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Glenoid version is associated with different labrum tear patterns in shoulder instability

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Background: Previous studies have evaluated glenoid version as a risk factor for anterior and posterior shoulder instability. However, the association of glenoid version with combined anterior-inferior-posterior (>180°) labrum injuries is unknown. The purpose of the present study was to investigate various parameters of glenoid morphology, including version, in >180° labral tears and to compare these values with isolated anterior and isolated posterior tears.

Methods: Magnetic resonance imaging studies from a consecutive series of shoulder instability patients were reviewed by 3 independent observers to measure the parameters of glenoid morphology including superior-inferior and anterior-posterior diameter, diameter ratio, glenoid version using the glenoid vault method, and percentage of glenoid bone loss using the best-fit circle method. These parameters were compared between patients with anterior (group 1), posterior (group 2), and >180° labral tears (group 3). Interobserver reliability coefficients were calculated for all measurements assessed.

Results: There were statistically significant differences for all group comparisons regarding the glenoid version, with group 2 having the most retroversion (19.9° ± 4.71°) followed by group 3 (14.21° ± 4.59°) and group 1 (11.24° ± 5.3°). Group 3 showed the lowest amount of glenoid bone loss; however, the group differences did not reach statistical significance. There was also no statistically significant group difference for the other measured parameters. Interobserver reliability was in the good to excellent range for all measurements.

Conclusions: Combined anterior-inferior-posterior labral tears are associated with an increased amount of glenoid retroversion compared with isolated anterior labral tears. Isolated posterior labral tears have the largest amount of glenoid retroversion of all tear patterns.

Level of evidence: Level II; Retrospective Design; Prognosis Study

Keywords: Shoulder; instability; labral tear; glenoid version; morphology; bone loss

Combined anterior, inferior, and posterior glenoid labrum injuries (>180° tears) are a unique subset of glenohumeral instability with a higher failure rate after surgical treatment compared with other labral injuries.[19] The pathomechanics of this injury are not well understood.[19] Recent studies have shown the importance of the bony geometry of the glenoid, especially the glenoid version, in the pathomechanics of glenohumeral instability. Studies demonstrated that anterior

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This study was approved by the local ethics committee of the University of Connecticut (IRB no. 20X-083-1).

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shoulder instability was associated with increased anteversion of the glenoid,[2,5,10,22] whereas posterior shoulder instability was associated with increased retroversion.[7,8,12,21,23] Katthagen et al[15] further demonstrated that increased retroversion was a risk factor especially for atraumatic onsets of posterior shoulder instability. Biomechanical data further emphasized the influence of the glenoid version in posterior shoulder instability. Imhoff et al[13] demonstrated that in the presence of posterior labrum lesions, a significantly decreased force was required for posterior glenohumeral translation and dislocation as glenoid retroversion was increased. Furthermore, the results of this study showed that in the setting of >15° glenoid retroversion, Bankart repair alone was not able to restore the force required for dislocation back to the normal state.[13]

To the authors' knowledge, there has not been a study that evaluated the glenoid version in >180° labrum tears as a possible risk factor for these types of injuries in a similar fashion to isolated anterior and posterior injuries. Understanding the implications of glenoid version and its association with instability could be important in identifying which patients may be more at risk for failure after arthroscopic capsulolabral repair.

The purpose of this study was to investigate differences in glenoid version in >180° labrum tears compared with isolated anterior and posterior labral injuries. It was hypothesized that there would be a greater amount of glenoid retroversion in >180° tears compared with anterior injuries. Posterior injuries were expected to have the highest amount of retroversion of all injuries.

Materials and methods

Patient cohort

All consecutive patients treated surgically because of symptomatic shoulder instability by a single surgeon (ADM) between January 2008 and December 2017 were included in the present study. The indication for surgery was a history of shoulder dislocation that resulted in symptomatic glenohumeral instability. In the preoperative physical examination, patients presented with 2+ anterior-inferior or posterior-inferior load shift, symptomatic apprehension test with positive relocation, symptomatic posterior jerk test, or a positive Kim test. Preoperative magnetic resonance imaging (MRI) was available for every patient included in the study and confirmed a tear of the glenoid labrum. Exclusion criteria were rotator cuff pathologies, fractures of the shoulder girdle other than bony Bankart lesions, osteoarthritis of the glenohumeral or acromioclavicular joint, and chronic systematic musculoskeletal disease (eg, rheumatoid arthritis).

Data acquisition

For this retrospective study, the surgery records, operation reports, and preoperative outpatient reports were reviewed for the inclusion and exclusion criteria as well as demographic data that included gender, age at surgery, body mass index, smoking habits, side of the affected shoulder, and number of shoulder dislocations. The exact location of the labral tear was taken from the intraoperative notes. According to the location of the tear, the cohort was classified into 3 groups: isolated anterior or anterior-inferior labral tear (group 1), isolated posterior or posterior-inferior labral tear (group 2), and combined anterior-inferior-posterior (>180°) labral tear (group 3). The >180° labral tears were defined as starting in the anterior superior quarter (between 12 and 3 o'clock) including the inferior half (between 3 and 9 o'clock) and ending in the posterior superior quarter (between 9 and 12 o'clock).[19] Accordingly, labral tears in group 1 were defined by an extension starting from the anterior superior quarter including the anterior inferior quarter (between 3 and 6 o'clock) and ending in the posterior inferior quarter (between 6 and 9 o'clock). Labral tears in group 2 were defined by an extension starting in the anterior inferior quarter including the posterior inferior quarter and ending in the posterior superior quarter (Fig. 1).

MRI examination

Preoperative MRI scans at a minimum of 1.5 Tesla of all included patients were available for a detailed analysis of the glenoid geometry. The primary parameter of measurements was the glenoid version, which was determined according to the glenoid vault method.[8,15,24] Although this method was initially developed for computer tomography imaging,[24] more recent studies showed a high interobserver and intraobserver reliability for MRI scans and a better accuracy in comparison with the measurement method of Friedman et al.[6,8,15] The glenoid vault method is based on the MRI axial plane that runs through the middle of the glenoid neck (Fig. 2). First, an isosceles triangle is drawn that fits exactly into the glenoid vault. Then the angle between the bisecting line of the triangle and a tangent line on the endosteal face of the glenoid is measured that represents the glenoid version (Fig. 3).

In addition, the size of the glenoid articular surface was determined by measuring the superoinferior and anteroposterior length as well as the ratio between these 2 lengths (superoinferior/anteroposterior). The superoinferior length was measured in the coronal plane that ran through the middle of the glenoid articular surface, and the anteroposterior length was measured in the axial plane that ran through the middle of the glenoid neck (Figs. 2 and 4). For the glenoid size measurements, the endosteal surface of the glenoid was taken into account excluding chondral and labral tissue as glenohumeral dislocations may have led to loosening of these structures and therefore to a higher variability of the measurements. In cases of bony Bankart lesions, the loose bone fragments were also excluded from the measurements.

Another parameter that describes the geometry of the glenoid includes traumatic or erosive bone loss. This was measured using the best-fit circle method. It has been demonstrated that this method shows a good interobserver and intraobserver reliability as well as good accuracy based on MRI scans.[9,11] For the measurement, an MRI sagittal plane tangential to the articular surface was used (Fig. 2). First, a vertical line along the long axis of the glenoid through the supraglenoid tubercle was drawn. Then a best-fit circle with its center on this line was placed along the inferior edge of the glenoid. The glenoid bone loss was calculated in percentage, as described in Fig. 5. The best-fit circle method was used to detect and measure anterior and posterior bone loss. If the glenoid showed bone loss at both the anterior and posterior edge,

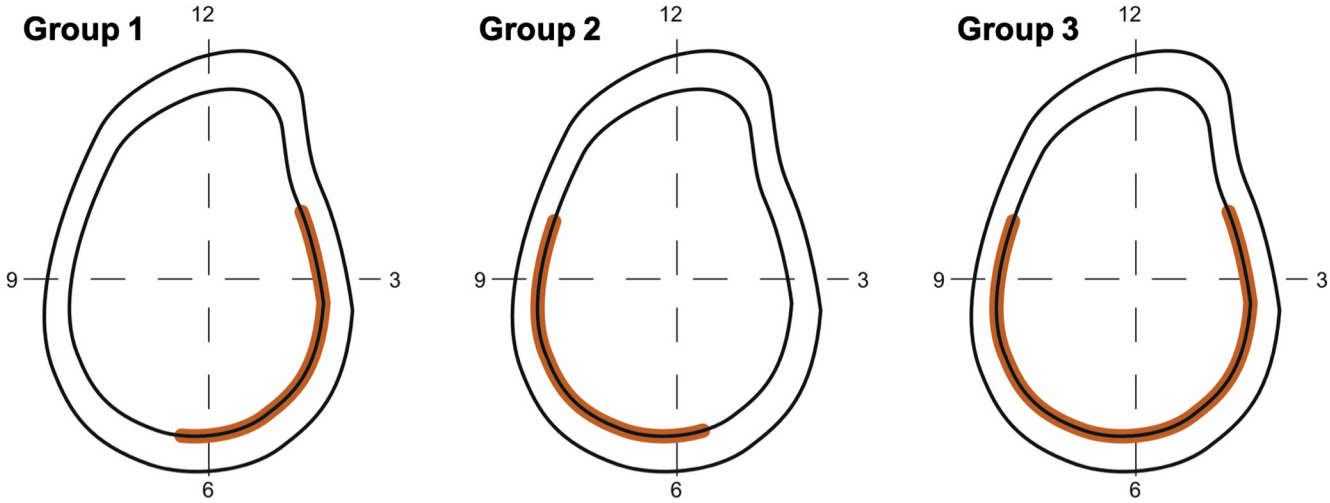

Figure 1 Group classification according to the labrum tear morphology. The schematic drawing represents the glenoid of a right shoulder. Group 1: labrum tear starting in the anterior superior quarter (12-3 o'clock) and reaching the posterior inferior quarter (6-9 o'clock); group 2: labrum tear starting in the anterior inferior quarter (3-6 o'clock) and reaching the posterior superior quarter (9-12 o'clock); group 3: labrum tear starting in the anterior superior quarter and reaching the posterior superior quarter.

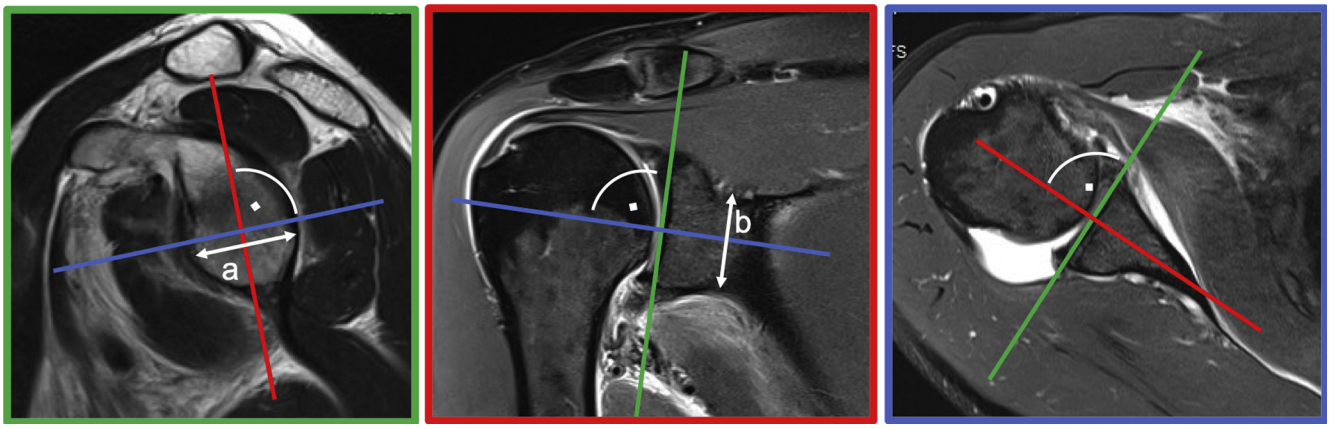

Figure 2 Definition of the magnetic resonance imaging planes for the measurements. The sagittal plane (*green*) is defined as the tangent plane to the glenoid surface. The coronal plane (*red*) is defined as perpendicular to the sagittal and axial plane (*blue*) and running through the middle of the glenoid width (a). The axial plane (*blue*) is defined as perpendicular to the sagittal and coronal plane and running through the middle of the width of the glenoid neck (b).

only the value for the larger loss was recorded, because this was considered as the clinically more relevant defect.

All measurements were performed by 3 independent observers using IntelliSpace PACS (Philips, Andover, MA, USA), and the averages were used as final values.

Statistical analysis

Continuous variables were calculated as mean ± standard deviation, and categorial variables were calculated as absolute and relative frequencies. The normal distribution of the data was examined and graphically confirmed with the Shapiro-Wilk normality test. A comparison between the 3 study groups was performed for the demographic data and for the MRI measurements using analysis of variance for continuous variables and using the χ^2 test and Fisher exact test for categorial variables. The Bonferroni-Holm correction was used to account for multiple comparisons. An interclass correlation coefficient (ICC) was calculated between the MRI measurements of the 3 observers. ICC values >0.9 were considered excellent, values between 0.8 and 0.9 were considered good, and values <0.8 were considered poor. The alpha level for all analyses was set at 0.05. Statistical analysis was conducted with Stata 15 software (StataCorp LLC, College Station, TX, USA).

Results

The characteristics of the 3 groups are listed in Table I. There was no significant group difference regarding the demographic parameters.

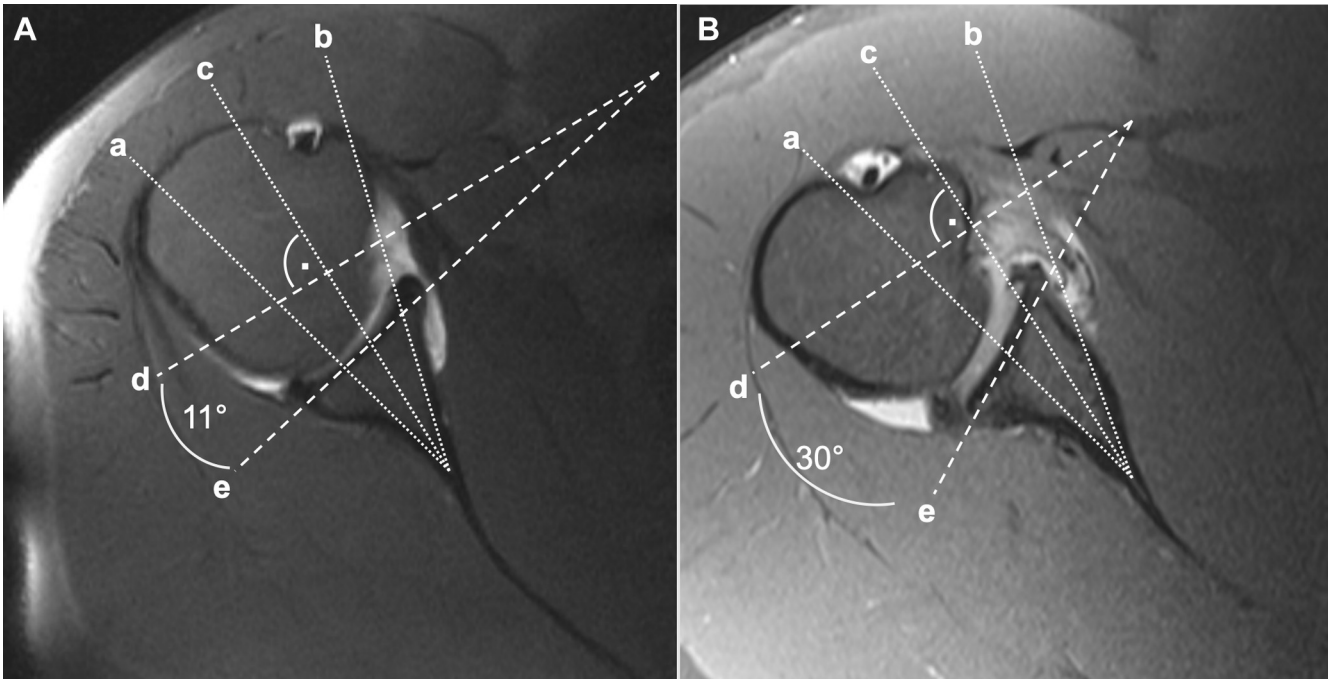

Figure 3 Measurement of glenoid version using the glenoid vault method comparing (**A**) minimal and (**B**) significant retroversion. The angle of the glenoid vault is measured from the endosteal surface (angle between *dotted lines* a and b). Then the bisecting line of the glenoid vault is defined (*dotted line* c). A perpendicular line is drawn from line c that represents neutral (0°) glenoid version (*broken line* d). The glenoid version is then measured between line d and a tangent line to the endosteal surface of the glenoid (*broken line* e). In these cases, the glenoid has 11° and 30° of retroversion, respectively.

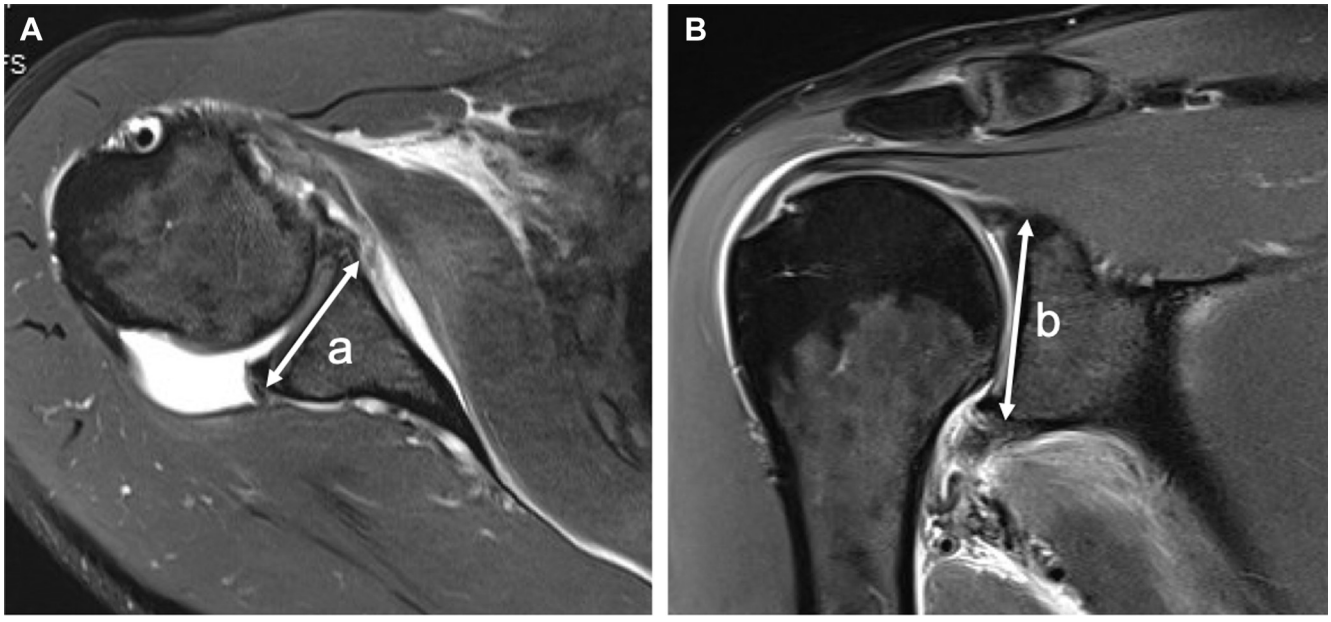

Figure 4 Measurement of the size of the glenoid. (**A**) The anteroposterior length of the glenoid is measured in the axial plane running through the middle of the glenoid neck (a). (**B**) The superoinferior length of the glenoid is measured in the coronal plane running through the middle of the glenoid surface (b).

The average glenoid version was 11.2° ± 5.3° of retroversion for group 1 (anterior tears), 19.9° ± 4.7° of retroversion for group 2 (posterior tears), and 14.2° ± 4.6° of retroversion for group 3 (combined anterior/posterior tears) with statistically significant differences for all group comparisons (Table II, Fig. 6). The percentage of glenoid

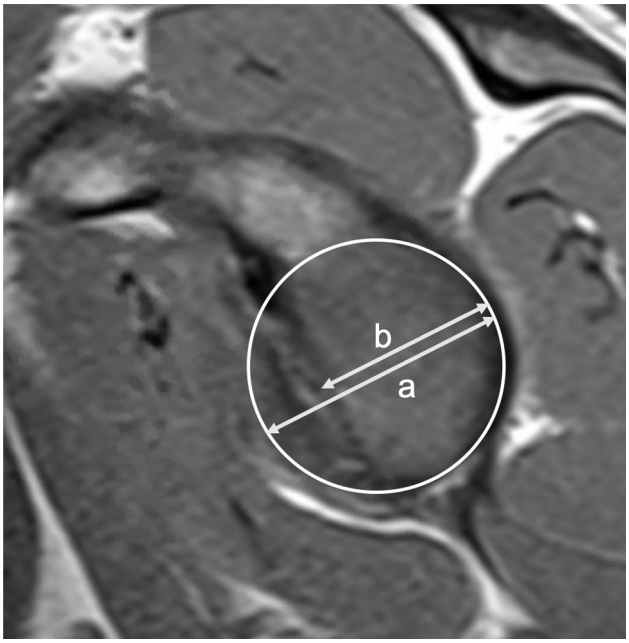

Figure 5 Measurement of glenoid bone loss using the best-fit circles method. A circle is fit to the inferior edge of the glenoid on the sagittal magnetic resonance imaging image that is just medial to the glenoid face. The width from the posterior (or anterior) edge of the circle to the remaining glenoid (b) is subtracted from the diameter of the full circle (a) and divided by the diameter of the full circle to produce the percentage of glenoid bone loss. Formula: Bone loss (%) = (a − b)/a × 100.

bone loss was lowest in group 3 at 4.7% ± 4.2%, but this was not significantly different in comparison with the other 2 groups. Also, for all other MRI measurements, the group differences did not reach significance.

The interobserver reliability of the measurements in this study was in the good to excellent range with an ICC over 0.8 for all measurements (Table III).

Discussion

The most important finding of this study was the significant association between the glenoid version and the location of labral tears in patients with glenohumeral instability. Combined anterior, inferior, and posterior labral defects showed a significantly increased retroversion in comparison with isolated anterior labral defects, whereas isolated posterior labral defects showed even higher angles of glenoid retroversion.

In the present study, 3 groups of patients were compared in order to investigate the correlation between the location of labral tears and the glenoid morphology. The results showed that the absolute size of the glenoid, the superior-inferior diameter, or the anterior-posterior diameter did not correlate with the location of labral tears. Also the ratio between these 2 measurements that represents the 2-dimensional shape of the glenoid did not show any significant group difference.

A further parameter that was investigated in the preoperative MRI scans was the glenoid bone loss. The importance of glenoid bone loss regarding anterior shoulder instability has been widely discussed in recent years. Clinically relevant bone loss of the anterior glenoid is typically caused by recurrent anterior shoulder dislocations.[16,20] However, Dickens et al[4] demonstrated in a prospective study on 714 athletes that even after first-time anterior shoulder dislocations a mean bone loss of 6.8% (range, 0.7%-17.6%) can be detected. As bone defects of the anterior glenoid are associated with inferior outcomes after Bankart repair, surgical bone transfer techniques should be considered in these cases.[3,25,27] So far, there is no consensus about the critical value of anterior bone defects beyond which sufficient glenohumeral stability cannot be restored by isolated Bankart repair. Values between 15% and 28% of the anteroposterior width of the glenoid have been discussed on the basis of biomechanical results.[14,26,28] In the present study, the patients with isolated anterior labrum tears showed a mean anterior bone loss of 7.1%. Interestingly, patients with isolated posterior labrum tears showed a similar amount of 7.9% posterior glenoid bone loss, when measured with the best-fit circle method. Although the comparisons with the >180° group did not show statistical significant differences, there was considerably less bone loss in these patients. Therefore, it may be noted that glenoid bone loss due to a single shoulder dislocation or due to chronic erosion is a minor problem in

Table I Demographic data of the 3 groups

	Number of patients	Operative side (R/L)	Number of dislocations (%)				Age at surgery	Dominant arm (R/L)	Number of smokers	BMI	Height (cm)
			1	2-5	6-10	>10					
Group 1	64	39/25	14	72	9	5	29.2 ± 10.5	56/8	4	26.5 ± 4.4	177.6 ± 8.7
Group 2	17	11/6	0	88	6	6	33.5 ± 14.4	16/1	1	28.1 ± 4.2	180.6 ± 1.8
Group 3	42	17/25	5	81	5	10	27.0 ± 12.2	39/3	0	26.9 ± 3.6	175.6 ± 6.9
P value		.11			.37		.15	.25	.29	.51	.19

BMI, body mass index.

Table II Between-group measurements for the glenoid morphology parameters

	Superior-inferior length (mm)	Anterior-posterior length (mm)	Superior-inferior to anterior-posterior ratio	Retroversion (°)	Bone loss (%)
Group 1	33.5 ± 3.7	25.9 ± 3.5	1.3 ± 0.2	11.2 ± 5.3	7.1 ± 8.1
Group 2	35.5 ± 3.4	27.3 ± 3.9	1.3 ± 0.2	19.9 ± 4.7	7.9 ± 8.4
Group 3	33.8 ± 3.2	26.4 ± 2.5	1.3 ± 0.1	14.2 ±4.6	4.7 ± 4.2
P value	.11	.23	.64	<.001*	.15

* Significant group difference.

patients with combined anterior/inferior/posterior labrum pathologies. However, further clinical data are needed to verify this statement.

The main focus of the present study was set on the evaluation of the glenoid version, which demonstrated a significant between-group difference. Previous studies have already identified a significant association between isolated posterior shoulder instability and increased glenoid retroversion.[8,15,17,21] Although Kim et al[17] found an increased retroversion in patients with isolated posterior instability compared with patients without glenohumeral pathology, Gottschalk et al[8] demonstrated that patients with posterior glenohumeral instability had significantly more glenoid retroversion than patients with anterior instability. These findings are in accordance with the results of the present study when the glenoid retroversion was compared between the patients with isolated posterior and isolated anterior labrum tears.

Besides these 2 patient groups with either anterior or posterior labrum defects, the present study also focused on patients with combined anterior, inferior, and posterior lesions. These extensive labral injuries were investigated by Mazzocca et al,[19] who performed a prospective clinical trial of 21 affected patients. The authors reported that arthroscopic repair led to a significant improvement of all measured outcome scores after a mean follow-up of 28 months.[19] However, there was a 15% failure rate with subsequent episodes of instability, which was significantly higher in comparison with the results after isolated anterior labrum repair as reported in the literature.[19] In a recent meta-analysis on the outcomes after arthroscopic anterior labrum repair, Alkaduhimi et al[1] reported a 6.6% redislocation rate in noncollision athletes. A detailed failure analysis, which would explain the worse results after combined anterior, inferior, and posterior stabilization, was not performed by Mazzocca et al.[19]

In the present study, all performed group comparisons for the glenoid version showed significant differences, with the >180° labral tear group showing significantly more retroversion than isolated anterior labrum tears and significantly less retroversion than isolated posterior labrum tears. This correlation between the glenoid morphology and glenohumeral instability is of distinct clinical relevance as the glenoid version has a relevant influence not only on the development of labral tears but also on the outcome after surgical repair. Katthagen et al[15] conducted a clinical trial with a mean follow-up of 4.1 years on 38 shoulders with isolated posterior glenohumeral instability, which were treated with arthroscopic capsulolabral repair. The authors reported that 2 patients needed revision surgery due to recurrent posterior instability, whereas 3 patients had self-reported redislocations or subluxations resulting in a failure rate of 13%.[15] Furthermore, their results showed that in comparison with traumatic onset of posterior instability, atraumatic onset was associated with significantly higher glenoid retroversion and significantly worse postoperative outcomes.[15]

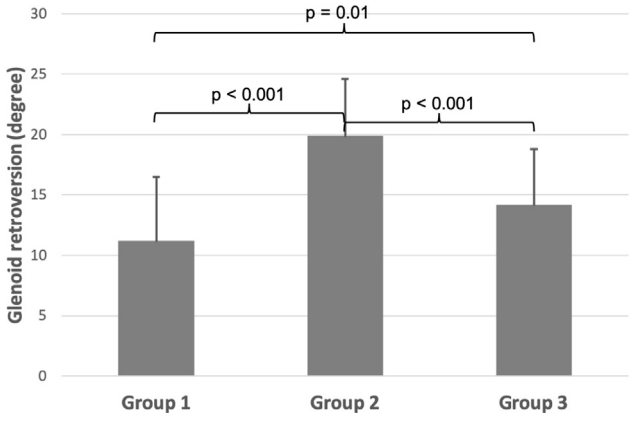

Figure 6 Glenoid retroversion. Bar chart representing the results of the glenoid retroversion in comparison between the 3 groups. The main bars represent the mean values, and the error bars represent the standard deviation.

Table III Interobserver reliability analysis of the various measurements

	ICC	95% Confidence interval
Superior-inferior length	0.839	0.593-0.920
Anterior-posterior length	0.916	0.882-0.941
Ratio superior-inferior/ anterior-posterior	0.868	0.814-0.906
Version	0.888	0.848-0.918
Bone loss	0.877	0.784-0.925

ICC, interclass correlation coefficient.

Although there is only limited clinical evidence regarding corrective osteotomies of the glenoid for the treatment of glenohumeral instability, the glenoid version must be taken into account when patients present with glenohumeral instability. In a recent study, Lacheta et al[18] retrospectively investigated 12 shoulders (11 patients) that underwent posterior glenoid osteotomy for posterior shoulder instability with increased glenoid retroversion. At a mean follow-up of 19.8 months, there were no postoperative redislocations, whereas 1 patient reported symptoms of recurrent shoulder instability.[18] Considering the significant association between the glenoid version and the morphology of labral tears, more clinical studies are needed to investigate the influence of glenoid version on the outcomes after surgical labral repair and the benefit of additional glenoid osteotomies.

There are several limitations to this study. First, the study design was retrospective based on preoperative radiological and intraoperative arthroscopic findings. Therefore, clinical correlation of our findings is limited, and conclusions about the influence of the glenoid morphology on postoperative outcomes are not possible. This, however, was not the aim of the present study, but rather to detect morphologic features of the glenoid in correlation with different labral defect patterns.

In addition, there was no control group without signs of labral pathologies and without problems of instability. Therefore, a comparison of the measurement results with healthy individuals was not possible.

The lack of information about the mechanism of first-time shoulder dislocation must be considered as further limitation. Glenoid version may have a different importance in traumatic vs. atraumatic shoulder dislocations. Also traumatic onset may have a different impact on glenoid bone loss.

In order to describe possible glenoid erosions, the best-fit circle method was used.[9,11] This method was originally established for anterior and anterior-inferior glenoid defects. In the present study, this method was also used for posterior glenoid defects in the patient group with posterior labrum tears. As there are no reference values for posterior erosions in the literature, the clinical relevance of these measurements is limited and comparison with anterior erosions is not possible. Therefore, these measurements have to be considered rather as descriptive within the patient groups than comparative between the patient groups.

The results of the present study are of distinct clinical relevance as the glenoid version is associated with the location and extension of labral tears. In comparison with isolated anterior labral tears both isolated posterior labral tears and $>180^{\circ}$ tears demonstrate increased glenoid retroversion. Although the results do not demonstrate a causal relation between the morphology of labral tear patterns and glenoid morphology, version should be considered when deciding on the treatment of these injuries, especially in revision cases, as it may explain the higher incidence of failures seen in this injury subset. However, further clinical study is needed to define the threshold of glenoid version at which a soft tissue procedure alone is likely to fail.

Conclusions

Combined anterior-inferior-posterior labral tears are associated with an increased amount of glenoid retroversion compared with isolated anterior labral tears. Isolated posterior labral tears have the largest amount of glenoid retroversion of all investigated labrum tear patterns.

Disclaimer

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References

1. Alkaduhimi H, van der Linde JA, Willigenburg NW, Paulino Pereira NR, van Deurzen DF, van den Bekerom MP. Redislocation risk after an arthroscopic Bankart procedure in collision athletes: a systematic review. J Shoulder Elbow Surg 2016;25:1549-58. https://doi.org/10.1016/j.jse.2016.05.002
2. Aygun U, Calik Y, Isik C, Sahin H, Sahin R, Aygun DO. The importance of glenoid version in patients with anterior dislocation of the shoulder. J Shoulder Elbow Surg 2016;25:1930-6. https://doi.org/10.1016/j.jse.2016.09.018
3. Boileau P, Villalba M, Hery JY, Balg F, Ahrens P, Neyton L. Risk factors for recurrence of shoulder instability after arthroscopic Bankart repair. J Bone Joint Surg Am 2006;88:1755-63. https://doi.org/1710.2106/JBJS.E.00817
4. Dickens JF, Slaven SE, Cameron KL, Pickett AM, Posner M, Campbell SE, et al. Prospective Evaluation of Glenoid Bone Loss After First-time and Recurrent Anterior Glenohumeral Instability Events. Am J Sports Med 2019;47:1082-9. https://doi.org/10.1177/0363546519831286
5. Eichinger JK, Massimini DF, Kim J, Higgins LD. Biomechanical evaluation of glenoid version and dislocation direction on the influence of anterior shoulder instability and development of Hill-Sachs lesions. Am J Sports Med 2016;44:2792-9. https://doi.org/10.1177/0363546516659281
6. Friedman RJ, Hawthorne KB, Genez BM. The use of computerized tomography in the measurement of glenoid version. J Bone Joint Surg Am 1992;74:1032-7.
7. Galvin JW, Parada SA, Li X, Eichinger JK. Critical findings on magnetic resonance arthrograms in posterior shoulder instability compared with an age-matched controlled cohort. Am J Sports Med 2016;44:3222-9. https://doi.org/10.1177/0363546516660076
8. Gottschalk MB, Ghasem A, Todd D, Daruwalla J, Xerogeanes J, Karas S. Posterior shoulder instability: does glenoid retroversion

predict recurrence and contralateral instability? Arthroscopy 2015;31: 488-93. https://doi.org/10.1016/j.arthro.2014.10.009
9. Gyftopoulos S, Hasan S, Bencardino J, Mayo J, Nayyar S, Babb J, et al. Diagnostic accuracy of MRI in the measurement of glenoid bone loss. AJR Am J Roentgenol 2012;199:873-8. https://doi.org/10.2214/ajr.11.7639
10. Hohmann E, Tetsworth K. Glenoid version and inclination are risk factors for anterior shoulder dislocation. J Shoulder Elbow Surg 2015; 24:1268-73. https://doi.org/10.1016/j.jse.2015.03.032
11. Huijsmans PE, Haen PS, Kidd M, Dhert WJ, van der Hulst VP, Willems WJ. Quantification of a glenoid defect with three-dimensional computed tomography and magnetic resonance imaging: a cadaveric study. J Shoulder Elbow Surg 2007;16:803-9. https://doi.org/10.1016/j.jse.2007.02.115
12. Hurley JA, Anderson TE, Dear W, Andrish JT, Bergfeld JA, Weiker GG. Posterior shoulder instability. Surgical versus conservative results with evaluation of glenoid version. Am J Sports Med 1992; 20:396-400.
13. Imhoff FB, Camenzind RS, Obopilwe E, Cote MP, Mehl J, Beitzel K, et al. Glenoid retroversion is an important factor for humeral head centration and the biomechanics of posterior shoulder stability. Knee Surg Sports Traumatol Arthrosc 2019;27:3952-61. https://doi.org/10.1007/s00167-019-05573-5
14. Itoi E, Lee SB, Berglund LJ, Berge LL, An KN. The effect of a glenoid defect on anteroinferior stability of the shoulder after Bankart repair: a cadaveric study. J Bone Joint Surg Am 2000;82:35-46.
15. Katthagen JC, Tahal DS, Montgomery SR, Horan MP, Millett PJ. Association of traumatic and atraumatic posterior shoulder instability with glenoid retroversion and outcomes after arthroscopic capsulolabral repair. Arthroscopy 2017;33:284-90. https://doi.org/10.1016/j.arthro.2016.07.020
16. Kim DS, Yoon YS, Yi CH. Prevalence comparison of accompanying lesions between primary and recurrent anterior dislocation in the shoulder. Am J Sports Med 2010;38:2071-6. https://doi.org/10.1177/0363546510371607
17. Kim SH, Noh KC, Park JS, Ryu BD, Oh I. Loss of chondrolabral containment of the glenohumeral joint in atraumatic posteroinferior multidirectional instability. J Bone Joint Surg Am 2005;87:92-8. https://doi.org/10.2106/JBJS.C.01448
18. Lacheta L, Singh TSP, Hovsepian JM, Braun S, Imhoff AB, Pogorzelski J. Posterior open wedge glenoid osteotomy provides reliable results in young patients with increased glenoid retroversion and posterior shoulder instability. Knee Surg Sports Traumatol Arthrosc 2019;27:299-304. https://doi.org/10.1007/s00167-018-5223-9
19. Mazzocca AD, Cote MP, Solovyova O, Rizvi SH, Mostofi A, Arciero RA. Traumatic shoulder instability involving anterior, inferior, and posterior labral injury: a prospective clinical evaluation of arthroscopic repair of 270 degrees labral tears. Am J Sports Med 2011; 39:1687-96. https://doi.org/10.1177/0363546511405449
20. McNeil JW, Beaulieu-Jones BR, Bernhardson AS, LeClere LE, Dewing CB, Lynch JR, et al. Classification and analysis of attritional glenoid bone loss in recurrent anterior shoulder instability. Am J Sports Med 2017;45:767-74. https://doi.org/10.1177/0363546516677736
21. Owens BD, Campbell SE, Cameron KL. Risk factors for posterior shoulder instability in young athletes. Am J Sports Med 2013;41:2645-9. https://doi.org/2610.1177/0363546513501508
22. Owens BD, Campbell SE, Cameron KL. Risk factors for anterior glenohumeral instability. Am J Sports Med 2014;42:2591-6. https://doi.org/10.1177/0363546514551149
23. Parada SA, Eichinger JK, Dumont GD, Burton LE, Coats-Thomas MS, Daniels SD, et al. Comparison of glenoid version and posterior humeral subluxation in patients with and without posterior shoulder instability. Arthroscopy 2017;33:254-60. https://doi.org/10.1016/j.arthro.2016.06.023
24. Poon PC, Ting FS. A 2-dimensional glenoid vault method for measuring glenoid version on computed tomography. J Shoulder Elbow Surg 2012;21:329-35. https://doi.org/10.1016/j.jse.2011.04.006
25. Shaha JS, Cook JB, Song DJ, Rowles DJ, Bottoni CR, Shaha SH, et al. Redefining ‘‘critical’’ bone loss in shoulder instability: functional outcomes worsen with ‘‘subcritical’’ bone loss. Am J Sports Med 2015;43:1719-25. https://doi.org/1710.1177/0363546515578250
26. Shin SJ, Koh YW, Bui C, Jeong WK, Akeda M, Cho NS, et al. What is the critical value of glenoid bone loss at which soft tissue Bankart repair does not restore glenohumeral translation, restricts range of motion, and leads to abnormal humeral head position? Am J Sports Med 2016;44:2784-91. https://doi.org/2710.1177/0363546516656367
27. Tauber M, Resch H, Forstner R, Raffl M, Schauer J. Reasons for failure after surgical repair of anterior shoulder instability. J Shoulder Elbow Surg 2004;13:279-85. https://doi.org/10.1016/j.jse.2004.01.008
28. Yamamoto N, Itoi E, Abe H, Kikuchi K, Seki N, Minagawa H, et al. Effect of an anterior glenoid defect on anterior shoulder stability: a cadaveric study. Am J Sports Med 2009;37:949-54. https://doi.org/910.1177/0363546508330139