA measurement has recently been shown to be susceptible to malposition, especially in anteversion and retroversion. However, the test setup used in this study allowed for consistent, repetitive measurements to eliminate this effect.

Conclusions

Arthroscopic anterolateral acromioplasty and a 5-mm lateral acromion resection each reduced the CSA significantly and did not damage the deltoid origin.

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