Original Research

Glenoid Orientation and Profile in Atraumatic or Microtraumatic Posterior Shoulder Instability

Morphological Analysis Using Computed Tomography Arthrogram

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Background: Posterior shoulder instability (PSI) is a relatively uncommon condition that occurs in about 10% of patients with shoulder instability. PSI is usually associated with dislocations due to acute trauma and multidirectional instability, but it can also occur with or without recognizable recurrent microtrauma. The infrequency of atraumatic or microtraumatic PSI and the lack of a full understanding of the pathoanatomy and the knowledge of management can lead to misdiagnosis or delayed diagnosis.

Purpose: To evaluate the morphologic factors of the glenoid that are associated with atraumatic or microtraumatic PSI.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Enrolled in this study were patients who underwent arthroscopic posterior labral repair between January 2013 and March 2017 and were diagnosed with posterior glenohumeral instability by means of preoperative computed tomography arthrography (CTA) (n = 39; PSI group). These patients did not have any significant dislocation or subluxation episodes. The morphologic factors of the glenoid as revealed using CTA were compared with the CTA images from a sex-matched control group (n = 117) of patients without PSI who had been diagnosed with adhesive capsulitis in an outpatient clinic. The glenoid version and shape were evaluated between the 2 groups using the CTA findings, and the degree of centricity of the humeral head to the glenoid was assessed in the PSI group. Multivariate logistic regression analysis was performed to identify factors associated with PSI.

Results: The results of the multivariate logistic regression analysis indicated no statistically significant difference between the PSI and control groups regarding glenoid version or a flat-shaped glenoid. However, statistically significant between-group differences were found regarding convex glenoid shape, with an odds ratio of 5.39 (95% CI, 1.31-23.35; $P = .0207$). The proportion of eccentricity was significantly higher in the PSI group (21/39; 54%) versus the control group (47/117; 40%) ($P = .031$).

Conclusion: The presence of convex glenoid shape was significantly associated with atraumatic or microtraumatic PSI. Humeral head eccentricity accounted for a high percentage of convex glenoid shape. However, there was no significant correlation between PSI and glenoid retroversion.

Keywords: posterior shoulder instability; microtrauma; computed tomography arthrography; glenoid retroversion; glenoid morphology; humeral head centricity

The incidence of posterior shoulder instability (PSI) in a relatively young population with shoulder instability may be as high as 10% to 24%, and recognition of symptomatic PSI is becoming more common owing to advancements in diagnostic modalities.[2,14,18,26] However, PSI is less common than is anterior shoulder instability.[22] PSI can occur because of a variety of reasons. PSI is usually associated with dislocation due to acute trauma and multidirectional instability, but it may also occur without trauma or with recurrent minor trauma that may not be perceptible.[6,17,25] The cause is not fully understood. Atraumatic or microtraumatic PSI is often more difficult to diagnose clinically and radiologically than are anterior shoulder instability and posterior shoulder dislocation, which are closely associated

The Orthopaedic Journal of Sports Medicine, 9(2), 2325967120982965
DOI: 10.1177/2325967120982965

with trauma. Physical examination findings for atraumatic PSI are typically less definitive and more subtle than those for anterior shoulder instability.[13,17] Recently, many authors have studied PSI and suggested predisposing causes, which include posterior humeral head subluxation, excessive glenoid retroversion, glenoid dysplasia, and increased posterior capsular area.[7,9,18,27,28] Despite the efforts of these studies, no clear relationship has been established between these structural variations and atraumatic or microtraumatic PSI. In particular, the association among glenoid version, glenoid shape, and glenohumeral instability has been studied extensively, but several reports[1,3,10-12,19,24,28] have shown conflicting results. A number of methods have been described in the literature[5,11,18,23,28] for measuring the glenoid version in both 2 and 3 dimensions using plain radiography, computed tomography (CT), CT arthrography (CTA), magnetic resonance imaging (MRI), and magnetic resonance arthrography (MRA). MRI, especially MRA, provides the most information about pathologic soft tissue in the case of shoulder instability, but CTA can be a viable alternative to MRA in diagnosing shoulder instability.[5] The aim of this study was to assess morphologic risk factors of the glenoid associated with atraumatic or microtraumatic PSI. We hypothesized that there would be morphologic risk factors of the glenoid closely associated with atraumatic or microtraumatic PSI.

METHODS

Patient Selection

This study was approved by the institutional review board of our affiliated institution. All patients who underwent arthroscopic posterior labral repair performed by the senior author (Y.S.Y.) between January 2013 and March 2017 were retrospectively identified. Of these, 51 patients were selected, and all CTA and arthroscopic findings were made available. After we excluded patients with previous shoulder dislocation, previous shoulder surgery, multidirectional instability, and moderate-to-severe degenerative glenohumeral changes, a total of 39 patients with atraumatic or microtraumatic PSI were enrolled. In this study, we defined PSI as nontraumatic when the patient was unable to recall trauma or an event that caused dislocation or when the cause was subluxation due to repetitive low-energy contact stress (eg, occupational) rather than high-energy contact (eg, a car accident or a fall during skiing or snowboarding).

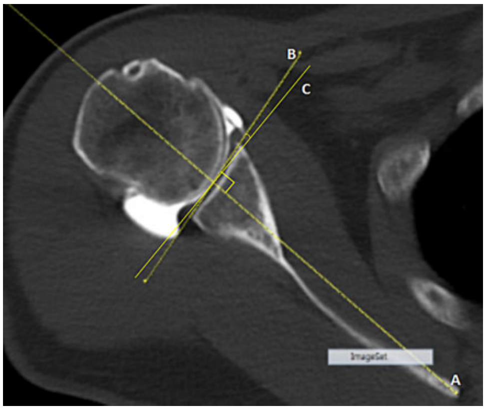

Figure 1. Glenoid version measurement (Friedman angle). The horizontal axis of the scapula (line *A*) was determined by the line from the center of the glenoid fossa to the medial edge of the scapula at the glenoid middle level. Line *B* is the line from the anterior to the posterior osseous border of the glenoid. Line *C* is perpendicular to line *A* and indicates the neutral version. The angle between lines *B* and *C* is the version measurement.

Patients without PSI during the same time period were identified among 303 patients diagnosed with adhesive capsulitis at an outpatient clinic. Among these patients, CTA had been conducted to find reasons for loss of shoulder motion in patients with adhesive capsulitis who had persistent symptoms and persistent pain after 6 months of nonoperative treatment. After we excluded patients with rotator cuff tear and moderate–to-severe degenerative glenohumeral changes, 117 patients were enrolled in the control group, matching the sex ratio of the PSI group.

Ultimately, 156 patients who had undergone preoperative CTA were enrolled. There were 35 men and 4 women in the PSI group and 105 men and 12 women in the control group.

Arthrography Procedure

Under fluoroscopic guidance, a puncture was made at the glenohumeral joint in the anterior approach using a 22-gauge spinal needle under aseptic technique and local anesthesia. After the intra-articular position of the needle tip was verified, about 13 mL of a contrast mixture of 10 mL of iohexol (Bonorex 300; Daihan Pharm) and 10 mL of normal saline was injected into the glenohumeral joint.

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Final revision submitted July 2, 2020; accepted August 10, 2020.
The authors have declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
Ethical approval for this study was obtained from Hallym University College of Medicine Dongtan Sacred Heart Hospital (study No. 2018-05-005).

Computed Tomography

All patients underwent CT in the neutral position with the arm resting at the side and the thumb pointing upward. All CT portions of the shoulder CTA were performed using a dual stellar detector row scanner (SOMATOM definition Flash CT; Siemens Healthcare) with 100-kV tube voltage and 200-mA tube current. Axial images were reconstructed, and oblique sagittal and coronal images were reformatted with 2-mm section thickness.

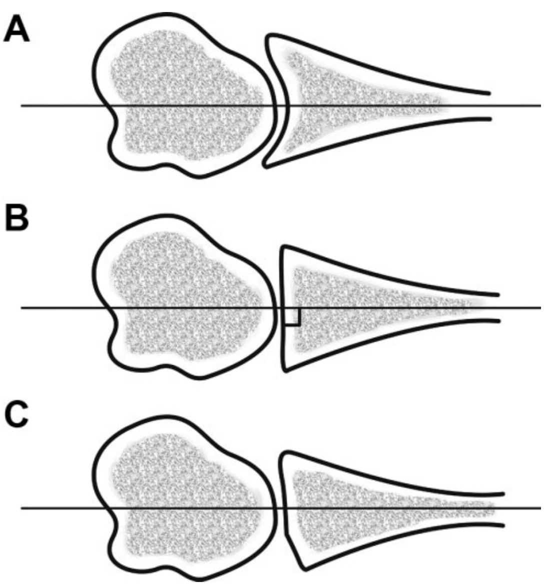

Figure 2. The 3 classifications of glenoid shape as determined from Inui et al[12] and Weishaupt et al[28]: (A) concave, (B) flat, and (C) convex (dysplastic glenoid with triangular bony deficiency).

Imaging Evaluation

From the CTA scans, we evaluated the glenoid version using the Friedman angle. The 2-dimensional method for measuring the glenoid version on CT, described by Friedman et al[8] in 1992, uses an angle between the line perpendicular to the transverse axis of the scapula and the line parallel to the glenoid articular surface (Figure 1).

The glenoid shape was determined and classified by modifying the method described by Inui et al[12] and Weishaupt et al.[28] The 3 classifications used were *concave*, *flat*, and *convex*, as shown in Figure 2. The convex classification indicated a dysplastic glenoid with a triangular bony deficiency or tiny bony fragment. All of the CT axial images were confirmed to be midglenoid level through the cross link of the coronal image using the scout view (Figure 3).

We also measured the degree of centricity of the humeral head to the glenoid using the method described by Pearl et al[20] (Figure 4). The anterior and posterior points where the articular cartilage terminated were identified. These 2 points were usually clearly and distinctly observed on CTA because they often coincided with the anterior and posterior rotator cuff muscle (subscapularis and infraspinatus) insertion point. A line connecting vertically from the center of the line connecting these 2 points was defined as the humeral center line. The humeral center line passed the center of the rotation point. We defined this line as having concentricity when it passed the glenoid surface center and having eccentricity when it was outside the center point (Figure 5).

To assess interobserver reliability for the glenoid version and glenoid shape assessments on CTA, 2 independent orthopaedic shoulder specialty fellows examined the same images. During CTA evaluation, both readers were blinded to the patient's diagnosis and clinical history. To assess the consistency of these measurements, each rater conducted a second measurement using the same images 2 weeks after the first measurement with no knowledge of the results of the initial assessment.

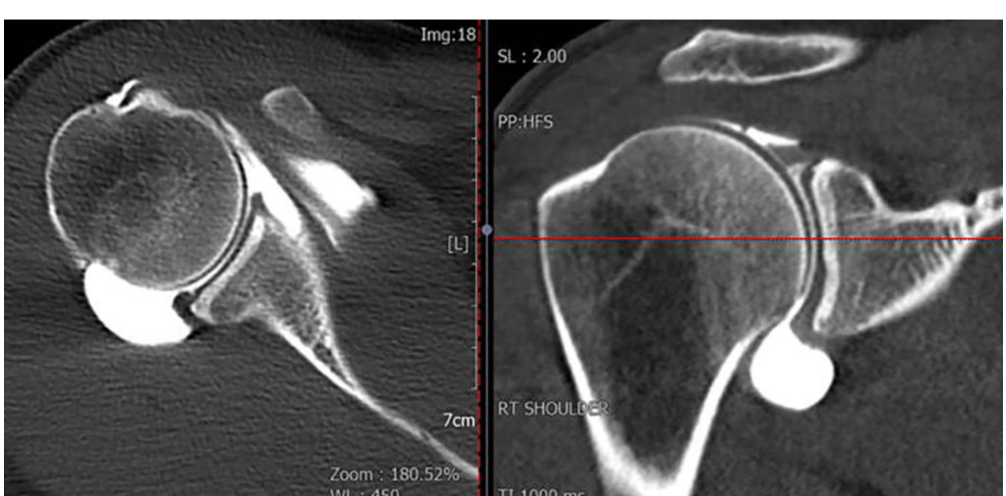

Figure 3. Axial computed tomography scout view (*left*) at the midjoint level through the cross-link of the coronal image (*right*). The red horizontal line represents the axial cut level.

Statistical Analysis

Univariate data or continuous variables are presented as mean and SEM or as median and range, whereas categorical variables are presented as counts and frequencies. Univariate analysis was performed using the *t* test for continuous variables and Fisher exact test for categorical variables. Multivariate logistic regression analysis was performed to identify factors associated with PSI, and odds ratios (ORs) and 95% CIs were calculated for all variables. $P < .05$ was considered statistically significant.

Interobserver reliability was quantified using the intraclass correlation coefficient (ICC) for glenoid version and the κ statistic for glenoid shape. Interpretation of the κ statistic was performed as described by Landis and Koch.[15]

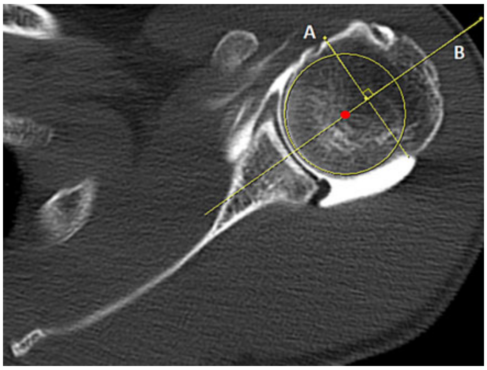

Figure 4. Method used to measure the degree of centricity of the humeral head relative to the glenoid articular surface, based on Pearl et al.[20] The anterior and posterior points where the articular cartilage terminated were identified. These 2 points are the anterior and posterior rotator cuff muscle (subscapularis and infraspinatus) insertion point. Line *A* is the line connecting these 2 points, and line *B* (humeral center line) is the vertical connecting line from the center of line *A*. The red dots indicate the center of rotation of the humeral head.

All statistical analyses were performed using SPSS version 12.0 (SPSS Inc.; Chicago, IL).

RESULTS

The study population consisted of 39 patients with atraumatic or microtraumatic PSI and 117 control patients with adhesive capsulitis. According to the arthroscopic findings of the PSI group, 13 patients showed an additional superior labral anterior-to-posterior lesion (Figure 6A); 18 patients had additional inferior labral damage (Figure 6B); and 8 patients had only a posterior labral tear with linear articular cartilage damage (Figure 6C). Of the 8 patients, 7 had inverted triangular articular cartilage defects; we called this lesion the "delta defect." This delta defect was not visible on the CT scan.

Univariate analysis showed statistically significant differences in mean age, with patients in the PSI group being younger than were the control patients (35.7 vs 46.3 years; $P = .001$). In addition, a statistically significant difference in glenoid shape was found, with a convex-shaped glenoid present in 9 of 39 patients (23%) in the PSI group versus 8 of 117 patients (6.8%) in the control group ($P = .002$). The proportion of eccentricity was significantly higher in the PSI group (21/39; 54%) versus the control group (47/117; 40%) ($P = .031$). However, the difference in glenoid version between the 2 groups was not statistically significant ($P = .610$) (Table 1).

The results of the multivariate logistic regression analysis indicated there were no statistically significant between-group differences in sex, glenoid version, flat-shaped glenoid, or humeral head eccentricity (Table 2). However, statistically significant differences were found for convex-shaped glenoid (OR, 5.39; 95% CI, 1.31-23.35; $P = .0207$) and age (OR, 0.89; 95% CI, 0.84-0.93; $P = .001$) (Table 2).

Of the 39 patients in the PSI group, 54% (21 patients) showed eccentricity, and 7 (78%) of the 9 patients with convex-shaped glenoid showed eccentricity (Figure 7).

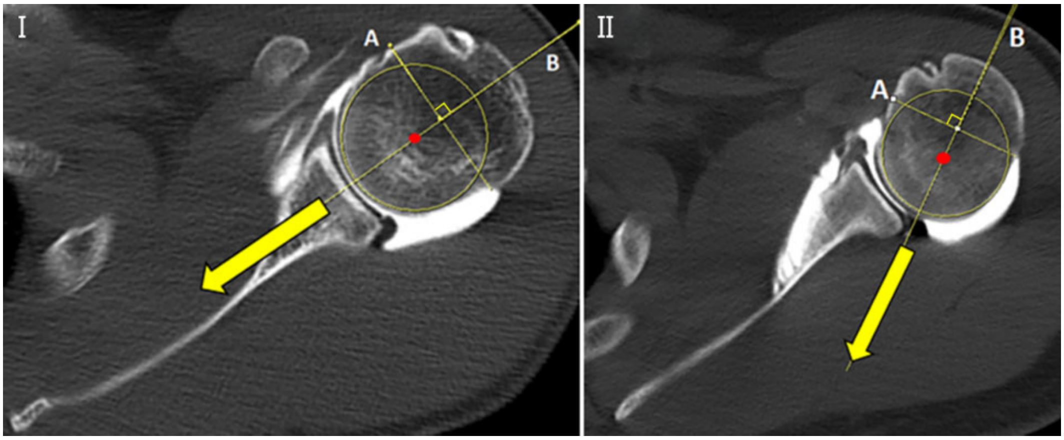

Figure 5. The degree of centricity of the humeral head to the glenoid: (I) concentricity and (II) eccentricity. The yellow arrows indicate force vectors. The red dot indicates the center of rotation of the humeral head. See Figure 4 for definitions of lines *A* and *B*.

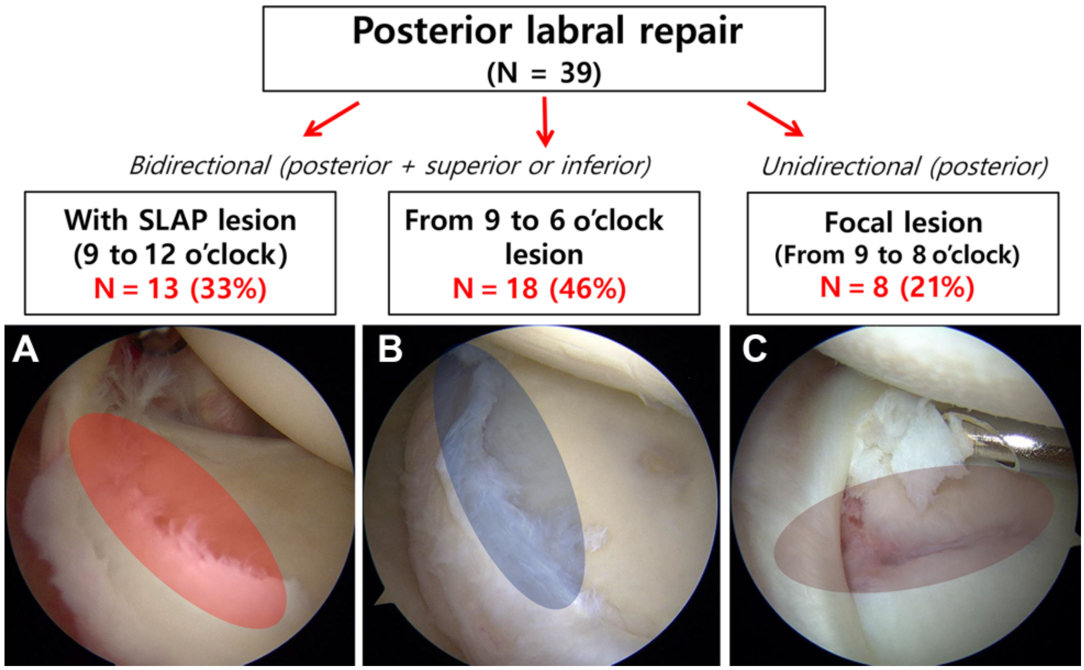

Figure 6. Classification according to lesion site in patients undergoing posterior labral repair. (A) View from a 30° arthroscope through the posterior portal of a right shoulder. (B and C) View from a 30° arthroscope through the transcuff portal of a left shoulder. SLAP, superior labral anterior-to-posterior.

TABLE 1
Descriptive Data From Univariate Analysis[a]

	Atraumatic PSI Group (n = 39)	Control Group (n = 117)	*P*
Sex, male/female, n	35/4	105/12	NA
Age, y, mean (range)	35.7 (22.0-45.0)	46.3 (31.0-59.0)	**.001**
Affected side, left/right, n	11/28	30/87	.6625
Mean glenoid version, deg[b]	–1.39	–1.03	.610
Glenoid shape (concave/flat/convex), n	8/22/9	54/55/8	**.002**
Concentricity/eccentricity of humeral head to the glenoid, n	18/21	70/47	**.031**

[a]NA, not applicable; PSI, posterior shoulder instability. Bolded *P* values indicate statistical significance ($P < .05$).
[b]A negative number indicates retroversion, and a positive number indicates anteversion.

Regarding the reliability of the CTA assessments, the interobserver reliability for glenoid version (ICC, 0.84) and glenoid shape (κ, 0.81) was very good.

DISCUSSION

In this study, the high incidence of convex glenoid shape in patients with atraumatic or microtraumatic PSI (23% vs 7% in the control group) is consistent with previous studies investigating the relationship between glenoid dysplasia and PSI. Galvin et al[9] found that the prevalence of glenoid dysplasia in patients with PSI was 49%, which was relatively high compared with that of the control group. In contrast to several previous studies[3,9,19,28] that reported a close relationship between PSI and glenoid retroversion, the present study did not find PSI and glenoid retroversion to be closely related.

Numerous studies[4,16,21] have reported differences in glenoid size and version according to sex. Sex was found to be the strongest independent predictor of glenoid size and version. Therefore, the strength of the present study was the comparison of radiologic evaluation (glenoid version and shape) between the PSI and control groups using sex-matched ratios.

A number of studies[4,16,23] have measured glenoid version using the method by Friedman et al,[8] which is based on a standard 2-dimensional axial CT slice at the level of the

TABLE 2
Results of Multivariate Analysis[a]

	Odds Ratio (95% CI)	*P*
Male sex	0.66 (0.15-3.48)	.5301
Age	0.89 (0.84-0.93)	**.001**
Glenoid version	1.06 (0.94-1.2)	.3357
Glenoid shape: flat	1.38 (0.51-3.91)	.5301
Glenoid shape: convex	5.39 (1.31-23.35)	**.0207**
Humeral head: eccentricity	1.57 (0.55-4.04)	.2307

[a]Bolded *P* values indicate statistical significance ($P < .05$).

midglenoid. This has the advantage of being easily identified and obtained in routine shoulder CT scans. Our results for the measurement of the glenoid version using the Friedman method also showed good interobserver reliability (ICC, 0.84).

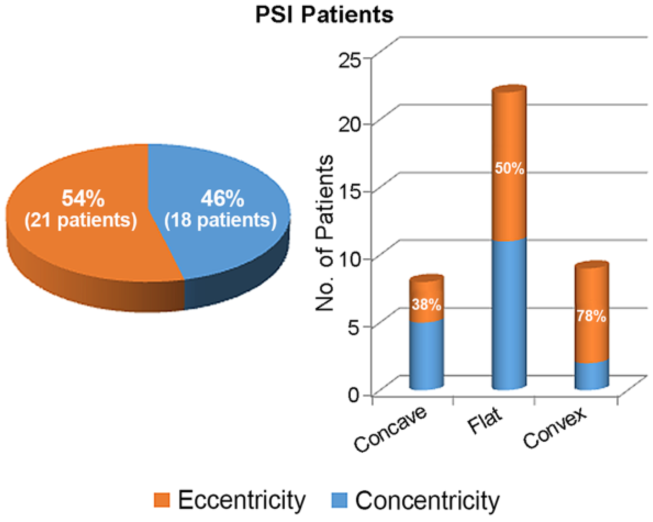

Figure 7. Rates of eccentricity and concentricity in the patients with posterior shoulder instability.

Galvin et al[9] used shoulder MRA to measure and compare multiple radiographic variables between 63 patients with symptomatic PSI and 49 controls. Those investigators reported that the presence of increased glenoid retroversion on MRA was significantly associated with symptomatic PSI. Although MRA has high sensitivity (88%-100%) and high specificity (91%-93%) in the detection of glenoid labral lesions,[6,25] MRA is more costly than is conventional CT. Furthermore, many radiologic measurements using MRA are complex and difficult to perform. In addition, the young, male, athletic military population represented in this study[9] may not be comparable with a civilian cohort.

Owens et al[18] reported a 17% increase in PSI whenever retroversion increased by 1°. However, that report did not provide a detailed description of the measurement method, the study used a single observer for measurements, and most patients in the study group had traumatic PSI.

Weishaupt et al[28] used CT examinations to compare the glenoid version and the shape of the posterior glenoid rim between 15 patients with atraumatic PSI and 15 patients without shoulder instability. In the 15 patients with atraumatic PSI, the investigators found a 93% incidence of deficiency of the posterior-inferior glenoid rim and increased glenoid retroversion. However, the study was conducted on a relatively small number of patients, and not all patients underwent CTA.

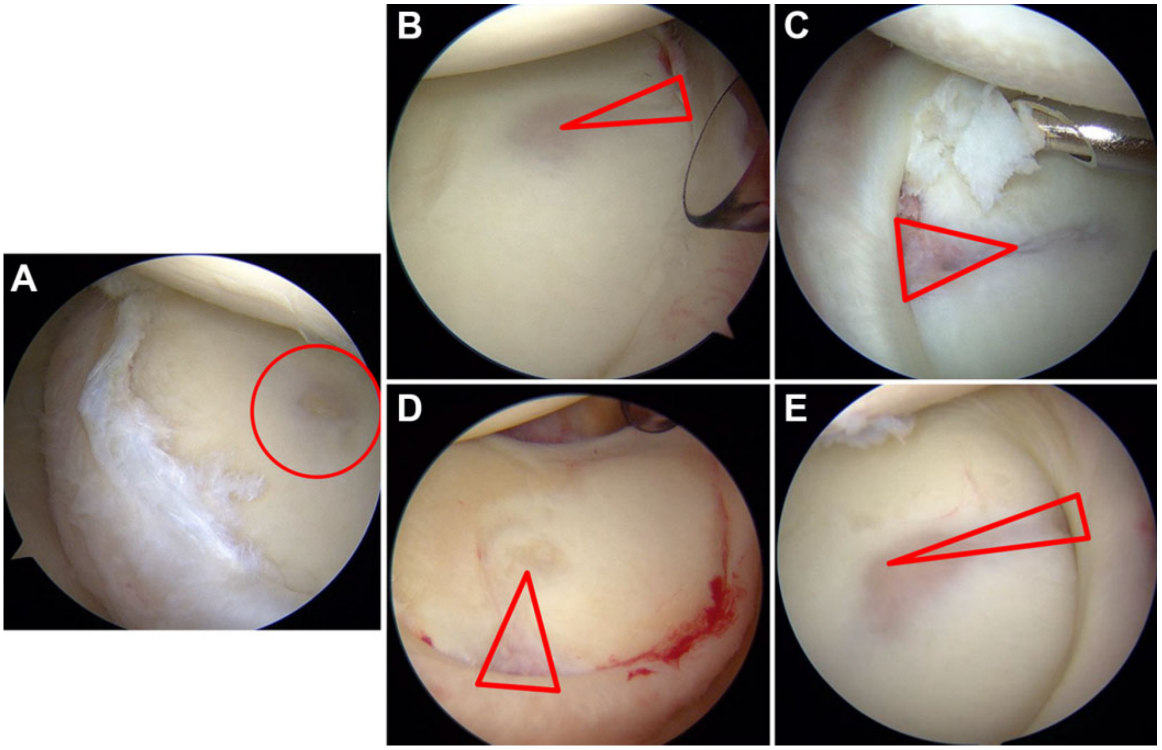

Figure 8. (A) Arthroscopic view from the posterior portal in a left shoulder demonstrating the posterior labral tearing and glenoid bare spot–bare area (red circle). (B-E) Posterior labrum from different portal sites and with an associated inverted triangular lesion or "delta defect" (red triangle): arthroscopic view from the transcuff portal in a (B, E) right shoulder and (C) left shoulder, and (D) arthroscopic view from the posterior portal in a left shoulder.

Although many studies have investigated glenoid version in patients with PSI, relatively few have focused on glenoid shape. Inui et al[12] investigated glenoid shape in 45 healthy individuals and 20 patients with atraumatic PSI and multidirectional laxity through use of 3-dimensional MRI. Those investigators found that the concave shape accounted for 0% of patients with PSI and 78% of healthy individuals. The loss of tilting angles and concavity of the inferior glenoid were found to be related to the direction of humeral head translation in PSI. However, the number of patients with atraumatic PSI was relatively small, and because the patient population included those with multidirectional instability, the findings were not necessarily applicable to pure PSI. Multidirectional instability may have represented a significant bias for those study results.

Because no previous studies have reported the relationship between PSI and the degree of centricity of the humeral head to the glenoid, the findings of the current study may be meaningful for future research. Recognition of these important parameters (convex glenoid shape, eccentricity of humeral head) may assist the surgeon in making an accurate diagnosis and improve the clinical management of PSI. In the 39 patients with PSI, we identified 8 patients with a focal labral lesion of the glenoid articular cartilage posteriorly from the 9- to 8-o'clock position (Figure 6C). CTA demonstrated no associated bony defect. A measurable inverted triangular articular cartilage defect, which we termed the delta defect, was seen in 7 of the 8 patients (Figure 8). We speculate that this lesion could be a result of posterior stress to the glenoid articular cartilage in patients with PSI.

The strengths of our research include the simplicity of the imaging evaluation method using a relatively economical CT scan, reliable assessment by 2 independent and highly experienced observers who were blinded to the results, and a comparative analysis using a control group with sex-matched ratios.

There are several limitations to the study. First, the retrospective design has inherent methodologic weaknesses. Second, the 2 study groups contained a significantly different number of patients (39 and 117), which may have weakened the statistical validity. Therefore, a greater number of patients should be recruited for a comparative study between 2 similarly sized groups. Third, the centricity measure of the humeral head to the glenoid was performed only in patients with PSI and was not compared with that of the control group. No statistical analysis was conducted on this measurement. Fourth, we did not compare nontraumatic and traumatic PSI, which have different mechanisms and may lead to different outcomes. Hence, future investigation is warranted. Fifth, the time from the onset of symptoms to the diagnosis of the patient varied considerably. Because the CT scan was not performed as soon as the symptoms appeared, we could not determine whether the convex shape of the glenoid was the cause or the consequence of PSI. The morphologic findings may in fact have been caused by the PSI.

CONCLUSION

The presence of convex glenoid shape was significantly associated with atraumatic or microtraumatic PSI in this study. Among patients with convex glenoid shape, humeral head eccentricity accounted for a high percentage of the atraumatic or microtraumatic PSI cases. However, this was not significantly correlated with glenoid retroversion.

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