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Scapular Notching Remains a Clinically Relevant Radiographic Finding in Reverse Shoulder Arthroplasty

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ABSTRACT

Objective: To evaluate the frequency of scapular notching and its association with functional outcomes following reverse shoulder arthroplasty (RSA).

Materials and Methods: This retrospective study included 83 patients with a minimum follow-up of 36 months who underwent RSA at a tertiary care center between 2010 and 2019. Radiographs were evaluated for scapular notching according to the Sirveaux classification. Clinical outcome assessment was based on pre- and post-operative results with the University of California–Los Angeles [UCLA] score and the American Shoulder and Elbow Surgeons (ASES) score, while pain was evaluated with the Visual Analog Scale (VAS). Patients were classified for the presence or absence of scapular notching.

Results: Scapular notching was detected in 46 patients (55.4%). All patients demonstrated significant post-operative improvement in UCLA, ASES, and VAS scores ($p<0.001$). However, patients without notching had significantly higher post-operative UCLA (27 vs. 25, $p=0.027$) and ASES scores (82 vs. 72, $p=0.007$) compared to those with notching. The magnitude of improvement (score change) in UCLA was also greater in the non-notching group (22 vs. 17, $p<0.001$). The groups were similar in terms of post-operative VAS scores and the decline in pain.

Conclusion: Scapular notching is a common complication following RSA and, despite overall clinical improvement, is associated with less favorable functional outcomes compared with patients without notching.

Keywords: Functional outcomes, Implant design factors, Reverse shoulder arthroplasty, Scapular notching, Sirveaux classification

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INTRODUCTION

Reverse shoulder arthroplasty (RSA) is now widely used for the management of complex shoulder pathologies, most notably rotator cuff arthropathy. In cases where conventional anatomical prostheses fail to provide satisfactory outcomes, RSA improves the biomechanical efficiency of the deltoid muscle in arm elevation, which improves function and clinical outcomes.[1,2] Despite its utility, RSA is associated with a number of clinically-relevant complications. The most frequently reported include instability, infection, scapular notching, mechanical failure, nerve injury, fracture, and component disassembly.[3] Among these, scapular notching arises from mechanical impingement between the scapular neck and the humeral component, which is due to altered biomechanics introduced by the prosthesis.[4,5]

Some clinicians consider scapular notching not as a complication in itself but as a characteristic finding after RSA[6] (Fig. 1). Regardless of how it is interpreted, scapular notching is most commonly detected radiographically within the first 6 months after surgery, with a prevalence ranging from 4.6% to 96%.[4] Multiple factors contribute to its development, with implant selection, component positioning, and patient-specific anatomical variations being the most critical.[7] The effect of scapular notching on functional outcomes, prosthesis stability, and patient satisfaction remains controversial. While some studies suggest an association with reduced function and increased risk of revision surgery, others have reported no significant influence on clinical results.[8-10] Further studies are therefore required to clarify its mid/long-term clinical implications.

We designed the present study as a midterm follow-up of patients who underwent RSA in a tertiary care hospital, with a focus on determining the prevalence of scapular notching and to evaluate its relationship with established outcome measures, including the University of California at Los Angeles Shoulder Score (UCLA), the American Shoulder and Elbow Surgeons Score (ASES), and the Visual Analog Scale (VAS). The aim was to explore whether scapular notching should be considered only radiographic or a clinically relevant complication. We hypothesized that the presence of scapular notching would be associated with inferior functional outcomes.

MATERIALS AND METHODS

Study Design and Ethical Approval

This investigation was conducted as a single-center retrospective cohort study. It involved a review of clinical and radiological follow-up data from patients who underwent RSA at the Department of Orthopedics and Traumatology, Gazi University Faculty of Medicine, between 1 January 2010 and 31 December 2019. Ethical approval was obtained from the Ethics Committee of Gazi University Faculty of Medicine (date: 31.12.2024, decision no: 2024–2003), and all procedures were carried out in accordance with the principles of the Declaration of Helsinki.

Patient Selection

The study population consisted of patients who underwent RSA and had attended at least 3 years of clinical follow-up. Inclusion criteria were: Older than 18 years, undergoing primary surgery with an indication for RSA, and having complete records of pre-operative and follow-up assessments of functional and pain scores, including UCLA, ASES, and VAS. We excluded patients who had undergone revision surgery, cases treated with RSA due to tumor(s), individuals with neuromuscular disorders, those who underwent bilateral

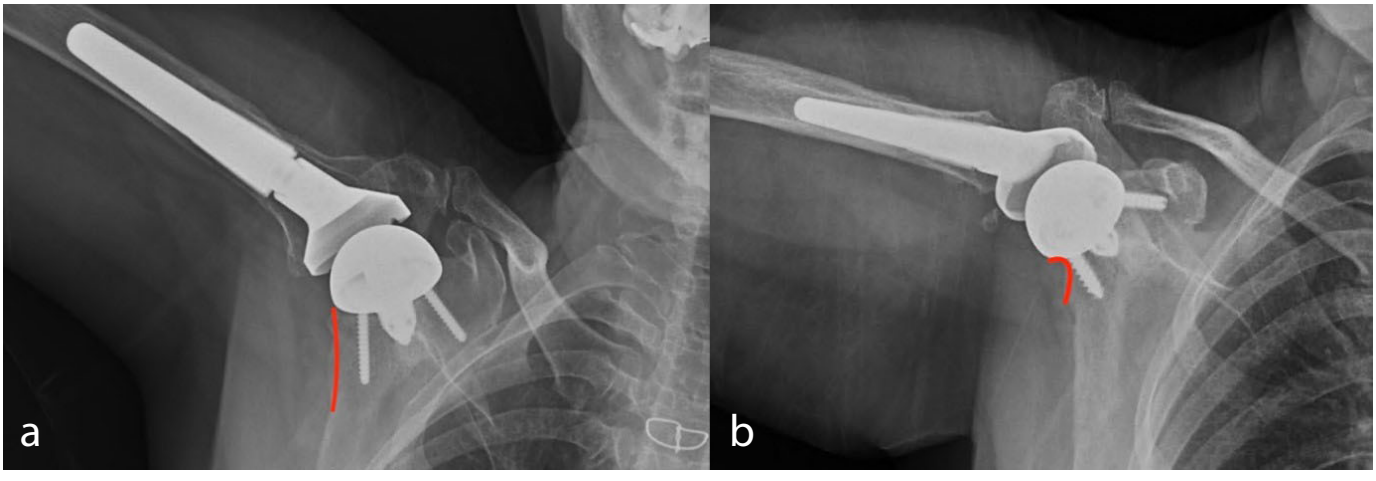

Figure 1. (a) Patient without a scapular notching, **(b)** Patient with a scapular notching.

procedures, and subjects with incomplete radiological follow-up. Ultimately, 83 patients who met the eligibility criteria were included in the analysis.

Surgical Approach and Rehabilitation

All patients underwent RSA (SMR, Lima, Italy) through a standard deltopectoral approach performed by the same orthopedic team. The primary objective of the procedure was to restore glenoscapular balance and to achieve implant positioning that would optimize deltoid muscle function. Whenever feasible, the subscapularis tendon was preserved and reattached. For glenoid component placement, an inferior position was preferred, with particular attention to maintaining adequate clearance between the inferior margin of the glenosphere and the inferior cervical border of the scapula. Following post-operative pain control, pendulum and passive range of motion exercises were initiated, with active range of motion exercises introduced after the 1st week. The rehabilitation program was tailored to each patient and carried out under physiotherapist supervision, with return to sports allowed between weeks 8 and 12.

Radiological Assessment

All post-operative shoulder radiographs were obtained digitally from the hospital archives, and for each patient included in the study, control radiographs taken at a minimum of 3 years post-operatively were evaluated. To avoid duplication, only the longest available follow-up images for each patient were included in the analysis. Assessments were performed independently by two orthopedic surgeons using standardized anteroposterior (true AP) and axillary views. The images were reviewed through the Picture Archiving and Communication System, and scapular notching was graded according to the Sirveaux classification. In cases of disagreement, a consensus evaluation was reached with the involvement of a third orthopedic surgeon. The degree of scapular notching was classified from 0 (none) to 4 (severe). For the primary comparison, patients were grouped as either without notching (grade 0) or with notching (grade ≥1).[11]

Clinical Assessment and Data Collection

In our clinic, patients undergoing RSA have routinely been evaluated for many years using the VAS, UCLA, and ASES at each pre- and post-operative follow-up visit, with results recorded in their medical files. For this study, clinical scores documented pre-operatively and at the final follow-up visit (minimum 3 years post-operatively) were retrieved retrospectively from the hospital archive system. Functional outcomes were assessed using Turkish validated UCLA and ASES, while pain was evaluated using VAS.[12,13] For each patient, the change between pre- and post-operative values was also calculated. All scores were derived from data recorded by the treating physician during in-person visits and documented in medical charts.

The ASES score, developed by the ASES, combines both patient-reported and clinician-assessed components, with a maximum of 100 points. In this study, we analyzed the patient-reported component, which consists of a 10 cm VAS for pain (50 points) and ten Likert-type items addressing functional capacity in activities of daily living (50 points).[13,14]

The UCLA shoulder score assesses five domains: Pain, function, active range of motion (forward flexion), muscle strength, and patient satisfaction. Each domain has its own score range, and the total score is calculated on a 35-point scale.[12,15] These assessments were performed during outpatient visits by non-surgical members of the orthopedic team through face-to-face evaluations and were documented accordingly. Both UCLA and ASES scores were applied pre-operatively and at the final follow-up. Changes between the 2 time points were also calculated.

Pain levels were evaluated using the VAS, consisting of a 10 cm horizontal line on which patients were asked to indicate their average pain intensity. A score of zero (0) represented "no pain," whereas ten (10) corresponded to "unbearable pain." Patients marked their perceived pain levels both pre-operatively and at the final follow-up. Scores were then measured in centimeters and converted into numerical values. All assessments were carried out at the bedside under the direct supervision of the trained clinical team.

Statistical Analysis

We used the IBM Statistical Package for the Social Sciences software (v27.0) to collect data and obtain descriptive and statistical analysis results (IBM Corp., Armonk, NY, USA). For statistical analyses, the classic *P* value threshold of <0.05 was defined as the threshold for significant results. Parametric assumptions were assessed (histogram, Q-Q plots, etc.). Descriptive statistics are presented using mean±standard deviation for normally distributed continuous variables, and with median (25th percentile - 75th percentile) for non-normally distributed continuous variables. Between groups, comparisons of continuous variables were performed using the Student's t test or Mann–Whitney U test, depending on the normality of distribution. Pre- and post-operative comparisons of scores were performed using the Wilcoxon signed-rank test due to non-normality of distribution. Categorical descriptives (nominal, ordinal) were reported as frequency (count, *n*) and percentage (column %). Between-groups comparisons of categorical variables were performed using the chi-square test or Fisher-Freeman-Halton test.

RESULTS

A total of 83 patients who underwent RSA were included in the study. Scapular notching was identified in 46 patients (55.42%), while 37 patients (44.58%) did not exhibit any notching. The overall age range was 26–88 years. Patients with scapular notching were significantly older than those without notching (66.41±11.05 vs. 61.22±11.68 years; p=0.041). No significant differences were observed between the groups regarding sex distribution, side of surgery, arm dominance, surgical indication, or follow-up duration (p>0.05 for all). The median follow-up duration for the entire cohort was 72 months (interquartile range [IQR]: 48–84 months), with a follow-up range of 37 to 117 months (Table 1).

Functional Outcomes

All 83 patients showed individual gains in functional scores (UCLA, ASES) and reductions in pain scores (VAS) following surgery. The median UCLA score improved from 6 (IQR: 5–8) pre-operatively to 26 (IQR: 23–30) post-operatively (p<0.001). The ASES score increased from 22 (IQR: 16–33) to 75 (IQR: 70–85) (p<0.001), while the VAS score decreased from 8 (IQR: 8–9) to 2 (IQR: 1–2) (p<0.001).

When stratified by scapular notching status, both groups showed significant improvements in UCLA, ASES, and VAS scores post-operatively (p<0.001 for all within-group comparisons). However, post-operative UCLA scores were significantly lower in the notching group compared to the non-notching group (median 25 vs. 27; p=0.027, Fig. 2). A

Table 1. Summary of patients' characteristics with regard to groups

	Total (*n*=83) (%)	Scapular notching		*p* (between groups)
		Present (*n*=46) (%)	Absent (*n*=37) (%)	
Age at surgery, years, mean±SD	64.10±11.56	66.41±11.05	61.22±11.68	**0.041**†
Sex				
Male	17 (20.48)	9 (19.57)	8 (21.62)	1.000§
Female	66 (79.52)	37 (80.43)	29 (78.38)	
Side				
Right	43 (51.81)	27 (58.70)	16 (43.24)	0.238§
Left	40 (48.19)	19 (41.30)	21 (56.76)	
Dominance				
Dominant arm	58 (69.88)	33 (71.74)	25 (67.57)	0.864§
Non-dominant arm	25 (30.12)	13 (28.26)	12 (32.43)	
Indication				
Primary glenohumeral arthritis	31 (37.35)	15 (32.61)	16 (43.24)	0.603¶
Proximal humerus fracture	23 (27.71)	14 (30.43)	9 (24.32)	
Failed osteosynthesis	11 (13.25)	6 (13.04)	5 (13.51)	
Massive irreparable rotator cuff tears	8 (9.64)	6 (13.04)	2 (5.41)	
Failed hemiarthroplasty	6 (7.23)	2 (4.35)	4 (10.81)	
Post-instability arthropathy	4 (4.82)	3 (6.52)	1 (2.70)	
Follow-up time, months	72 (48–84)	72 (60–84)	60 (48–84)	0.127‡
Sirveaux classification				
Grade 1	36 (43.37)	36 (78.26)	-	N/A
Grade 2	7 (8.43)	7 (15.22)	-	
Grade 3	3 (3.61)	3 (6.52)	-	
Grade 4	0 (0.00)	0 (0.00)	-	

Descriptive statistics are presented using mean±standard deviation for normally distributed continuous variables, median (25th percentile–75th percentile) for non-normally distributed continuous variables, and frequency (percentage) for categorical variables. † Student's *t* test, ‡ Mann–Whitney U test, § Chi-square test, Fisher-Freeman-Halton test. Statistically significant p values are shown in bold. N/A, Non-applicable.

similar difference was observed in post-operative ASES scores (median 72 vs. 82; p=0.007, Fig. 3). No significant difference was found in post-operative VAS scores between the two groups (median 2 vs. 1; p=0.782).

In terms of score changes, the increase in UCLA score was greater in patients without scapular notching (median 22 [IQR: 19–25] vs. 17 [15–21]; p<0.001). This difference in improvement was also replicated for ASES scores, albeit not reaching statistical significance (median 57 [45–65] vs. 49 [42–57]; p=0.074). The reduction in VAS scores was also comparable between groups (median –7 [–8 to –6] vs. –6 [–8 to –4]; p=0.275) (Table 2).

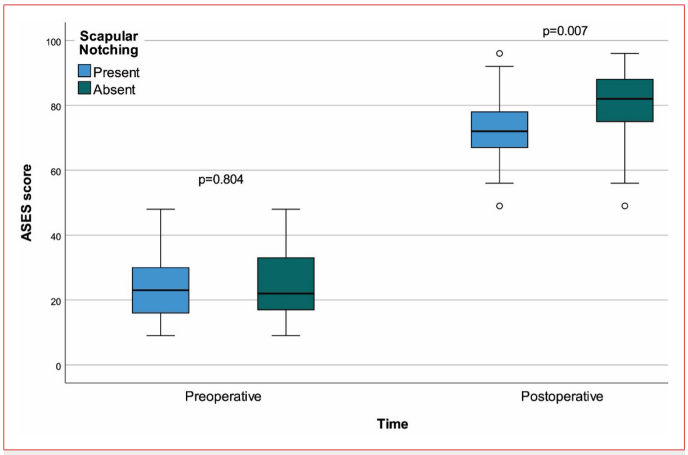

Figure 2. Box plots of the University of California–Los Angeles score with regard to scapular notching.

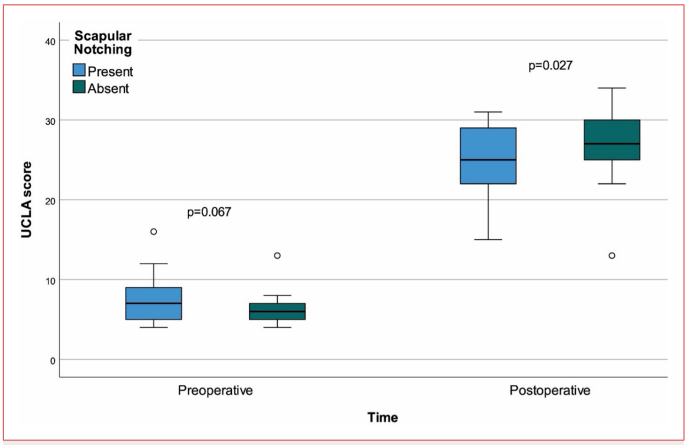

Figure 3. Box plots of American Shoulder and Elbow Surgeons score with regard to scapular notching.

Table 2. Summary of pre-operative and post-operative scores with regard to groups

	Scapular notching			
	Total (*n*=83)	**Present (*n*=46)**	**Absent (*n*=37)**	***p* (between groups)**
UCLA score				
Preoperative	6 (5–8)	7 (5–9)	6 (5–7)	0.067‡
Post-operative	26 (23–30)	25 (22–29)	27 (25–30)	**0.027**‡
p (within groups)	**<0.001**#	**<0.001**#	**<0.001**#	
Change [1]	20 (17–24)	17 (15–21)	22 (19–25)	**<0.001**‡
ASES score				
Pre-operative	22 (16–33)	23 (16–30)	22 (17–33)	0.804‡
Post-operative	75 (70–85)	72 (67–78)	82 (75–88)	**0.007**‡
p (within groups)	**<0.001**#	**<0.001**#	**<0.001**#	
Change [1]	52 (42–60)	49 (42–57)	57 (45–65)	0.074‡
VAS score				
Pre-operative	8 (8–9)	8 (7–9)	9 (8–9)	0.265‡
Post-operative	2 (1–2)	2 (1–2)	1 (1–2)	0.782‡
p (within groups)	**<0.001**#	**<0.001**#	**<0.001**#	
Change[1]	–6 (–8––5)	–6 (–8––4)	–7 (–8––6)	0.275‡

Descriptive statistics are presented using median (25th percentile–75th percentile) for non-normally distributed continuous variables. (1) Difference between post- and pre-operative, positive values represent an increase, and negative values represent a decrease. ‡ Mann–Whitney U test, # Wilcoxon signed ranks test. Statistically significant *p* values are shown in bold. UCLA: University of California-Los Angeles; ASES: American Shoulder and Elbow Surgeons; VAS: Visual analog scale.

DISCUSSION

Despite its efficacy in rotator cuff insufficiency and glenohumeral joint degeneration, RSA has procedure-specific complications that may influence long-term clinical outcomes and patient satisfaction. In the present study, the prevalence of scapular notching and its relationship with clinical outcomes were evaluated in patients treated with RSA, demonstrating that scapular notching is a common condition. Furthermore, although both functional and pain scores improved significantly in all patients, functional scores were found to be impacted by the presence of scapular notching.

The fact that scapular notching persists as a clinically relevant despite advances in surgical techniques and implant design is an important finding for practitioners of this surgery. In the present study, the observed notching rate was 55.4%. The wide range of prevalence reported in the literature (4.6–96%) has classically been associated with surgical technique, implant selection, patient anatomy, and imaging methodology,[6,7,16] the latter of which might indicate that the detection of this condition can be impacted by improper imaging or inconsistent definitions. Systematic reviews describe a more conservative estimate of 12% and 52% depending on prosthesis design, which could be associated with the advances in implants and their configurations,[17,18] especially since modern designs reduce the incidence of notching compared to traditional inlay components, with rates as low as 15%.[19] Inferior placement, lateralization of the glenosphere, and the inclination angle of the humeral component are known to influence the risk of contact between the scapular neck and the humeral implant. For instance, a large long-term cohort study demonstrated that the incidence of notching exceeded 70% in implants with a 155° neck–shaft angle, whereas prostheses with a 145° angle showed significantly lower frequency.[20] Notching is also understood as a dynamic process that can develop with progressive changes in the implant (polyethylene wear) and bone structure (osteolysis).[21,22] Over time, both the frequency and the reported significance of notching appear changed. A systematic review indicated that prevalence ranged from 35.4% to 47.1% before 2010, but decreased to 22.5% after this cut-off, most likely due to improved implant designs and increasing surgical experience.[23] In addition to implant factors, patient-related variables, such as body mass index have also been associated with notching.[24] Furthermore, mechanical impingement between the humeral component and the scapula during extension, adduction, and external rotation has been implicated as a contributor to inflammation and prosthetic loosening.[2] Nevertheless, the relatively short follow-up durations and potential selection bias in many studies could be obfuscating the true prevalence. While our results show the continuing relevance of scapular notching in RSA and its association with functional outcomes, the lack of detailed implant data in our study prevented implant-specific analyses.

The potential impact of scapular notching on functional recovery after RSA has long been debated. In our cohort, although all patients showed post-operative improvement, those with notching demonstrated significantly lower post-operative UCLA and ASES scores compared with patients without notching. Moreover, the improvement in UCLA score was also significantly less in patients with notching, suggesting that notching may limit functional gains. Our findings are consistent with systematic reviews and meta-analyses, which have clearly shown that scapular notching exerts a clinically relevant negative effect on functional scores, including shoulder range of motion, flexion, and abduction.[10] Several previous studies have similarly demonstrated adverse effects of notching on range of motion and clinical outcomes at midterm follow-up.[11,25-27] Conversely, a smaller number of studies have reported no significant association between post-operative notching and either function or pain.[28,29] Differences in follow-up duration, implant design, assessment methods, and patient heterogeneity could each explain the differing interpretations regarding this topic. Taken together, we believe that our results support the majority of the literature in classifying scapular notching as a clinical problem that impacting function rather than a purely radiographic phenomenon. Accordingly, minimizing the risk and severity of notching would appear to be crucial to improving functional outcomes.

In our study, a significant post-operative reduction in VAS scores was observed in both patients with and without notching, and both groups appeared to experience similar magnitudes of improvement. This indicates that the functional impact of scapular notching does not reflect on perceived pain intensity. The association between notching and pain remains controversial in the literature.[30] Several studies have failed to demonstrate a link between high rates of notching and increased pain levels.[8,31] Conversely, other series have reported associations between notching, pain, functional decline, and even early aseptic loosening.[9,29,30] Pain perception is known to vary considerably between individuals, and multiple factors, including implant conformity, capsular tension, deltoid adaptation, medications, and even post-operative behavioral adjustment to minimize pain, may contribute to reported pain levels. Based on the present results, we believe that scapular notching is largely unassociated with pain severity.

The retrospective design of this study limits data collection to availability and record accuracy, which prevents analysis of other factors associated with notching or functional outcomes. The presence and grading of scapular notching were assessed

visually on standard radiographs. Although this modality is widely used for diagnostic purposes even when other methods are readily-available, it is possible that diagnostic accuracy would have been improved by more sensitive and quantitative imaging methods (computed tomography or magnetic resonance imaging). The relatively small sample size was arrived upon due to strict inclusion and exclusion criteria. We believe this was necessary for unconfounded analyses; however, statistical analysis comparing different notching grades were not possible. Pain was evaluated using VAS, which is inherently subjective, and potential confounders were not controlled. Finally, detailed technical information regarding prosthesis configuration, including implant type, surgical technique, glenosphere size, and component positioning, was not consistently available in the retrospective records, preventing further analysis of these parameters.

CONCLUSION

Scapular notching is a common complication following RSA and, despite overall clinical improvement, is associated with less favorable functional outcomes compared with patients without notching.

DECLARATIONS

Ethics Committee Approval: This study was approved by the Gazi University Faculty of Medicine Ethical Committee (Date: 31.12.2024, Decision no: E-1130153).

Informed Consent: All participants consented to participate in the study.

Conflict of Interest: None declared.

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