Original Article

Correlation of Some Anatomical Angles of the Shoulder with Rotator Cuff Syndrome

Abstract

Background: Shoulder movement occurs through the coordinated work of muscles, tendons, ligaments, and bones, primarily that affect the glenohumeral joint. Some distances and the angles between the bones forming this joint are important in shoulder pathologies. In this study, we aimed to determine the evaluation of nine different radiological parameters related to acromion and humerus in rotator cuff syndrome and control group patients. **Materials and Methods:** A total of 400 patients' routine clinic radiographs were retrospectively assessed, which have rotator cuff syndrome (n = 210), and control group (n = 190). We measured the critical shoulder angle (CSA), distance of glenoid-acromion (GA), distance of glenoid-humeral head (GH), acromial index, lateral acromial angle (LAA), total shoulder arthroplasty angle (TSA), reverse shoulder arthroplasty angle (RSA), Point T represents the superior border of the glenoid cavity, Point S represents the inferior border of the glenoid cavity, point R represents the intersection of the supraspinatus fossa line with the glenoid surface. RST angle, and greater tuberosity angle (GTA) angle. We determined the type of acromion. **Results:** We determined that the GH, TSA, RST, and GTA were significantly different between rotator cuff syndrome and control group patients. When we evaluated the acromion type, Type 2 was the most common type. Different from the literature, when we evaluated the relationship between acromion types and angles, we determined that LAA, GA, and TSA parameters were significantly different between acromion types. **Conclusions:** In this study, we determined the importance of measurements and angles in rotator cuff syndrome. We think that the relationship between acromion types and parameters can contribute to the literature. Moreover, we believe that our study will contribute to the literature in terms of gathering many angles that are important in shoulder pathologies in a single study.

Keywords: *Acromial index, acromion type, rotator cuff syndrome, shoulder joint*

Busra Candan, Ebru Torun[1], Rumeysa Dikici, Seda Avnioglu, Mehmet Yalcin Gunal[2]

Departments of Anatomy, [1]Radiology and [2]Physiology, School of Medicine, Alanya Alaaddin Keykubat University, Alanya, Turkey

Introduction

The humerus, scapula, and clavicula form the shoulder girdle. Also, the shoulder girdle consists of three main joints, the sternoclavicular joint, the acromioclavicular joint, and the glenohumeral joint. The glenohumeral joint is one of the most mobile joints in the body, and it is formed between the glenoid cavity of the scapula and humeral head.[1] It is frequently stated in the literature that the angles between the bones forming this joint are important in shoulder pathologies such as rotator cuff syndrome.[2] And, acromion morphology has been related to shoulder pathologies, and the shape of the acromion is among the primary causes of shoulder impingement; thus, various attempts have been made to classify acromion's morphologic appearance on standard radiographs.[3] Radiographs allow imaging of acromion anomalies, tendinitis, fractures, and neoplasms and diagnose impingement and shoulder pain.[1]

This study's primary purpose was to investigate the efficacy of angles between the scapula and humerus on the presence of rotator cuff syndrome on standard radiographs, as well as to identify the supporting literature for this conclusion.

Materials and Methods

This study was a retrospective, observational study, and it was carried out on 400 (200 male and 200 female) patients who attended to the hospital for various reasons and had shoulder radiographs between January 2018 and December 2020. This study was performed in line with the principles of the Declaration of Helsinki. This study was approved by the Non-Interventional Clinical Research Ethics Committee (Decision No. 2020:20–27).

Article Info

Received: 15 November 2021
Revised: 29 August 2022
Accepted: 13 September 2022
Available online: 27 March 2023

Address for correspondence:
Dr. Busra Candan, Departments of Anatomy, School of Medicine, Alanya Alaaddin Keykubat University, Alanya, Turkey.
E-mail: busra.candan@alanya.edu.tr

Access this article online

Website: www.jasi.org.in
DOI: 10.4103/jasi.jasi_186_21
Quick Response Code:

How to cite this article: Candan B, Torun E, Dikici R, Avnioglu S, Gunal MY. Correlation of some anatomical angles of the shoulder with rotator cuff syndrome. J Anat Soc India 2023;72:22-8.

Study design

After obtaining ethical approval, all measurements were taken electronically on radiographs displayed on a PACS. Four hundred radiographs of the shoulders were reviewed. Patients were included in the study if they had routine clinical radiographs of the shoulder taken within the last 2 years of acceptable quality. All patients with previous shoulder surgery, fractures, infections, and tumors were excluded. The patients were divided into two groups according to syndromes, as follows:

- Group 1: Patients with rotator cuff syndrome (210 patients)
- Group 2: Control group (190 patients): Radiographs of the patients in this group were radiographs taken for routine diagnosis and examination.

We determined the acromion type according to the Bigliani classification observationally: Type 1 represents acromion being flat in shape, Type 2 represents a curved acromion that lies parallel to the humeral head, and Type 3 represents a hooked undersurface of the acromion.[4] In addition, the relationship between acromion type and angles was evaluated. We measured the following nine different parameters: the critical shoulder angle (CSA) was measured as the angle between a line connecting the glenoid's superior and inferior margins and a line between the inferolateral border of the acromion and the glenoid's inferior margin [Figure 1a]. The acromial index (AI) was obtained by dividing the distance from the glenoid to the acromion (GA) by the distance from the glenoid to the lateral of the humeral head (GH) [Figure 1b]. The greater tuberosity angle (GTA) was measured as the angle between a parallel line through the humeral head center of rotation and a line connecting the upper border of the humeral head to the greater tuberosity's most superolateral edge [Figure 1c]. The lateral acromial angle (LAA) was determined by the intersection of a line parallel to the acromion undersurface and a second line parallel to the glenoid fossa [Figure 1d]. The total shoulder arthroplasty (TSA) was measured as the angle between a line connecting the glenoid's superior and inferior margins and the line connecting the humeral head to the glenoid's inferior margin [Figure 2a]. The reverse shoulder arthroplasty (RSA) was measured as the angle between a line connecting the supraspinatus fossa and the glenoid's inferior margin and the line connecting the humeral head to the glenoid's inferior margin [Figure 2b]. The RST angle was measured as the angle between a line connecting the supraspinatus fossa and the glenoid's inferior margin and the line connecting the glenoid's superior margin to the inferior margin of the glenoid [Figure 2c].

Statistical analysis

SPSS Inc, Chicago, IL, USA. All measurements, means, standard error mean (SEM), and minimum and maximum values were calculated. Moreover, they were tested for correlation to each other and sex, side, and group. "Kolmogorov-Smirnov" and "Shapiro–Wilk" tests were performed to determine whether the data were suitable for normal distribution. In the evaluation of parameters according to gender, the Mann–Whitney U-test was used for those who did not show typical distribution characteristics, and the independent *t*-test was used for those who did show. Differences between patient and control groups were analyzed using the independent *t*-test. Differences between acromion type and angles were analyzed using a one-way analysis of variance. All values were of mean ± SEM. P <0.05 was considered statistically significant in all statistical analyses.

Results

Four hundred shoulders were studied in this paper. The mean age was 50 years (53 years in female and 48 years in male patients). When the acromion type was evaluated, Type 1 acromion was seen in 13.69%, Type 2 in 79.47%, and Type 3 in 6.84% of the rotator cuff patients, and Type 1 acromion was seen in 5.72%, Type 2 in 91.90%, and Type 3 in 2.38% of the control groups in our study. When we evaluated the angles according to the acromion type, LAA, GA, and TSA parameters were found to be significantly different according to the acromion types [Figure 3].

The LAA was significantly higher (P = 0.001) in individuals with Type 1 and Type 2 acromion than in individuals with Type 3 acromion. The distance from the GA was significantly lower (P = 0.002) in individuals

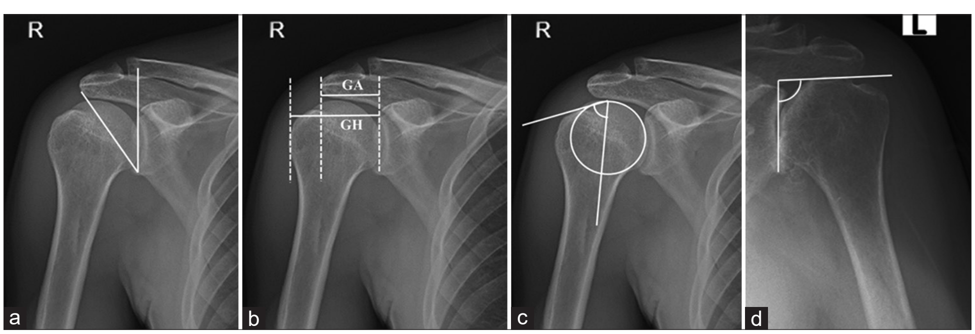

Figure 1: Measurements of CSA (a), AI (GA/GH) (b), GTA (c) and LAA (d). CSA: CSA, AI: Acromial index, GA: Glenoid acromion distance, GH: Glenoid humeral head, GTA: Greater tuberosity angle, LAA: Lateral acromial angle

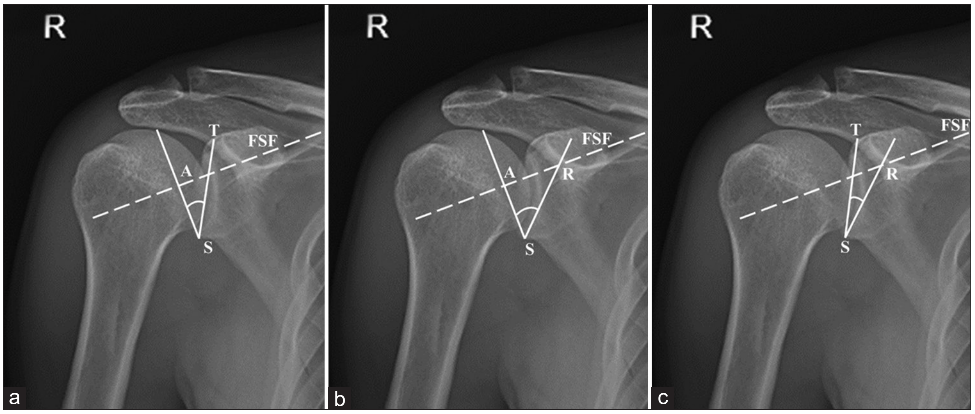

Figure 2: Measurements of TSA (a), RSA angle (b), and RST angle (c) FSF. TSA: Total shoulder arthroplasty, RSA: Reverse shoulder arthroplasty, FSF: Floor of the supraspinatus fossa

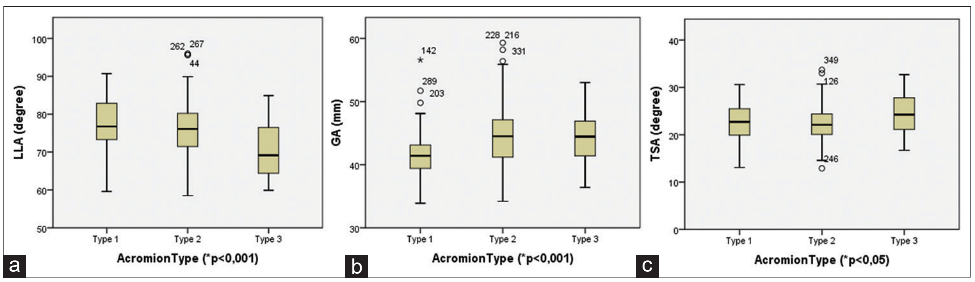

Figure 3: Statistically significant difference according to acromion types in the LAA (a), GA distance (b), and TSA angle TSA (c). LAA: Lateral acromial angle, GA: Glenoid-acromion, TSA: Total shoulder arthroplasty

with Type 1 acromion than in individuals with Type 2 and Type 3 acromion [Figure 3]. The total shoulder arthroplasty angle (TSA) was significantly higher (P = 0.004) in individuals with Type 3 acromion than in individuals with Type 1 and Type 2 acromion [Figure 3]. In the evaluation of parameters according to gender, it was seen that all measurements were significantly different between males and females [Table 1]. The mean values of the measurements according to gender and sides are listed in Table 1. According to syndromes, GH (P = 0.013), TSA (P = 0.000), RST (P = 0.015), and GTA (P = 0.000) were significantly different between the rotator cuff syndrome and control groups in evaluating parameters [Figure 4]. There was no statistically significant difference between the syndrome groups in AI, GA, RSA, CSA, and LAA measurements. According to syndromes, the mean values of the measurements are listed in Table 2.

Discussion

In this study, we tried to determine whether the angles and distances around the shoulder joint between the scapula and humerus are associated with gender, sides, and rotator cuff syndrome. Among the measurements we made, GH, TSA, RST, and GTA angles were statistically significant among the rotator cuff syndrome and control groups [Figure 4].

Bigliani *et al*. classified the acromion into three types with a progressive increase in impingement incidence from a Type 1 to Type 3 acromion. They stated that Type 3 acromion might impinge on the rotator cuff on the arm's elevation.[4] When the acromion shape was evaluated, the most common type seen was Type 2 acromion (79% in Group 1 and 92% in Group 2) in our study. Type 2 was reported as the most common acromion type: Banas,[5] Vahakari *et al*.,[6] and Balke *et al*.[3] reported Type 2 acromion in 51%, 81.3%, and 80% of cases, respectively. The ratio of Type 3 acromion was detected to be higher in the rotator cuff group (7%) than that in the control group (2%) in our study. The authors found a higher prevalence of rotator cuff tears in patients with a hooked acromion than in individuals with a curved or flat acromion.[7] The higher rate of Type 3 acromion in the rotator cuff syndrome group compared to the control group supported this information in our study.

The CSA has been reported for various degenerative shoulder problems which are significantly different from the corresponding angle in normal shoulders.[8] Our population had a CSA of 46.4°±0.61 in routine clinical radiographs, which is considerably higher than that of previous reports [Table 3].[8-19] In routine clinical radiographs, the CSA is subject to errors due to the viewing plane's orientation concerning the scapula.[25] Our investigation confirmed that the magnitude of the CSA depends on the viewing perspective of the X-ray beam. The literature reported that an abnormal CSA was a leading factor in

Table 1: Mean values of angles and measurements according to gender and sides

Measurement	Gender	*n*	Mean±SEM	Side	*n*	Mean±SEM
CSA	Male	200	45.98±0.48	Right	232	46.14±0.45
	Female	200	48.86±0.45	Left	168	49.20±0.48
LAA	Male	200	76.08±0.46	Right	232	76.49±0.45
	Female	200	75.55±0.48	Left	168	74.87±0.49
GA	Male	200	46.04±0.28	Right	232	45.26±0.28
	Female	200	42.23±0.26	Left	168	42.57±0.29
GH	Male	200	54.11±0.30	Right	232	51.30±0.35
	Female	200	47.38±0.26	Left	168	49.97±0.38
AI	Male	200	0.84±0.005	Right	232	0.88±0.005
	Female	200	0.88±0.005	Left	168	0.85±0.006
TSA	Male	200	21.39±0.22	Right	232	21.99±0.22
	Female	200	23.35±0.23	Left	168	22.89±0.24
RSA	Male	200	37.27±0.27	Right	232	37.08±0.21
	Female	200	37.85±0.18	Left	168	38.23±0.24
RST	Male	200	17.88±0.19	Right	232	17.24±0.21
	Female	200	16.93±0.23	Left	168	17.63±0.21
GTA	Male	200	87.35±0.48	Right	232	80.98±0.46
	Female	200	77.89±0.41	Left	168	84.88±0.66

P<0.05, differences between groups, (*n*, mean±SEM). *n*: Number of patients, SEM: Standard error mean, CSA: Critical shoulder angle, LAA: Lateral acromial angle, GA: Glenoid-acromion, GH: Glenoid-humeral head, AI: Acromial index, TSA: Total shoulder arthroplasty, RSA: Reverse shoulder arthroplasty, GTA; Greater tuberosity angle

Table 2: Mean values of angles and measurements according to syndrome

Measurement	Rotator cuff tears (210)	Control group (190)
CSA	47.57±0.47	47.27±0.48
LAA	75.32±0.46	76.36±0.49
GA	44.38±0.29	43.87±0.32
GH	51.37±0.35	50.06±0.39
AI	0.88±0.006	0.86±0.006
TSA	21.78±0.23	23.02±0.24
RSA	37.46±0.23	37.68±0.22
RST	17.77±0.19	17.01±0.24
GTA	84.95±0.53	80.05±0.53

P<0.05, differences between groups, (*n*, mean±SEM). *n*: Number of patients, SEM: Standard error mean, CSA: Critical shoulder angle, LAA: Lateral acromial angle, GA: Glenoid-acromion, GH: Glenoid-humeral head, AI: Acromial index, TSA: Total shoulder arthroplasty, RSA: Reverse shoulder arthroplasty, GTA; Greater tuberosity angle

developing rotator cuff tears.[8,25] According to our study, accurate measurement of the CSA is variable concerning the scapula's location. One study did not find a significant relationship between the CSA and the presence of rotator cuff syndrome.[19] The present study shows how highly sensitive the CSA is to radiograph the alignment of the scapula.

The morphological appearance of the acromion has been evaluated by many authors, as it is thought to be associated with various shoulder pathologies. AI is a criterion by which they determine acromion morphology. As stated in the literature, AI was lower in the control group than in the rotator cuff group in this study.[3,20,21] As our study result showed, Hamid *et al*. reported that AI was higher in females than males [Table 1].[21] We also evaluated GA (glenoid-acromion) and GH (glenoid-humerus) measurements in our study, different from the literature. The differences in the GH (*P* = 0.013) between the patients with rotator cuff syndrome and the control group were significant. GA was significantly lower (*P* = 0.002) in individuals with Type 1 acromion than in individuals with Type 2 and Type 3 acromion. A higher prevalence of rotator cuff syndrome in patients with a hooked acromion than in individuals with a curved or flat acromion was reported in the literature. Based on this, the fact that the distance between the glenoid and acromion is less in individuals with flat acromion type shows that this distance may also help in the diagnosis of rotator cuff syndrome. We concluded that GA and GH values, which were not taken into account in other studies, are helpful measurements for investigating the relationship between the humerus and the scapula.

In the present study, we evaluated LAA on routine radiographs. This angle is significantly different between genders in our study. The measurements of LAA in this study are consistent with the literature, and this angle was seen to be higher in the control group than that in the rotator cuff group [Table 3].[2,3,5] When we evaluated the relationship between acromion type and LAA, this angle was significantly lower in individuals with Type 3 acromion. The authors found a higher prevalence of rotator cuff syndrome in patients with a hooked acromion. So, we believe that a smaller LAA may cause pressure on the shoulder, and it can cause various pathology in the shoulder, such as impingement or rotator cuff syndrome.

Glenoid inclination (TSA, ß angle) has been defined and measured in many different ways.[7] The TSA angle is a modification of the ß angle, which provides a measure of the inclination of the glenoid surface and is useful for planning total shoulder arthroplasty.[22] In our study, we determined that the TSA (*P* = 0.000) was significantly lower in patients with rotator cuff syndrome than in the control groups. Also, TSA and RST (*P* = 0.014) angles were significantly different between the rotator cuff syndrome and control groups in this study. Boileau *et al*. and Shi *et al*. stated that TSA was a risk factor in the supraspinatus [Table 3].[22,23] Usually, the most rupture muscle is the supraspinatus muscle in rotator cuff syndrome. And, a higher prevalence of rotator cuff syndrome in patients with a hooked acromion was reported in the literature. And, we determined that TSA was significantly higher (*P* = 0.004) in individuals with Type 3 acromion in this study. Maurer *et al*. stated that the TSA between the glenoid fossa and the floor

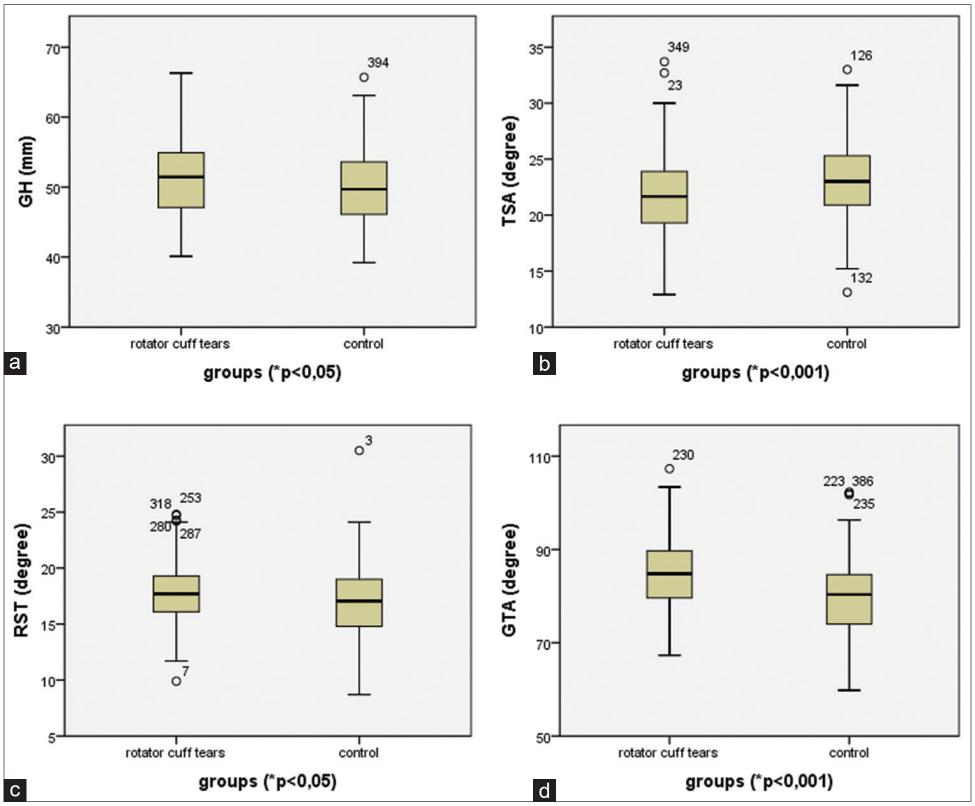

Figure 4: Statistically significant difference in the GH (a), TSA angle (b), reverse shoulder arthroplasty angle (RST) (c), and GTA (d) between the rotator cuff and control groups. TSA: Total shoulder arthroplasty, GH: Glenoid-humeral head, GTA: greater tuberosity angle

of the supraspinatus fossa was the most reproducible measurement method on conventional anteroposterior radiographs, providing good resistance to positional variability of the scapula.[26] From a surgical standpoint, the TSA is useful when planning a total shoulder arthroplasty implantation. Furthermore, although the TSA is appropriate to measure glenoid component inclination in total shoulder arthroplasty, it is not relevant to the reverse shoulder arthroplasty baseplate. Therefore, knowledge of the RSA is important for reverse shoulder arthroplasty operations.[22] We believe that these angles, which have been mentioned in very few articles yet, should be evaluated more.

Studies have shown that greater tuberosity malunion is associated with poor outcomes due to rotator cuff tension alteration and subacromial impingement, and rotator cuff tears.[24] Cunningham *et al*. reported that GTA values were significantly higher in patients with rotator cuff syndrome, compared with the control group. Consistent with this study, we found that GTA was significantly higher in patients with rotator cuff syndrome compared to the control group [Table 3 and Figure 4]. They stated that GTA could also guide treatment and serve as a postoperative control marker.[24] We believe that this angle, which has been defined quite recently and is mentioned in very few articles yet, should be evaluated more.

Limitations

The present study had some limitations. Despite our useful findings in this large study, we are aware that further research using prospectively collected data, including more detailed pathology definitions and broader ranges of shoulder diseases, is essential.

Conclusions

In this study, the importance of measurements and angles was evaluated in the diagnosis of shoulder diseases. We determined that overall the GH, TSA, RST, and GTA are associated with rotator cuff syndrome. Different from the literature, when we evaluated the relationship between acromion types and angles, we determined that LAA, GA, and TSA parameters were significantly different between acromion types. LAA was significantly higher (P = 0.001) in individuals with Type 1 and Type 2 acromion; GA was significantly lower (P = 0.002) in individuals with Type 1 acromion and TSA was significantly higher (P = 0.004) in individuals with Type 3 acromion. It has been stated in the literature that these parameters differ in rotator cuff syndrome. For this reason, we think that the relationship between acromion types and these parameters can contribute to the literature. And, we believe that our study will contribute to the literature in terms of gathering many angles that are important in shoulder pathologies in a single study.

Table 3: Comparison of CSA, LAA, AI, TSA, RSA, RST and GTA in rotator cuff patients and control patients between literatures

Literature	Angle	Rotator cuff tears	Control
Moor *et al.*[9]	CSA	38°	33.1°
Daggett *et al.*[10]	CSA	37.9°	-
Spiegl *et al.*[11]	CSA	37.3°	32.7°
Blonna *et al.*[8]	CSA	40°	34°
Suter *et al.*[12]	CSA	-	33.4°
Chalmers *et al.*[13]	CSA	34°	32°
Cherchi *et al.*[14]	CSA	36.4°	33.3°
Gomide *et al.*[15]	CSA	39.75°	33.59°
Peltz *et al.*[16]	CSA	36.9°	34.5°
Watanabe *et al.*[17]	CSA	34.4°	32.1°
Heuberer *et al.*[18]	CSA	36.3°	-
Bjarnison *et al.*[19]	CSA	33.9°	33.9°
Present study	CSA	47.98°	46.4°
Nyffeler *et al.*[20]	AI	0.73	0.64
Balke *et al.*[3]	AI	0.75	0.67
Hamid *et al.*[21]	AI	-	0.69
Present study	AI	0.88	0.86
Balke *et al.*[3]	LAA	77°	84°
Banas *et al.*[5]	LAA	-	78°
Li *et al.*[2]	LAA	-	78°
Present study	LAA	75°	76°
Boileau *et al.*[22]	TSA	-	16°
Shi *et al.*[23]	TSA	-	16°
Boileau *et al.*[22]	RSA	-	25°
Boileau *et al.*[22]	RST	-	9°
Present study	TSA	22°	23°
Present study	RSA	37°	38°
Present study	RST	18°	17°
Cunningham *et al.*[24]	GTA	73°	65°
Present study	GTA	85°	80°

CSA: Critical shoulder angle, LAA: Lateral acromial angle, AI: Acromial index, TSA: Total shoulder arthroplasty, RSA: Reverse shoulder arthroplasty, GTA; Greater tuberosity angle

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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