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Predictability and functional impact of lateral acromioplasty using preoperative 2D planning on the correction of the critical shoulder angle (CSA) in patients with rotator cuff repair

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Background: Rotator cuff tears are highly prevalent, and their association with critical shoulder angle (CSA) has been reported. There is controversy regarding whether the morphology of the acromion influences its incidence, as well as whether acromioplasty would impact the results of a rotator cuff repair. Lateral acromioplasty does not play a decompressive role; rather, it aims to correct the deltoid vector. According to some publications, this would achieve less loading on the repaired rotator cuff, a lower retear rate, and better function. CSA correction with lateral acromioplasty can be planned with radiography (2-dimensional [2D]), but its predictability has not been fully studied. The primary objective of this study is to evaluate the predictability of 2D planning with radiography in CSA correction in patients with rotator cuff repair. The secondary objective is to analyze the association between the correction of the CSA and the functional outcomes.
Methods: This single-center, prospective, observational, analytical study included candidates for arthroscopic repair of a rotator cuff tear with a CSA > 35°. Lateral acromioplasty was performed as planned with preoperative radiography (2D) to achieve a CSA of 35°. The degrees to be corrected were calculated. CSA was recalculated with a postoperative radiography; and the error in the planned grades to be corrected was calculated. At the end of follow-up, Visual Analog Scale, Subjective Shoulder Value (SSV), and Quick–Disabilities of the Arm, Shoulder, and Hand (Quick-DASH) scores were evaluated.
Results: Forty one cases were included, 43.9% were men, and the mean age was 55.5 ± 8.6 years. The mean preoperative and postoperative CSA were 39.6° ± 1.9° and 35.7° ± 2.3°, respectively; 41.5% achieved a postoperative CSA ≤ 35°. The mean CSA planned correction error was 45.7 ± 28.8%. At the end of the follow-up, 33 (78.6%) had a functional evaluation, with an average follow-up of 41 ± 6.8 months. The mean Visual Analog Scale, Quick-DASH, and SSV were 0.9 ± 1.6, 5.3 ± 7.5, and 92.7 ± 10.6, respectively. There was a significant difference in Quick-DASH (P = .01) and SSV (P = .02) according to whether a postoperative CSA ≤ 35° was achieved.
Conclusion: In lateral acromioplasty, planning of CSA correction with radiography (2D) is imprecise. Reaching a CSA ≤ 35° positively influences functional results.

Rotator cuff tears (RCTs) are highly prevalent, and their association with critical shoulder angle (CSA) has been published.[1,15,22,30,35,37,42,45] There is controversy regarding whether the morphology of the acromion influences its incidence, as well as whether acromioplasty would impact the results of a rotator cuff repair (RCR). Lateral acromioplasty does not play a decompressive role; rather, it aims to correct the deltoid vector.[9] In theory, this would achieve less loading on the repaired rotator cuff, a lower retear rate, and better function. CSA correction can be planned with radiography (2-dimensional [2D]), but its predictability has not been fully studied.

The primary objective of this study is to evaluate the accuracy of lateral acromioplasty 2D planning with a standardized anteroposterior (AP) X-ray in CSA correction in patients with RCR. The secondary objective is to analyze the association between CSA correction and functional outcomes.

This study was reviewed and approved by the scientific ethics committee of the Clinic (Clínica Alemana) and University (Universidad del Desarrollo), with the assigned code 2014-122.

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Materials and methods

Study design

Analytical observational study with prospective recruitment. Reviewed and approved by the scientific ethics committee of the Clinic and University, with the assigned code 2014-122.

Participants

Patients underwent acromioplasty during arthroscopic repair of degenerative RCTs, treated by the shoulder and elbow team at a single center, between August 2018 and December 2019. The inclusion criteria were patients aged more than 30 years, with a preoperative CSA > 35°, and with a minimum follow-up of 2 years. The exclusion criteria were traumatic RCT, isolated subscapularis tear, presence of os acromiale, congenital or acquired deformities, previous surgery, and inadequate (nonstandardized) true AP-view radiography.

Preoperative assessment and surgery planification

All preoperative radiographic examinations were visualized through digital Picture Archiving and Communication System and Radiology Information System (PACS-RIS). Preoperative CSA was measured with a standardized true AP-view X-ray (Suter-Henninger A1). This involved measuring the angle between the line connecting the superior and inferior glenoid margins (glenoid line) and the line connecting the inferior glenoid margin to the lateral-most aspect of the acromion (preoperative CSA line) (Fig. 1*A*). Subsequently, a planned CSA line was drawn from the inferior glenoid margin, forming a 35° angle with the glenoid line (planned CSA line). The millimeters of lateral acromion that needed to be resected were measured as the distance between the preoperative CSA lines and the planned CSA line (Fig. 1*B*). The estimated CSA correction (in degrees) was calculated as the difference between the preoperative CSA and the planned CSA (35°).

Surgical technique

Surgeries were performed by 3 senior shoulder and elbow surgeons. Anesthesia protocol included general anesthesia and ultrasound-guided interscalene regional block. Patients were operated in beach chair position. The skin was marked preoperatively, and a posterior portal was used for intra-articular visualization with a 30° scope. The subscapularis and biceps tendons were evaluated, and direct visualization of the supraspinatus and infraspinatus was performed for rupture confirmation. The number of portals, and the management of the biceps tendon (tenodesis and tenotomy) as well as subscapularis injuries were at the surgeon's discretion. The subacromial space was then evaluated from the posterior portal. A bursectomy was performed until correct visualization of the acromion and rotator cuff. The cuff repair was performed according to the surgeon's preferred technique; generally, transosseous equivalent double-row technique for tears more than 1 cm, and single row for tears equal to or less than 1 cm.

For a precise lateral acromioplasty, an arthroscopic burr was marked according to the millimeters of resection previously calculated (Fig. 2). From a posterior view, the resection was performed with the burr up to this mark.

Postoperative assessment

An immediate postoperative radiograph was obtained to measure the postoperative CSA (Fig. 1*C*). The effective correction of the CSA was calculated by subtracting the postoperative CSA from the preoperative CSA (preoperative CSA°−postoperative CSA° = Effective correction°). The CSA correction error rate was calculated as a percentage using absolute values (Correction error rate (%) = [estimated correction−effective correction/estimated correction] × 100) and classified as good (0%-25%), acceptable (25%-50%), or unsatisfactory (50%) prediction of CSA correction.

For example, in a patient with a preoperative CSA of 40°, their estimated correction (40°-35°) would be 5°. If their postoperative CSA was 34°, their effective correction (40°-34°) would be 6°. The correction error rate would be calculated as follows: ([5°-6°]/5°) × 100 = 20% (good).

Rehabilitation protocol

Rehabilitation was guided by the team of musculoskeletal physiotherapists and generally consisted of immobilization for the first 4 postoperative weeks, passive range of motion exercises after 4 weeks, and allowing active-assisted motion after 6 weeks. Active range of motion exercises were initiated after 8 weeks and strengthening exercises after 12 weeks.

Final evaluation

At the end of follow-up, the Visual Analog Scale (VAS) was calculated, as well as the Subjective Shoulder Value (SSV) score and the Quick−Disabilities of the Arm, Shoulder, and Hand (Quick-DASH) score for functional evaluation.

Statistical analysis

Sample size determination and statistical analysis were performed using the Stata v.15 program (StataCorp, College Station, TX, USA). A 95% confidence interval and a level of statistical significance of $P < .05$ were defined. Mean with standard deviation was used to present the results. The distribution of quantitative variables was assessed using the Shapiro−Wilk test. The association between qualitative variables was analyzed using the Chi-square test. To analyze the association between qualitative and quantitative variables, the Student's *t*-test was used for parametric data and the Mann−Whitney U test for nonparametric data.

Results

Demographic data

A total of 40 patients underwent 41 shoulder surgeries, with 1 patient receiving bilateral surgery. The patients had a mean age of 55.5 ± 8.6 years (range 38-75), and 43.9% of them were male.

Radiographic outcomes

The preoperative and postoperative mean CSA values were 39.6° ± 1.9° (range 36.7°-44°) and 35.7° ± 2.3° (range 32°-42°), respectively. The mean estimated and effective CSA correction values were 4.5° ± 2.1° and 3.9° ± 2.1°, respectively. All surgeries led to a decrease in CSA, with 41.5% of surgeries achieving a CSA value of 35° or less. The mean CSA correction error rate was 45.7% + −28.8% (range 4.7°-123.8°), and prediction accuracy was good in 29.3% of cases, fair in 24.4%, and unsatisfactory in 46.3%.

Functional outcomes

At the end of follow-up, 33 (78.6%) patients underwent functional evaluation, with an average follow-up duration of 41 ± 6.8

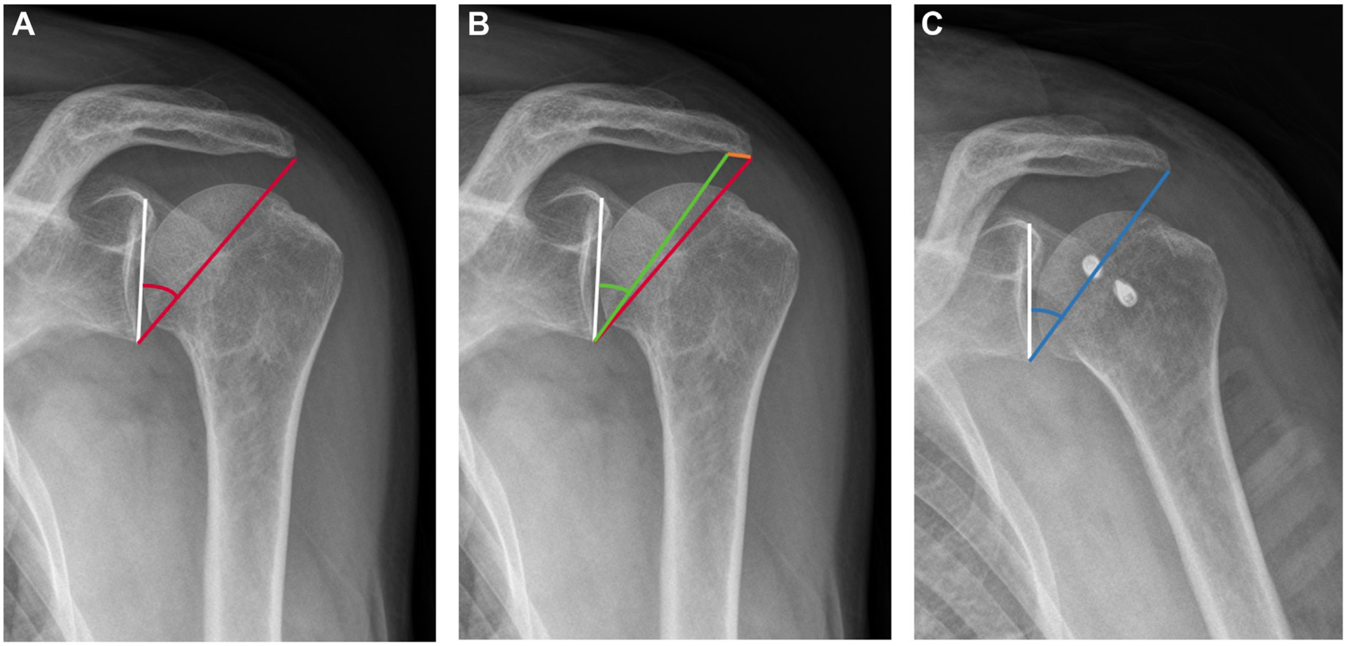

Figure 1 Example of lateral acromioplasty 2D planning. (**A** and **B**) Preoperative radiography. (**C**) Postoperative radiography. *White line*: glenoid line, *red line*: preoperative CSA, *green line*: planned CSA, *orange line*: millimeters to be resected, and *blue line*: postoperative CSA. *CSA*, critical shoulder angle.

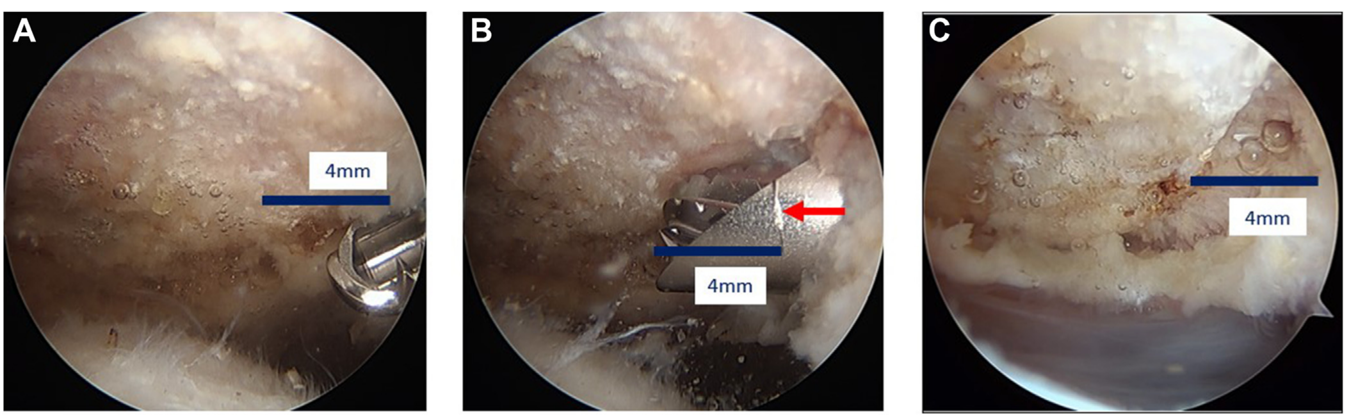

Figure 2 Acromioplasty with marked burr. (**A**) Exposed undersurface of the acromion. (**B**) Burr with mark (*red arrow*) at 4 mm from the tip according to preoperative planning. (**C**) Lateral acromioplasty in progress. The undersurface has been resected as planned.

months. The mean scores for VAS, Quick-DASH, and SSV were 0.9 ± 1.6, 5.3 ± 7.5, and 92.7 ± 10.6, respectively.

Statistical analysis

There was a nonparametric distribution observed for all functional variables (VAS, Quick-DASH, and SSV). Age, preoperative and postoperative CSA, and CSA correction error rate demonstrated a parametric distribution.

No significant association was found between functional scores and variables such as age, gender, and CSA correction error rate. A statistically significant distributional difference was observed between Quick-DASH ($P = .012$) and SSV ($P = .017$) based on the achievement of a postoperative CSA of 35° or less (Fig. 3 *A* and *B*).

Discussion

Rotator cuff pathology has been linked to the morphology of the acromion.[1,15,18,22,24,30,32,35,42,45] However, the causal relationship between the 2 remains controversial. Some researchers propose that the shape of the acromion can lead to impingement and increase the risk of RCT,[32,34] while others argue that these morphological changes do not contribute to rotator cuff pathology.[4,5,19,20,33] Another theory is that the anatomy of the acromion influences the mechanics of the rotator cuff through the deltoid vector, changing the compression and shear joint forces.[9]

The CSA allows for a more standardized measurement of this variation in the deltoid insertion. Studies have shown that a larger CSA is associated with an increased risk of rotator cuff pathology.[1,15,22,30,35,37,42,45] Gerber et al proved biomechanically that the supraspinatus tendon load during abduction is dependent on CSA.[9] A smaller CSA optimizes the biomechanics of the rotator cuff, even in patients with rotator cuff arthropathy.[26] Clinically, a CSA of more than 35° has been proposed as a cutoff value for RCT risk.[30] The impact of CSA on the outcomes of RCR remains inconclusive in the scientific literature. In their retrospective study, Como et al did not find any correlation between CSA values and the rates of retear or functional outcomes in 164 patients who underwent

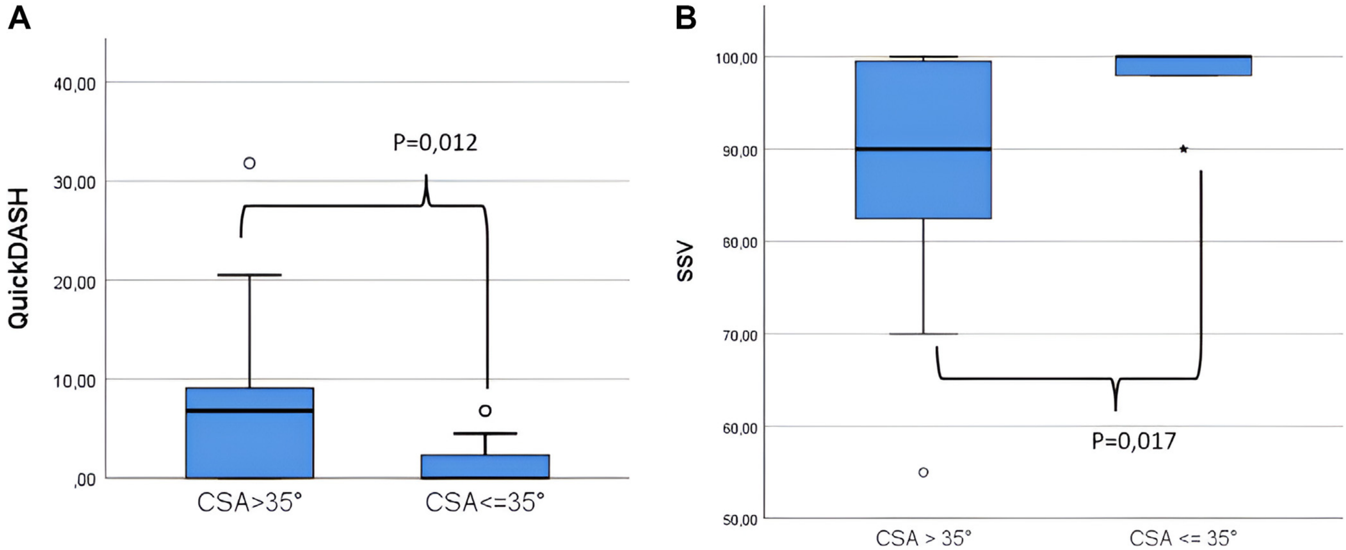

Figure 3 Functional outcomes according to whether a CSA of ≤ 35° was achieved. (**A**) QuickDASH. (**B**) SSV. *CSA*, critical shoulder angle; *SSV*, subjective shoulder value; *QuickDASH*, quick-disabilities of the arm, shoulder and hand.

arthroscopic RCR.[6] In contrast, other authors, such as Li et al and Garcia et al, reported a higher retear rate with higher CSA.[8,21] One of the largest reviews, conducted by Liu et al, included 11 studies and concluded that there is a strong association between CSA and the risk of rotator cuff retear, but it does not seem to affect the functional outcomes.[24]

The impact of acromial morphology on the outcomes of RCR has led to the proposal of acromioplasty as a supplementary procedure,[31] but standardization of surgical techniques is lacking. Anterolateral acromioplasty may correct the CSA,[2,11,12,23] but this result is not always reproducible[27,41] as it primarily aims to create a flat lower surface on the acromion and alleviate pressure on the rotator cuff rather than altering the deltoid vector. Studies have shown that subacromial decompression does not provide any significant clinical or structural benefit on surgical repair of RCT. Rossi et al reviewed 5 randomized clinical trials and found no significant difference in outcomes between RCR with and without decompressive acromioplasty.[36] Lateral acromioplasty, in contrast, aims to modify the deltoid force vector. While there are concerns about the risk of damaging the deltoid insertion during lateral acromioplasty, anatomical studies have shown that the procedure can be safely performed without compromising the deltoid.[16,29] This has been clinically verified by Gerber et al, who assessed the deltoid insertion with postoperative magnetic resonance imaging.[10]

Lateral acromioplasty can decrease CSA,[34,40] as demonstrated in the systematic review by Zhang et al.[44] Similarly in our results, all patients achieved a decrease in CSA. The problem with this technique is that CSA correction is not always accurate, especially if not planned based on preoperative CSA. Recommendations have been proposed such as resection of 1 mm of the acromion for each degree of CSA to be corrected,[34] an empirical value such as 6 mm[10] or 1 cm in higher CSA,[3] or using trigonometric calculations.[7] Another way to plan is by drawing a line that corresponds to the desired CSA, and according to this, measuring the millimeters of lateral acromion that need to be resected. Using this technique, in our study, there was a mean error rate in CSA correction of 45.7% and an unsatisfactory error rate (> 50%) in 46.3% of cases. Only 41.5% of cases achieved a postoperative CSA ≤ 35°.

A potential issue is that the accuracy of X-ray measurements and planning may not be completely reliable.[14] The quality of the radiograph influences the measurement.[13] Gerber mentions that up to 20° of rotation changes only up to 2° of CSA, which for him would be negligible. The Suter-Henninger classification was developed to evaluate CSA values based on the position of the scapula, and types A1 and C1 have been shown to decrease measurement errors.[17,39] Hou J. et al suggested using the ratio of the transverse to longitudinal diameter of the glenoid projection to evaluate the reliability of CSA measurements in malpositioned radiographs. They established that a value < 0.25 indicates good reliability of CSA measurements.[14] Yıldız A. et al suggest that this same measurement should be < 0.1 for good reliability, using magnetic resonance imaging featuring 3-dimensional (3D) 0 echo time sequencing as control.[43] Mah et al evaluated whether the use of computer tomography (CT) would be useful. Both X-ray and CT had good interobserver correlation and excellent intraobserver correlation, a little better in CT.[28]

Another issue is reproducing the planned resection during surgery. While the millimeters to be resected may seem precise when using a marked burr, it is difficult to accurately determine the axis of resection when under arthroscopic vision, to ensure that the resection is truly “lateral”. When using a camera with an angled view, we do not have exact references to determine if our resection is in a perfect angle or slightly angled from the AP axis. Long et al proposed a 3D-CT–based planning approach to identify 3 specific points on the acromion (anterior, posterior, and lateral), measure the distances between them, and mark them on the skin as reference points; however, the outcomes of this approach are still pending publication.[25] In their study, Smith G. et al used 3D-CT to compare the axial plane orientation, width, and length of acromial resections based on the lateral acromial border with an ideal resection parallel to the glenoid. They found that the acromial-based resection methods (anterolateral, lateral, and posterolateral) were not able to accurately replicate the ideal resection, which could result in larger resections than necessary. As a result, the authors concluded that a CT-based plan specific to the patient that takes into account the orientation of the glenoid is essential, and that the operative technique should focus on the glenoid orientation rather than referencing the acromion.[38] An alternative technique that we have used to orient the axis of lateral acromioplasty intraoperatively may be to use an AP needle from outside to inside, parallel to the lateral border of the acromion. In theory, this could improve axis control, but it was not used in the patients of the present study.

Regarding functional outcomes, in this study, RCR in combination with lateral acromioplasty achieved very good results. A significant difference was observed in Quick-DASH ($P = .01$) and SSV ($P = .02$) based on whether a postoperative CSA $\leq 35°$ was achieved. While many studies suggest that acromioplasty may not be useful in improving the functional outcomes of RCR, one of the common issues is the use of nonstandardized and unplanned techniques. Moreover, most of these studies focus on inferior and anterolateral acromioplasty. There have been only a few studies evaluating lateral acromioplasty. Franceschetti et al showed better functional outcomes and decreased retear rates when a lateral acromioplasty was performed.[7]

There are some limitations in this study. Although it is a prospective study, it does not compare resections performed with different planning or resection methods. Additionally, this work is insufficient to correctly establish that a CSA < 35° improves functional outcomes, primarily due to the limited number of cases and hence its low statistical power, and also because the main objective was to assess the precision of the planning, so there is no control group. Furthermore, the statistical difference observed is a distribution difference; therefore, it does not establish a mean difference value that would allow us to determine if it is clinically relevant. However, the study does reveal a potential statistical difference that should be further studied in the future. Previous studies have evaluated the effectiveness of lateral acromioplasty in correcting the CSA, but to our knowledge, this is the first study to evaluate the precision, in terms of percentage error, of 2D preoperative planning for lateral acromioplasty in clinical practice.

Conclusion

Lateral acromioplasty is a safe additional procedure to RCR, which can reduce the CSA in all cases and achieve good functional outcomes. A CSA < 35° can improve deltoid vectoring and potentially enhance the functional results of RCR. To achieve this outcome, careful planning of the correction is necessary. Although 2D preoperative planning is a useful tool, it remains unsatisfactorily imprecise in almost half of the cases. New planning techniques are needed to improve accuracy, along with resection techniques that standardize the lateral resection axis.

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