



# Does the critical shoulder angle decrease after anterior acromioplasty?

Anselme Billaud<sup>1</sup> · Eduardo Cruz-Ferreira<sup>1</sup> · Lionel Pesquer<sup>1</sup> · Pierre Abadie<sup>1</sup> · Yacine Carlier<sup>1</sup> · Pierre-Henri Flurin<sup>1</sup>

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## Abstract

**Introduction** No clinical studies to date have analyzed the critical shoulder angle (CSA) following anterior acromioplasty. Our study's main objective was to measure the change in the CSA after acromioplasty.

**Materials and methods** Ninety patients were included in this retrospective series. The CSA and the type of acromion were evaluated before and after surgery.

**Results** The average CSA for patients before surgery was  $35.9^\circ$  ( $\pm 3.7$ , 26.2, 44.2) and  $33^\circ$  after the acromioplasty ( $\pm 3.5$ , 24.8, 41.4). The decrease was significant and  $2.9^\circ$  on average ( $\pm 2.2$ ,  $-2.2$ , 11.9,  $p=0.000$ ). Preoperatively, 58% of patients had a CSA  $\geq 35^\circ$  ( $n=52$ ) and 24% postoperatively ( $n=22$ ,  $p=0.000$ ).

**Conclusions** Standardized anterior acromioplasty allows for a significant decrease in the CSA without lateral resection of the acromion. This study confirms the tight link between the CSA and the anterior acromion as well as the interest of this angle to quantify acromioplasty whether anterior or lateral.

**Level of evidence** Level IV, Case Series, Retrospective design.

**Keywords** Acromioplasty · Critical shoulder angle · Rotator cuff tear · Rotator cuff repair

## Introduction

The etiology of rotator cuff pathologies is multifactorial and poorly understood. The extrinsic risk factors and, in particular, the acromial morphology have been the subject of numerous studies [1–9]. Many radiological morphologic acromial measurements exist. The Bigliani classification is the most popular, but suffers from a lack of inter- and intra-observer reproducibility [10–14] which has made it a controversial parameter [1, 11, 15–18].

Other parameters have been described [2, 17, 19, 20]. The latest and the most studied in recent years is the critical shoulder angle (CSA), published in 2013 [21]. The lateral extension of the acromion, measured by the acromial index, showed a good correlation with cuff pathologies [12, 20]. Including the glenoid inclination in the calculation, CSA appears to correlate better with cuff problems [17, 20]. Hence, patients with a CSA greater than  $35^\circ$  are more likely to develop a pathology of the cuff [21]. Despite

contradictory studies [5, 22–24], several series show comparable results [1, 20, 25–31]. In 2015, Garcia et al. showed that, after rotator cuff repair (RCR), a CSA exceeding  $38^\circ$  increases healing failure [32], which was later confirmed by Li et al. in 2018 [33]. In 2018, Gerber et al. also demonstrated that, after RCR, patients with a CSA exceeding  $35^\circ$  had a poorer clinical result and a higher retear rate compared to patients with a CSA corrected to  $33^\circ$  or less by acromioplasty [34].

The CSA has gained popularity and provides a quantitative measurement of the acromion. It is easy to measure on a standard radiograph and studies of reproducibility have underscored its reliability [20, 25, 26]. Acromioplasty, nonetheless, remains a questionable procedure with poor convincing results [35–41]. Despite those controversial results, the mechanical concept of the subacromial impingement remains firmly entrenched, and the straightforward technique of acromioplasty makes it still widely practiced. More recently, with the popularization of the CSA, several authors have investigated the surgical options for direct reduction of the CSA by acting on the lateral offset of the acromion by an arthroscopic lateral resection (ALAR) [34, 42, 43].

However, there have been no clinical studies analyzing the CSA after conventional anterior acromioplasty. The main

✉ Anselme Billaud  
anselme75@gmail.com

<sup>1</sup> Clinique du Sport-CCOS, 2 Rue Georges Negrevergne,  
33700 Mérignac, France

objective of this study was to measure the change in the CSA after performing a standardized anterior acromioplasty. Our hypothesis is that a standardized anterior acromioplasty allows for a significant reduction in the CSA.

## Materials and methods

### Compliance with ethical standards

This series of consecutive retrospective cases received approval from our local ethics committee. All procedures have been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

### Study population

All of the patients who underwent acromioplasty surgery for tendinopathy of the rotator cuff, with or without repair of the cuff, between April 2014 and June 2017 at our institution were eligible.

The criteria for inclusion and exclusion are summarized in Table 1.

For all of the included patients, the indication for acromioplasty was subacromial decompression in the setting of

a non-ruptured tendinopathy of the cuff or as a procedure associated with a repair of the rotator cuff.

### Standardized acromioplasty technique

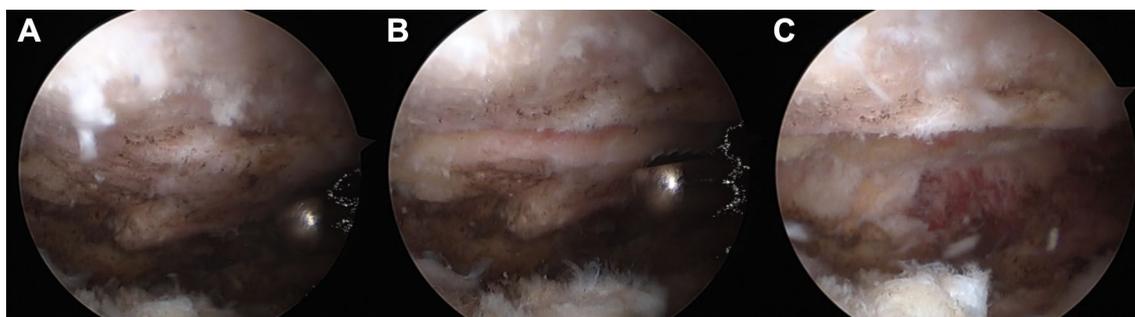
The patients were operated on by three surgeons specialized in shoulder surgery. The acromioplasty procedure was standardized and carried out in the same way by the three surgeons (Fig. 1). All acromioplasties were performed arthroscopically. A preoperative planning of bone to be resected by the acromioplasty was estimated upon the lateral X-ray depending on the Bigliani classification. An arthroscope with a 30° oblique viewing angle is introduced through a posterior portal. The oblique viewing lens is oriented toward the anterolateral edge of the acromion. A lateral approach at the junction of the anterior third and the posterior 2/3 of the acromion is performed. The shaver is introduced through the lateral portal, and a resection line is made from the lateral edge of the acromion up to the acromioclavicular joint. The depth of the line is half the shaver burr. This line marks the anterior third of the acromion to be resected. The area of the acromion in front of the line is resected and the area behind the line is flattened until a visually flat type 1 acromion is obtained. The orientation of the oblique viewing lens is maintained throughout the procedure.

### Protocol for performing the radiography

The preop and postop-radiography of the included patients was performed at our institution. The patients underwent a radiological assessment less than 6 months before the surgery and less than 6 months afterwards. The radiographs were taken with a flat panel system, providing digital images based on a standard protocol comprising anteroposterior radiographs in external, neutral, and internal positions, and a Lamy-type lateral image. The anteroposterior images were taken standing upright with a descending beam tilted to 20° with the following parameters: 60–66 kV, 160 mA, 200 ms.

**Table 1** Criteria for inclusion and exclusion in the study

Criteria for inclusion	
1.	The patient underwent acromioplasty surgery
2.	Anteroposterior and lateral preop and postop digital radiographs of the operated shoulder taken at our institution
3.	Valid anteroposterior images for measurement of the CSA
Criteria for exclusion	
1.	Prior history of malformation or of trauma
2.	Prior history of surgery of the operated shoulder



**Fig. 1** Standardized acromioplasty technique. **a** Posterolateral view of the anterior acromion under arthroscopy. The oblique viewing lens is maintained in this position throughout the entire procedure. **b** A

resection line is performed allowing delimitation of the anterior third of the acromion to be resected. **c** Final view after acromioplasty

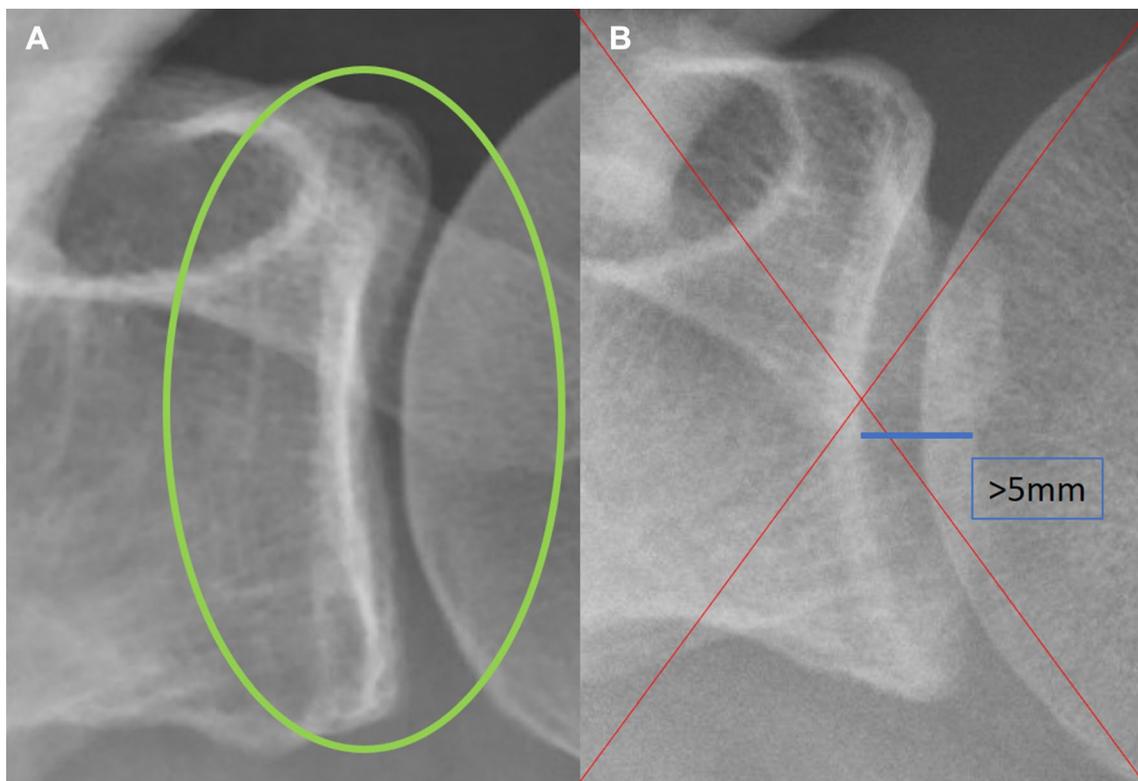
The average delivered dose was 32 mAs (comprising a lateral view and acromioclavicular views). The criteria for quality were the following: visualization of the glenohumeral joint line, overlap of the anterior and the posterior edges of the glenoid cavity, and clearance of the subacromial space.

### Validation of the anteroposterior images for measuring the CSA

To be valid, the anteroposterior images needed to be as stringent as possible, since measurement of the CSA is sensitive to rotations in the horizontal plane (Fig. 2) [44]. We followed the protocol of Blonna et al. [25]. An image not affected by rotation was defined by the head-on overlay of the anterior and the posterior edges of the glenoid cavity. If the anterior and the posterior edge of the glenoid cavity were visible, the maximal tolerated distance between these two anterior edges was 5 mm. If not, the image was considered to have too much risk of skewing the CSA. Thus, each included patient had to have at least one valid image from one of the three preop anteroposterior radiographs and for one of the three postop anteroposterior radiographs.

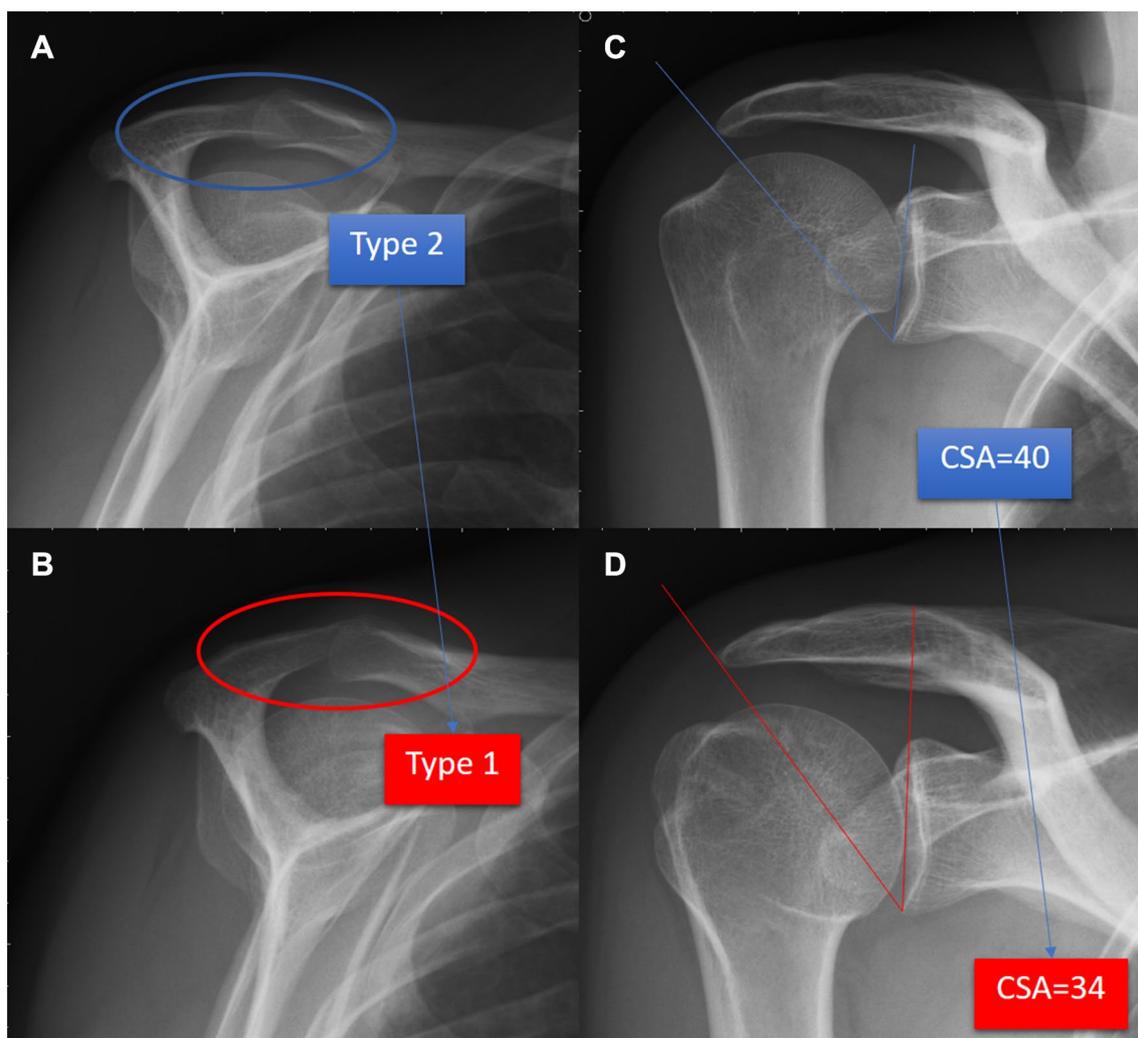
### Measurement of the CSA

The selected anteroposterior and lateral digital images were analyzed using ImageJ software (v1.5j8, National Institutes of Health, Bethesda, MD, USA). The CSA on the anteroposterior image was defined by the angle formed between the line connecting the inferior border of the glenoid cavity and the inferolateral point of the acromion and the line connecting the inferior and upper borders of the glenoid cavity (Fig. 3) [21]. The measurements were taken by a shoulder surgeon (AB) and a radiologist (LP). The measurements of the CSA were taken twice by two observers, separated by 15 days. When the average of the two measurements by each observer differed by more than 3 degrees, we suspected an error of reading and two new measurements were taken by each observer after discussing the image that presented a problem. This allowed the risk of measurement errors linked to the interpretation of the images to be reduced. Finally, the average of the four measurements of the CSA (or of the two measurements, if a new measurement was made) on each anteroposterior image was calculated and retained as a reference value.



**Fig. 2** Protocol for validation of the anteroposterior radiographic images so as to limit the issues with horizontal rotation. **a** The image is valid with a nearly perfect overlay of the anterior and posterior

edges of the glenoid cavity. **b** The image is not valid. The anterior and the posterior edges are not aligned and the gap between them exceeds 5 mm



**Fig. 3** Preop and postop radiographs. **a** Lateral preop with a type 2 acromion. **b** In postop, the acromion is type 1. **c** The CSA of 40° in preop decreased to **d** 34° in postop

## Statistics

The statistical analysis for the study was performed with R V3.3.2 software (Copyright 2016, The R Foundation for Statistical Computing, Auckland, New Zealand). The inter- and intra-observer correlation coefficients were evaluated for the CSA measurements by a Pearson's test.

Comparison of the CSA before and after surgery for one and the same group was carried out using a unilateral Student's test for matched series if  $n > 30$  and a Wilcoxon test if  $n < 30$ . Comparisons of the measurement of the CSA between groups of more than 30 individuals were carried out using a unilateral Student's test for independent series, or a Wilcoxon test for matched series if  $n < 30$ . Statistical significance was set at  $p < 0.05$ .

The proportions of the distributions of the variables between two groups were compared by comparative tests of the observed frequency.

## Results

### Characteristics of the sample

Of the 2,992 patients who underwent acromioplasty surgery between May 2014 and May 2017, 138 had preop and postop radiographs that were taken by our unit. After exclusion of the invalid images according to our protocol, 90 patients were retained, of whom 35 were women and 55 men with

an average age of 58 years ( $\pm 8.3$ , 41, 76). For each of these patients, we did not encounter other exclusion criteria.

For the 90 selected patients, the acromioplasty was associated with a repair of the cuff in 97% of the cases ( $n = 87$ ). There were no complications linked with the acromioplasty.

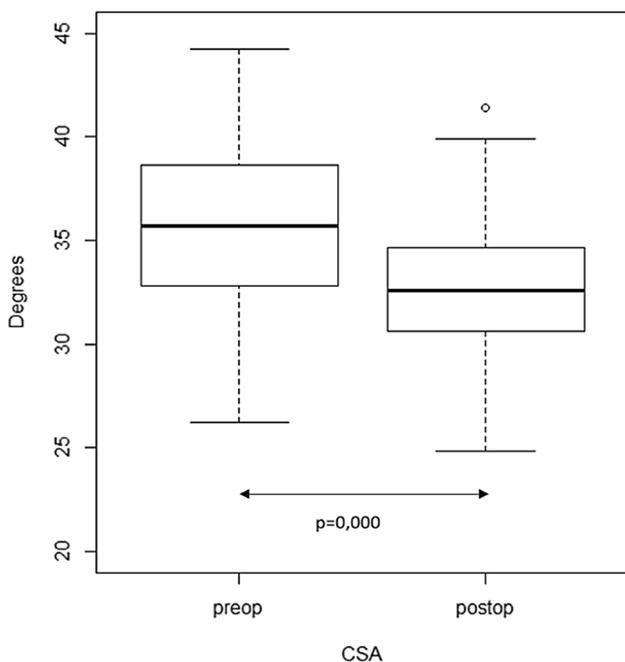
### Change in the CSA

The inter-observer reproducibility was 90% and the intra-observer reproducibility was 97% for measurement of the CSA. The protocol for carrying out a new measurement by the two observers only had to be used 13 times for the 180 measurements that were compared.

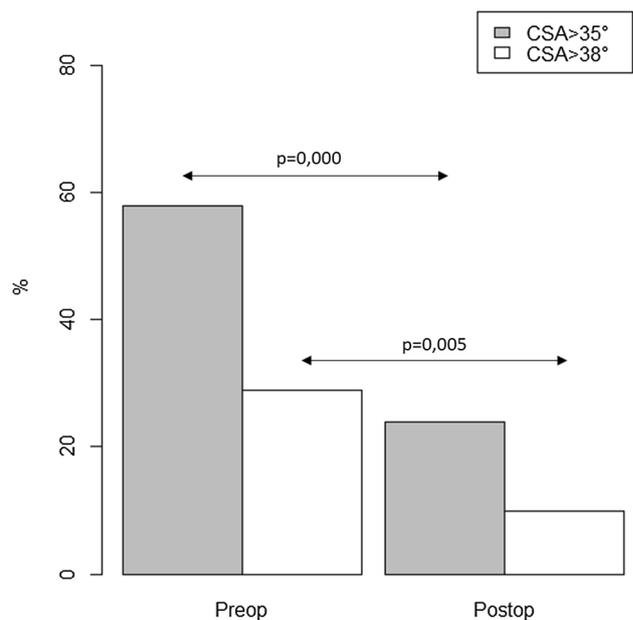
The average CSA for the patients was  $35.9^\circ$  ( $\pm 3.7$ , 26.2, 44.2) before surgery and  $33^\circ$  ( $\pm 3.5$ , 24.8, 41.4) after the acromioplasty. The average decrease in the CSA after acromioplasty was  $2.9^\circ$  ( $\pm 2.2$ ,  $-2.2$ , 11.9). This decrease was significant ( $p < 0.001$ ) (Fig. 4).

In preop, 58% of the patients had a CSA  $\geq 35^\circ$  ( $n = 52$ ) and 24% in postop ( $n = 22$ ,  $p < 0.001$ ). For 29% ( $n = 26$ ) of the patients, the CSA was  $\geq 38^\circ$  in preop and 10% ( $n = 9$ ,  $p = 0.0005$ ) in postop (Fig. 5).

For the patients for whom the CSA exceeded or equaled  $35^\circ$  in preop, group A ( $n = 52$ ), the CSA varied from  $38.4^\circ$  to  $35.2^\circ$ , with an average decrease of  $3.3^\circ$  ( $\pm 2.4$ ,  $-2.2$ , 11.9). For the patients for whom the CSA was less than  $35^\circ$  in preop, group B ( $n = 38$ ), the CSA decreased from  $32.4^\circ$  to  $30.1^\circ$ , with an average decrease of  $2.4^\circ$  ( $\pm 1.7$ ,  $-2.0$ , 5.6). The decrease in the CSA for group A was significantly

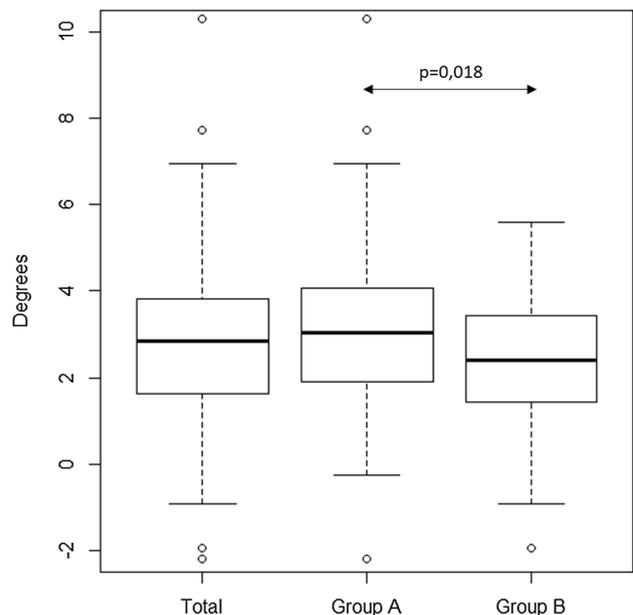


**Fig. 4** Change in the CSA after acromioplasty. The average decrease of  $2.9^\circ$  in the angle is significant ( $p = 0.000$ )



**Fig. 5** Preop and postop percentages of patients with a CSA  $\geq 35^\circ$  and a CSA  $\geq 38^\circ$

higher than that for group B ( $p = 0.018$ ) (Fig. 6). For group A, in 58% of the cases ( $n = 30$ ), the CSA was reduced under  $35^\circ$ . The median for the postop CSA for group A was  $34.4^\circ$ .



**Fig. 6** Decrease in the CSA after acromioplasty for the full set of patients (Total), for the patients with a CSA  $\geq 35^\circ$  in preop (Group A), and for the patients with a CSA  $< 35^\circ$  in preop (Group B). The patients with a CSA  $\geq 35^\circ$  had a more pronounced decrease in their CSA after acromioplasty ( $p = 0.018$ )

## Discussion

This is the first clinical study to measure the change in the CSA after anterior acromioplasty. Our results reveal a decrease in the CSA after acromioplasty of  $\sim 3^\circ$ . Karns et al. recently showed that the critical acromial point responsible for the acromial contribution to the CSA was, on average, localized at 21% of the acromial anteroposterior length from the anterolateral corner [45]. It is, therefore, situated at the level of the anterior third of the acromion. Our results are in keeping with this and they confirm that there is a link between the CSA and the anterior third of the acromion. They also support the notion that the acromioplasty procedure is effective at reducing the CSA and, if confirmed by other studies, that this has a potential protective effect on the operated cuff.

The population of our study was relatively homogenous with regard to gender, with a predominance of men. The average age was 58 years. These characteristics are typical for a population operated on for tendinopathy of the rotator cuff [46]. For 97% of the patients of the study, the acromioplasty was performed in association with a repair of the cuff. This corresponds with our normal practices, with a predominance of cuff repair relative to subacromial decompression only. We systematically perform an acromioplasty in association with a repair of the cuff.

In terms of measurement of the CSA, the excellent intra- and inter-reproducibility of our study confirms the results of other studies [20, 26]. To obtain the most reliable measurement possible of the CSA, we implemented a strict methodology. Having the same team takes the digital images, the establishment of a protocol involving three images, and double measurements with averaging of a total of four measurements constitute additional strengths of our study. Our results reveal a significant decrease in the CSA after acromioplasty by  $2.9^\circ \pm 2.4^\circ$ . The only study that has investigated the change in the CSA after anterior acromioplasty is that of Katthagen et al. in 2016 on ten cadaverous shoulders [42]. They found a decrease of  $1.4^\circ \pm 0.6^\circ$ . We, therefore, found a considerably more pronounced decrease in the CSA. We also showed that, for the group of patients with a CSA  $\geq 35^\circ$ , the effect of the acromioplasty was more significant, with an average decrease of  $3.3^\circ$ . Before surgery, 52 patients had a CSA  $\geq 35^\circ$ , and after surgery 22 patients, this means that, for 58% of the acromions at risk, the anterior acromioplasty without lateral resection of the acromion met the theoretical aim of reducing the CSA under  $35^\circ$ .

Katthagen et al. have also studied the change in the CSA after 5 mm lateral acromioplasty [42] on 10 cadavers and Gerber et al. in 2018 studied the change in the CSA after a 6 mm lateral acromioplasty on 49 patients [34]. They,

respectively, found a reduction of the CSA by  $2.8^\circ \pm 0.7^\circ$  and  $3.6^\circ$ . By resecting 1 cm of lateral acromion, Altintas et al. achieved a decrease of nearly  $10^\circ$  in the CSA with 8 cadaveric shoulders [47]. Thus, without lateral resection of the acromion, our results are quite similar to those of Katthagen et al. and Gerber et al., but lower than those of Altintas et al.

Acromioplasty has never been proven to be effective and it remains controversial in level 1 studies [35, 36, 38–41, 46, 48]. However, all of these studies were carried out without quantification of the acromioplasty. Only Soyer et al. described an anteroposterior quantification of acromioplasty, but failed to correlate the clinical results with the quantity of acromion resected, although using an unvalidated measurement [49]. Thus, quantification of acromioplasty by measurement of the CSA before and after acromioplasty and its correlation with the clinical outcomes may be warranted in future studies. In this regard, the following two questions are of particular interest: Are the clinical outcomes better for patients for whom the CSA has dropped below the threshold of  $35^\circ$ ? Or are the outcomes better for the patients for whom the acromioplasty has allowed for a reduction of the CSA by a certain quantity:  $3^\circ, 5^\circ, 7^\circ, \dots$ ? Either way, several studies have reported results in favor of acromioplasty [39, 50, 51], especially Gerber et al. recently with the first study showing a correlation between clinical result and a quantified acromioplasty [34]. As suggested by Song et al. in their meta-analysis, studies with larger numbers and stratification of the type of acromion are needed [48].

Our study has several limitations. It is a retrospective study. Nonetheless, this has allowed for evaluation of an acromioplasty technique carried out by three surgeons who, at the time of performing the procedure, were not aware that the CSA would be evaluated. This limits the possible intention bias. The study did not have a control group and the reproducibility over time for measurement of the CSA is not known. Performing relatively closed radiographic imaging before and after surgery and having digital images taken by the same team limited this bias. Despite this, some CSA increased in postop. This is probably due to variations in the incidence despite our protocolized selection of the images. The protocol for selecting images was evaluated by Blonna et al., although they did not pursue this in further studies [25]. Its main advantage is its ease of implementation relative to the more onerous guidelines of Suter for control of the incidence [44]. It should also be noted that the technique used for anteroposterior radiography of the shoulder involved a double oblique incidence. This incidence improves visualization of the subacromial space. Although it is not what was used originally by Moor [21], Cherchi et al. have shown that this technique yields comparable results to those of a strict anteroposterior view [26]. Finally, our study is based on radiological and not clinical results. Even though

a link between clinical results and reduction of the CSA has been shown [34], those results need to be consolidated.

## Conclusions

Our study confirms the initial hypotheses. Standardized anterior acromioplasty allows for a significant decrease in the CSA without lateral resection of the acromion. Our results confirm the tight link that exists between the anterior acromion and the CSA. In most cases, anterior acromioplasty allows for the CSA to drop below the threshold of 35°. Our study also suggests that the CSA could be a good measurement tool to quantify the resected bone after acromioplasty whether anterior or lateral.

## Compliance with ethical standards

**Conflict of interest** AB, EC, LP, PA, YC, and P-H F declare that they have no conflict of interest.

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