J Shoulder Elbow Surg (2019) 28, 893–899

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Glenoid morphology is associated with the development of instability arthropathy

CrossMark

Maximilian Haas, MD[a,*], Fabian Plachel, MD[a,b], Guido Wierer, MD[a], Philipp Heuberer, MD[c], Thomas Hoffelner, MD[c], Eva Schulz, MD[a], Werner Anderl, MD[c], Philipp Moroder, MD[b]

[a]*Department of Orthopedics and Traumatology, Paracelsus Medical University, Salzburg, Austria*
[b]*Center for Musculoskeletal Surgery, Campus Virchow, Charité—Universitaetsmedizin, Berlin, Germany*
[c]*Department of Orthopedic Surgery, St. Vincent Shoulder & Sports Clinic, Vienna, Austria*

Background: Instability arthropathy (IA) is a major long-term concern in patients with anterior shoulder instability. This study investigated the association of glenoid morphology with the development of IA.
Methods: The study included 118 patients with unilateral anterior shoulder instability and available bilateral computed tomography scans. Instability-specific information was obtained from all patients. The glenoid morphology of the affected shoulder was compared with the nonaffected contralateral side resembling the constitutional preinjury glenoid shape. Both shoulders were evaluated independently by 3 observers to assess the grade of IA according to a Comprehensive Arthropathy Rating (CAR) system. Associations between IA and the glenoid morphology parameters were investigated.
Results: The average glenoid retroversion ($P < .001$), glenoid depth ($P < .001$), glenoid diameter ($P < .001$), and the bony shoulder stability ratio ($P < .001$) of the affected shoulder were significantly reduced compared with the contralateral side due to bony defects in 79.6% of the patients. The CAR of the affected side was significantly higher ($P < .001$), with more osteophytes ($P = .001$) and more sclerosis and cysts ($P < .001$). Differences in CAR (Δ-CAR) correlated positively with the age at the time of the computed tomography scan ($P < .001$), age at the initial dislocation ($P = .001$), size of the glenoid defect ($P = .005$), and the contralateral glenoid depth ($P = .011$), glenoid diameter ($P = .016$), and bony shoulder stability ($P = .029$), and negatively with glenoid retroversion of the affected side ($P = .027$).
Conclusion: Development of IA arthropathy is associated not only with the age of the patients but also with morphologic parameters of the glenoid, including glenoid defect size and the constitutional glenoid concavity shape.
Level of evidence: Level IV; Case Series; Prognosis Study

Keywords: Arthropathy; instability arthropathy; shoulder; recurrent shoulder instability; traumatic shoulder instability; glenoid; glenoid morphology; conservative treatment

Instability arthropathy (IA) is a major long-term concern when treating patients with shoulder instability,[10] and multiple factors might contribute to its development. Several studies have observed the occurrence of IA after operations to stabilize the shoulder.[1,11,18,20] Hovelius et al[9] suggested that

The Ethikkommission Land Salzburg approved this study (415-EP/73/523-2015).

*Reprint requests: Maximilian Haas, Muellner Hauptstrasse 48, Salzburg 5020, Austria.

E-mail address: maximilian.haas@alumni.pmu.ac.at (M. Haas).

1058-2746/$ - see front matter © 2018 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
https://doi.org/10.1016/j.jse.2018.09.010

IA is not necessarily a long-term adverse effect of surgery but rather of the shoulder instability itself.

Up to now, studies investigating the natural development of IA are scarce. Samilson and Prieto[19] were the first authors to identify factors correlating with the severity of IA in patients without any prior surgical treatment. Older age at the time of the initial dislocation, posterior direction of the dislocation, delayed reduction, and prior operations in which fixation devices disrupted cartilage resulted in a higher grade of arthropathy.[19] No correlation of bony lesions of the glenoid or the humeral head with the severity of IA was observed.[19] However, Buscayret et al[5] analyzed preoperative data of 570 patients who underwent shoulder stabilizing surgery. They found that not only age at the time of computed tomography (CT) scan and interval from initial dislocation to surgery (delay of treatment) but also bony glenoid lesions or impaction fractures of the humeral head as well as rotator cuff tears were associated with the development of IA.[5] Other factors, such as the number of previous instability episodes, type of instability (dislocation vs. subluxation vs. chronic pain), kind and level of sport, hand dominance, and sex were factors that were not associated with IA.[5]

The present study analyzed the effect of glenoid morphology and patient-specific characteristics on the natural development of IA. For that purpose, bilateral CT scans were used to compare the affected side with the nonaffected side in a large cohort of patients with untreated unilateral shoulder instability.

Materials and methods

Study population

Medical records were screened for patients who underwent treatment for anterior shoulder instability at our institution between 2006 and 2014. Patients with unilateral anterior shoulder instability with available bilateral CT were included. Patients with previous surgical interventions of either shoulder were excluded. Of an initial 169 patients with anterior shoulder instability, 118 patients (69.8%) met the inclusion criteria and were enrolled into the study. We excluded 3 patients due to bilateral shoulder instability, 40 had undergone previous surgery, and 8 did not receive a CT scan.

For all included patients, baseline patient characteristics together with further information, including reason for instability, patient age at the initial dislocation, and at the time of imaging, time from first dislocation to surgery and radiologic evaluation, and the number of dislocations were assessed.

CT analysis

Bilateral CT scans were performed as a routine diagnostic examination[16] in patients with shoulder instability using a 64-slice Somatom Sensation 64 CT scanner (Siemens, Erlangen, Germany). A multiplanar reconstruction tool for the IMPAX EE R20 VIII software (Agfa HealthCare, Mortsel, Belgium) was used to create a standardized imaging plane in the main direction of dislocation (3 to 9 o'clock position, Fig. 1) according to a previously published method.[14] Three-dimensional reconstructions of the CT scans were accomplished to create standardized en face views according to recent recommendations (Fig. 1).[15] Evaluation of the bony defects was performed according to the Pico method,[2] which was shown to be the most reliable method for that purpose.[4] Glenoid morphology, including diameter, depth, retroversion, and radius, was assessed. The bony shoulder stability ratio (BSSR) was calculated based on a validated formula[13] with proven reliability[14] (Fig. 2).

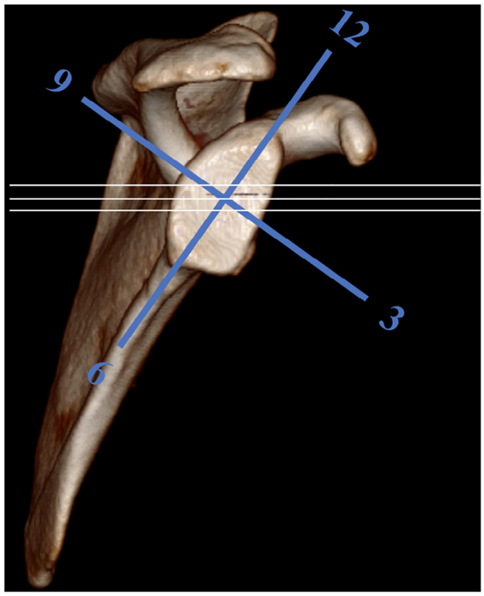

Figure 1 En face view of a 3-dimensional glenoid reconstruction with regular transversal imaging planes (*white lines*), marked long axis of the glenoid (6 o'clock to 12 o'clock), and the main measurement plane (3 o'clock to 9 o'clock, perpendicular to the long axis of the glenoid) according to a previously published method.[14]

One specialized shoulder surgeon (P.M.), experienced in the described measurement techniques, performed all measurements of both shoulders. The CT scans were also independently evaluated for the degree of IA by 3 shoulder surgeons (T.H., P.H., P.M.) from 3 different departments. In particular, presence of joint space narrowing, cysts, sclerosis, and osteophytes was assessed and each subitem was scored with the Comprehensive Arthropathy Rating (CAR) system (Table I). The intraclass coefficient (ICC) was applied as a validation tool for the CAR grading because it provides information on the reproducibility and consistency of quantitative measurements performed by different investigators. Samilson and Prieto (S&P) grading[19] was also used to determine the grade of IA of both shoulders. The differences in S&P grading and CAR between the affected and the nonaffected side were noted as Δ-S&P or Δ-CAR, respectively.

Statistical analysis

Statistical analysis was performed using SPSS Statistics 25 software (IBM, Armonk, NY, USA). Interobserver reliability of the CAR and the S&P grading was calculated using the intraclass coefficient (ICC). In case of interobserver disagreement, the mean score was calculated and rounded off to whole numbers for further statistical analysis. After testing for normal distribution, the interside comparison of the glenoid morphology parameters was accomplished using Wilcoxon signed rank tests for ordinal or non-normally

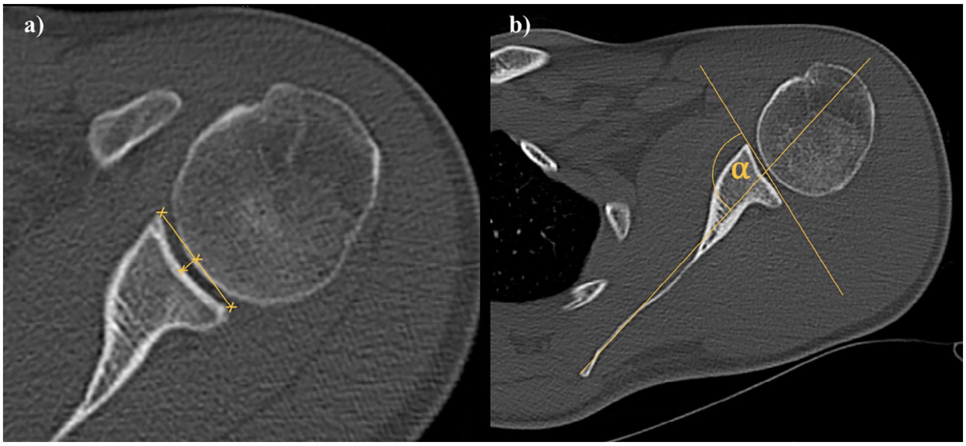

Figure 2 **(a)** The glenoid concavity diameter was measured by drawing a straight line from 1 apex to the other. Glenoid depth corresponded to the distance from the deepest point of the glenoid concavity to the glenoid diameter line. **(b)** Glenoid retroversion was determined according to Friedman et al[6] by placing a tangential line on the glenoid concavity and a second line from the medial border of the scapula through the middle of the glenoid concavity. The anteromedial angle (α) was used to measure glenoid retroversion.

Table I Calculation of the Comprehensive Arthropathy Rating (CAR) and the respective grade of arthropathy based on the different subitems

	Joint-space		Cysts/sclerosis		Osteophytes		
0	Normal	+	Not existing	+	Not existing	=	CAR
1	Narrowed		Either cysts or sclerosis		Head or glenoid		
2	Not existing		Both present		Deformity of the articular surface		
CAR grade of arthropathy		0 None		1-2 Mild	3-4 Moderate	5-6 Severe	

distributed continuous data, or paired *t* tests for continuous normally distributed variables. Associations between IA and the glenoid morphology parameters were assessed using Spearman correlation coefficients. An $\alpha < 0.05$ indicated statistical significance. All analyses were 2-tailed.

Results

Patient characteristics

Within the study population, the mean age at initial dislocation was 26.2 ± 13.2 years (range, 11-75 years) and mean age at index CT scan was 30.1 ± 13.4 years (range, 16-75 years). The right side was affected in 62 patients (52.5%) and 101 patients were male (85.6%). Overall, 88 patients (74.6%) suffered from a traumatic anterior shoulder instability. The average number of dislocations before the CT scan was 11 ± 15 (range, 2-85), with a mean interval of 4.4 ± 5.2 years (range, 0-36 years) from the first dislocation to the radiologic assessment.

Instability arthropathy

Inter-rater reliability between the 3 observers investigating IA was high with regards to the S&P classification (ICC = 0.756) and the CAR (ICC = 0.756). The CAR of the affected shoulders was significantly higher ($P < .001$) than on the contralateral side due to more osteophytes ($P = .001$) and to more sclerosis and cyst formation ($P < .001$; Table II). Accordingly, the S&P grading was also higher on the affected side ($P = .003$; Table II). Detailed information on interside differences with regards to the respective scoring system is provided in Table III. Table IV summarizes the resulting distribution patterns of arthropathy among our participants.

Glenoid morphology

A bony glenoid defect was present in 94 patients (79.6%), with an average size of 5.0% ± 4.8% (range, 0.3%-18.4%) of the glenoid surface. Glenoid retroversion, depth, diameter, and the BSSR of the affected side were significantly reduced compared with the contralateral shoulder (Table V).

Factors associated with IA

Correlation analysis revealed an association of several morphologic and patient-specific characteristics with the CAR of the affected side and the Δ-CAR (Table VI).

Discussion

IA is frequently recognized as a long-term adverse effect in patients with anterior shoulder instability.[10] The present study aimed to identify patient-specific factors and glenoid

Table II Interside differences of arthropathy with regards to the Comprehensive Arthropathy Rating (CAR) with the respective subitems and the Samilson and Prieto (S&P) grading

Variable	Score		Affected side	Contralateral side	*P* value
Joint-space†	0	Normal	115	117	.564
	1	Narrowed	3	1	
	2	Not existing	0	0	
Cysts/sclerosis†	0	Not existing	98	117	<.001*
	1	Cysts or sclerosis	19	1	
	2	Both present	1	0	
Osteophytes†	0	Not existing	107	118	.001*
	1	Head or glenoid	11	0	
	2	Deformity of the articular surface	0	0	
CAR†	0		92	116	<.001*
	1		20	2	
	2		3	0	
	3		3	0	
	4		0	0	
	5		0	0	
	6		0	0	
Arthropathy according to the CAR†	None		92	116	<.001*
	Mild		23	2	
	Moderate		3	0	
	Severe		0	0	
Arthropathy according to S&P†	Grade 0		108	117	.003*
	Grade 1		7	1	
	Grade 2		3	0	
	Grade 3		0	0	

* Indicates statistical significance ($P < .05$).
† Numbers represent the number of patients attributed to the respective score.

morphology parameters that are associated with the natural development of IA.

Although patients enrolled in the presented study had no surgical intervention at the time of the CT scan, IA of the affected side was still significantly more severe than arthropathy of the nonaffected side. Therefore, it seems a logical conclusion that the IA is not necessarily a long-term adverse effect of a surgical procedure but rather of the shoulder instability itself, as already pointed out in previous studies.[5,9] However, it is not yet fully understood which factors are associated with the development of IA, which seems to be more pronounced in some patients than in others.

The factors investigated in this study can grossly be divided into instability-related information and morphologic characteristics of the glenoid. Previous studies have described the association of instability- and patient-related factors with IA.[5,10,19] These investigations revealed a significant effect of patient age on the development of IA.[5,19] In fact, age at the initial dislocation and age at the time of imaging had the greatest effect on arthropathy of all investigated variables in the

Table III Interside differences in the Comprehensive Arthropathy Rating (CAR) and the Samilson & Prieto (S&P) grade between the affected and the nonaffected side

Interside difference (Δ values)*	CAR score†	S&P grade‡
0	92	108
1	20	8
2	5	2
3	1	0
Total	118	118

* Values indicate interside difference of the scores with regards to the respective rating system.
† Numbers represent the number of participants with respective interside differences of CAR scores.
‡ Numbers represent the number of participants with respective interside difference of the Samilson & Prieto grading.

Table IV Distribution patterns of arthropathy with regards to the Comprehensive Arthropathy Rating (CAR) and the Samilson & Prieto (S&P) grading

Contralateral	Affected side	CAR*	S&P*
None	None	92	108
None	Mild	23	7
None	Moderate	1	2
Mild	Moderate	2	1
Total		118	118

* Numbers indicate the number of patients with the respective distribution pattern of arthropathy.

Table V Interside-differences of glenoid morphology parameters

Variable	Affected side	Contralateral side	*P* value
Glenoid			
Diameter, mm	22.6 ± 2.9 (16.2-33.0)	25.4 ± 2.3 (20.0-32.3)	<.001*
Depth, mm	1.5 ± 0.9 (0.3-5.9)	1.9 ± 0.9 (0.4-7.0)	<.001*
Retroversion, °	92.0 ± 5.7 (76.9-104.9)	95.5 ± 4.4 (84.0-108.4)	<.001*
Radius, mm	56.2 ± 34.2 (10.2-165.5)	52.5 ± 25.2 (14.5-154.4)	.153
BSSR, %	25.4 ± 11.2 (4.4-82.0)	29.4 ± 11.4 (7.4-71.5)	<.001*

BSSR, bony shoulder stability ratio.
Data are presented as the mean ± standard deviation (range).
* Indicates statistical significance ($P < .05$).

Table VI Association between glenoid morphology parameters or patient-specific characteristics and the absolute Comprehensive Arthropathy Rating (CAR) or relative (Δ) CAR

Variable	CAR		Δ-CAR	
	Coefficient	*P* value	Coefficient	*P* value
Glenoid affected side				
Retroversion	−0.204	.027*	−0.204	.027*
Depth	0.002	.985	0.002	.984
Diameter	−0.124	.182	−0.126	.175
Radius	−0.053	.571	−0.054	.565
BSSR	0.011	.907	0.011	.904
Defect	0.254	.006*	0.256	.005*
Glenoid contralateral side				
Retroversion	−0.013	.882	−0.014	.882
Depth	0.235	.011*	0.235	.011*
Diameter	0.222	.016*	0.221	.016*
Radius	−0.174	.059	−0.174	.060
BSSR	0.202	.028*	0.202	.029*
Sex	−0.033	.740	−0.071	.447
Atraumatic/traumatic instability	−0.045	.629	−0.041	.665
Number of dislocations	0.176	.057	0.177	.055
Age at initial dislocation	0.295	<.001*	0.294	.001*
Age at CT scan	0.357	<.001*	0.357	<.001*
Time from initial dislocation				
To CT scan	0.063	.495	0.066	.478
To surgical treatment	0.065	.484	0.067	.471

BSSR, bony shoulder stability ratio; *CT*, computed tomography.
* Indicates statistical significance ($P < .05$).

current study as well. However, the interval from the initial diagnosis to the CT scan or to surgical treatment had no effect on IA development, suggesting that a delay in treatment might not necessarily lead to higher rates of arthropathy. Although there was a certain trend, a higher number of redislocations did not correlate significantly with a higher grade of arthropathy.

A main goal of this study was to analyze the effect of glenoid morphology on the development of IA. Interestingly, glenoid morphology parameters of the uninjured contralateral side, which represents the constitutional preinjury shoulder morphology without traumatic changes, showed a significant association with the development of IA. There was a positive correlation between IA and the contralateral glenoid diameter, depth, and the BSSR. The BSSR is a mathematical equation based on glenoid radius and glenoid depth. It is a tool for predicting the maximal translational force against which the shoulder can be stabilized.[13]

At first it may be difficult to see how a patient who has a high constitutional shoulder stability and is therefore less likely to sustain a shoulder dislocation is particularly at risk for a high degree of arthropathy. A possible explanation could be that the more stable a shoulder joint is, the higher is the force necessary to provoke anterior dislocation of the humeral head. Thus, if the sustained force is high enough to cause dislocation in a patient with a high BSSR, the likelihood of structural damage to the joint with subsequent development of IA as a long-term effect might be higher as well. This also explains why patients with muscle-patterning instability and low concavity compression forces during instability episodes do not develop major structural defects or IA despite the high frequency of sustained dislocations.[7,12]

Correspondingly, the findings of our study revealed a significant association between IA and the size of glenoid defects, which is an indicator of the extent of structural damage. Furthermore, large defects cause a reduction of the glenoid articular surface, which increases the forces on the remaining contact surface and possibly causes degenerative changes.[3,8,17] Almost 80% of all patients in this study showed a glenoid defect of various extent on the affected side, which caused an interside difference regarding glenoid retroversion, diameter, depth, and ultimately, BSSR. However, retroversion was the only ipsilateral glenoid morphology parameter associated with IA other than the size of the glenoid defect. Less retroversion was associated with a higher degree of IA, which is likely explained by the confounding effect between the presence of a glenoid defect and the ensuing reduction of retroversion.[14]

A limitation of our study is that we were not able to retrospectively gather sufficient information to reliably identify and quantify potentially asymmetric use of both shoulders during work or sports activity. A higher joint wear could have influenced the severity of arthropathy and therefore confounded the results.

Because the rate of IA among our patients was rather low, the CAR system, as a presumably more sensitive measure, was chosen over S&P grading[19] to analyze the relationship between the investigated factors and IA. The CAR scoring system rates arthropathy from 0 points (no arthritic changes) to 6 points (radiographic signs of severe arthrosis), allowing for a subtle distinction of different severity grades of arthropathy while maintaining a high interobserver reliability.

We used Spearman correlation coefficients to analyze factors associated with IA because many of the investigated factors, including the dependent variables CAR, Δ-CAR, S&P, and Δ-S&P, were ordinal or non-normally distributed data. The presence of potential confounders can therefore not be excluded.

Conclusion

Compared with the nonaffected contralateral side, the affected glenoid has significantly different morphologic characteristics in patients with unilateral anterior shoulder instability due to bony defects. The development of IA seems to be associated not only with the age of the patients but also with morphologic parameters of the glenoid, including glenoid defect size and the constitutional glenoid concavity shape.

Disclaimer

The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Auffarth A, Schauer J, Matis N, Kofler B, Hitzl W, Resch H. The J-Bone Graft for anatomical glenoid reconstruction in recurrent posttraumatic anterior shoulder dislocation. Am J Sports Med 2008;36:638-47. http://dx.doi.org/10.1177/0363546507309672
2. Baudi P, Righi P, Bolognesi D, Rivetta S, Rossi Urtoler E, Guicciardi N, et al. How to identify and calculate glenoid bone deficit. Chir Organi Mov 2005;90:145-52.
3. Bhatia S, Van Thiel GS, Gupta D, Ghodadra N, Cole BJ, Bach BR Jr, et al. Comparison of glenohumeral contact pressures and contact areas after glenoid reconstruction with Latarjet or distal tibial osteochondral allografts. Am J Sports Med 2013;41:1900-8. http://dx.doi.org/10.1177/0363546513490646
4. Bois AJ, Fening SD, Polster J, Jones MH, Miniaci A. Quantifying glenoid bone loss in anterior shoulder instability: reliability and accuracy of 2-dimensional and 3-dimensional computed tomography measurement techniques. Am J Sports Med 2012;40:2569-77. http://dx.doi.org/10.1177/0363546512458247
5. Buscayret F, Edwards TB, Szabo I, Adeleine P, Coudane H, Walch G. Glenohumeral arthrosis in anterior instability before and after surgical treatment: incidence and contributing factors. Am J Sports Med 2004;32:1165-72. http://dx.doi.org/10.1177/0363546503262686
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. Gerber C, Nyffeler RW. Classification of glenohumeral joint instability. Clin Orthop Relat Res 2002;(32):65-76.
8. Ghodadra N, Gupta A, Romeo AA, Bach BR Jr, Verma N, Shewman E, et al. Normalization of glenohumeral articular contact pressures after Latarjet or iliac crest bone-grafting. J Bone Joint Surg Am 2010;92:1478-89. http://dx.doi.org/10.2106/jbjs.i.00220
9. Hovelius L, Rahme H. Primary anterior dislocation of the shoulder: long-term prognosis at the age of 40 years or younger. Knee Surg Sports Traumatol Arthrosc 2016;24:330-42. http://dx.doi.org/10.1007/s00167-015-3980-2
10. Hovelius L, Saeboe M. Neer Award 2008: arthropathy after primary anterior shoulder dislocation–223 shoulders prospectively followed up for twenty-five years. J Shoulder Elbow Surg 2009;18:339-47. http://dx.doi.org/10.1016/j.jse.2008.11.004
11. Hovelius LK, Sandström BC, Rösmark DL, Saebö M, Sundgren KH, Malmqvist BG. Long-term results with the Bankart and Bristow-Latarjet procedures: recurrent shoulder instability and arthropathy. J Shoulder Elbow Surg 2001;10:445-52. http://dx.doi.org/10.1067/mse.2001.117128
12. Lewis A, Kitamura T, Bayley JIL. The classification of shoulder instability: new light through old windows! Curr Orthop 2004;18:97-108. http://dx.doi.org/10.1016/j.cuor.2004.04.002
13. Moroder P, Ernstbrunner L, Pomwenger W, Oberhauser F, Hitzl W, Tauber M, et al. Anterior shoulder instability is associated with an underlying deficiency of the bony glenoid concavity. Arthroscopy 2015;31:1223-31. http://dx.doi.org/10.1016/j.arthro.2015.02.009
14. Moroder P, Hitzl W, Tauber M, Hoffelner T, Resch H, Auffarth A. Effect of anatomic bone grafting in post-traumatic recurrent anterior shoulder instability on glenoid morphology. J Shoulder Elbow Surg 2013;22:1522-9. http://dx.doi.org/10.1016/j.jse.2013.03.006

15. Moroder P, Plachel F, Huettner A, Ernstbrunner L, Minkus M, Boehm E, et al. The effect of scapula tilt and best-fit circle placement when measuring glenoid bone loss in shoulder instability patients. Arthroscopy 2018;34:398-404. http://dx.doi.org/10.1016/j.arthro.2017.08.234
16. Moroder P, Resch H, Schnaitmann S, Hoffelner T, Tauber M. The importance of CT for the pre-operative surgical planning in recurrent anterior shoulder instability. Arch Orthop Trauma Surg 2013;133:219-26. http://dx.doi.org/10.1007/s00402-012-1656-7
17. Pauzenberger L, Dyrna F, Obopilwe E, Heuberer PR, Arciero RA, Anderl W, et al. Biomechanical evaluation of glenoid reconstruction with an implant-free J-bone graft for anterior glenoid bone loss. Am J Sports Med 2017;45:2849-57. http://dx.doi.org/10.1177/0363546517716927
18. Rosenberg BN, Richmond JC, Levine WN. Long-term followup of Bankart reconstruction. Incidence of late degenerative glenohumeral arthrosis. Am J Sports Med 1995;23:538-44.
19. Samilson RL, Prieto V. Dislocation arthropathy of the shoulder. J Bone Joint Surg Am 1983;65:456-60.
20. van der Zwaag HM, Brand R, Obermann WR, Rozing PM. Glenohumeral osteoarthrosis after Putti-Platt repair. J Shoulder Elbow Surg 1999;8:252-8.