J Shoulder Elbow Surg (2019) 28, 1298–1307

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

SHOULDER

Neer Award 2019: Latarjet procedure vs. iliac crest bone graft transfer for treatment of anterior shoulder instability with glenoid bone loss: a prospective randomized trial

Philipp Moroder, MD[a,*], Eva Schulz, MD[b], Guido Wierer, MD[b], Alexander Auffarth, MD[b], Peter Habermeyer, MD[c], Herbert Resch, MD[b], Mark Tauber, MD[c]

[a]*Department for Shoulder and Elbow Surgery, Center for Musculoskeletal Surgery, Campus Virchow, Charité-Universitaetsmedizin Berlin, Berlin, Germany*
[b]*Department of Traumatology and Sports Injuries, Paracelsus Medical University, Salzburg, Austria*
[c]*Department of Shoulder and Elbow Surgery, ATOS Clinic Munich, Munich, Germany*

Background: The Latarjet and iliac crest bone graft transfer (ICBGT) procedures are competing treatment options for anterior shoulder instability with glenoid bone loss.
Methods: In this bicentric prospective randomized study, 60 patients with anterior shoulder instability and glenoid bone loss were included and randomized to either an open Latarjet or open ICBGT (J-bone graft) procedure. Clinical evaluation was completed before surgery and 6, 12, and 24 months after surgery, including the Western Ontario Shoulder Instability index, Rowe score, Subjective Shoulder Value, pain level, satisfaction level, and work and sports impairment, as well as assessment of instability, range of motion, and strength. Adverse events were prospectively recorded. Radiographic evaluation included preoperative, postoperative, and follow-up computed tomography analysis.
Results: None of the clinical scores showed a significant difference between the 2 groups ($P > .05$). Strength and range of motion showed no significant differences except for diminished internal rotation capacity in the Latarjet group at every follow-up time point ($P < .05$). A single postoperative traumatic subluxation event occurred in 2 ICBGT patients and 1 Latarjet patient. The type and severity of other adverse events were heterogeneous. Donor-site sensory disturbances were observed in 27% of the ICBGT patients. Computed tomography scans revealed a larger glenoid augmentation effect of the ICBGTs; this, however, was attenuated at follow-up.
Conclusion: The Latarjet and ICBGT procedures for the treatment of anterior shoulder instability with glenoid bone loss showed no difference in clinical and radiologic outcomes except for significantly

Approval for this study was obtained from the local ethical committee of Salzburg, Austria (No. 415-E/1439/5-2012) and the institutional ethical committee of ATOS Clinic Munich, Munich, Germany (No. 3-12).

*Reprint requests: Philipp Moroder, MD, Department for Shoulder and Elbow Surgery, Center for Musculoskeletal Surgery, Campus Virchow, Charité-Universitaetsmedizin Berlin, Augustenburgerplatz 1, 14193 Berlin, Germany.

E-mail address: philipp.moroder@charite.de (P. Moroder).

https://doi.org/10.1016/j.jse.2019.03.035

worse internal rotation capacity in the Latarjet group and frequently noted donor-site sensory disturbances in the ICBGT group.
Level of evidence: Level I; Randomized Controlled Trial; Treatment Study

Keywords: Shoulder instability; glenoid bone loss; Latarjet; iliac crest bone graft transfer; J-bone graft

Soft-tissue stabilization procedures for the treatment of anterior shoulder instability were proved to be less effective in patients with extensive glenoid bone loss.[11] Therefore, bone grafting techniques are recommended instead of soft-tissue stabilization procedures in the case of extensive glenoid bone loss.[12]

Among these bone grafting techniques are 2 competing types of procedures: coracoid transfer techniques and free bone grafting techniques. A commonly used coracoid transfer procedure is the modern-type Latarjet procedure, which involves the transfer of the coracoid process along with the attached conjoined tendons to the anterior glenoid rim through a permanent horizontal split of the subscapularis.[65] The Latarjet procedure stabilizes the shoulder primarily by means of the combined bone grafting and sling effect.[28,65] A commonly used free bone grafting technique is the modern Eden-Hybinette procedure or iliac crest bone graft transfer (ICBGT), which involves harvesting a bone graft from the iliac crest and transferring it through a temporary horizontal subscapularis split to the anterior glenoid rim.[4,61] The ICBGT primarily aims at stabilizing the shoulder by means of restoring the glenoid concavity.[44,64] Although several modifications exist including arthroscopic execution, options for bone graft fixation, alternative bone harvesting sites, or use of allografts, both described procedures maintain their distinctive character.[3,4,8,17,26,34,35,41,47,52,56-62,66]

Although several articles on the clinical outcomes of both procedure types have been published and the superiority of one technique over the other has been a common topic at several shoulder conferences, no randomized comparative trials with a high level of evidence are currently available.[2,40] The goal of this study was to perform a prospective randomized trial comparing both competing techniques to provide more reliable data for discussion. The hypothesis of the study was that the results after ICBGT would be better than the results after coracoid transfer for the treatment of anterior shoulder instability with glenoid bone loss.

Methods

General information

The study was designed as a bicentric prospective randomized trial and was registered online prior to its beginning (ISRCTN registry), including the prespecified outcome parameters. The defined inclusion criteria were (1) anterior shoulder instability with recurrent dislocations ($\geq$2) and (2) glenoid bone loss affecting at least 15% of the glenoid articular surface measured with the Pico method[6] on 3-dimensional computed tomography (CT) scans. The exclusion criteria were (1) any concomitant shoulder pathologies (eg, cuff tears, nerve lesions, and osteoarthritis $> 1°$), (2) any previous surgical procedures on the affected shoulder except for open or arthroscopic Bankart repair, (3) neuromuscular pathologies including seizure disorders, (4) history of infection, (5) compliance problems (eg, alcohol or drug abuse), and (6) unwillingness to participate in the study.

A total of 60 consecutive patients fulfilling the inclusion and exclusion criteria were enrolled in the study by 1 of the 4 involved surgeons (as discussed later). Patients were assigned to the Latarjet or ICBGT intervention with a 1:1 allocation ratio based on an allocation sequence that was generated by a professional statistician using a computer-based block randomization process (block size of 6) and was placed in sequentially numbered sealed envelopes. The recruitment period was between 2012 and 2015. After baseline assessment, patients underwent the assigned surgical stabilization procedure. Longitudinal follow-up included clinical and radiologic evaluation. The follow-up rate decreased from 97% at 6 months to 95% at 12 months and to 90% at final follow-up, 24 months after surgery (29 of 30 ICBGTs and 25 of 30 Latarjet cases). Follow-up for the last patient was concluded in 2017 (Fig. 1). Reporting of the clinical trial was accomplished according to the CONSORT (Consolidated Standards of Reporting Trials) guidelines for reporting randomized controlled trials.

Interventions

Patients were assigned to receive either an open Latarjet procedure according to the technique described by Young et al[65] or an open ICBGT according to the J-bone graft technique described by Auffarth et al.[4] The Latarjet procedure is characterized by release of the pectoralis minor tendon, osteotomy of the coracoid close to the base with the conjoined tendon and parts of the coracoacromial ligament left attached, a permanent horizontal split of the subscapularis, a vertical split of the capsule, transposition of the coracoid to the anterior glenoid rim flush with the glenoid articular surface, fixation with 2 screws, and attachment of the lateral aspect of the capsule to the stump of the coracoacromial ligament on the graft. The J-bone graft technique is characterized by a temporary horizontal split of the subscapularis and capsule, monocortical incomplete osteotomy of the anterior glenoid neck, implant-free press-fit insertion of a J-shaped bicortical bone graft harvested from the iliac crest, surface shaping of the graft with an electrical burr to restore the articular concavity, and side-to-side closure of the subscapularis.

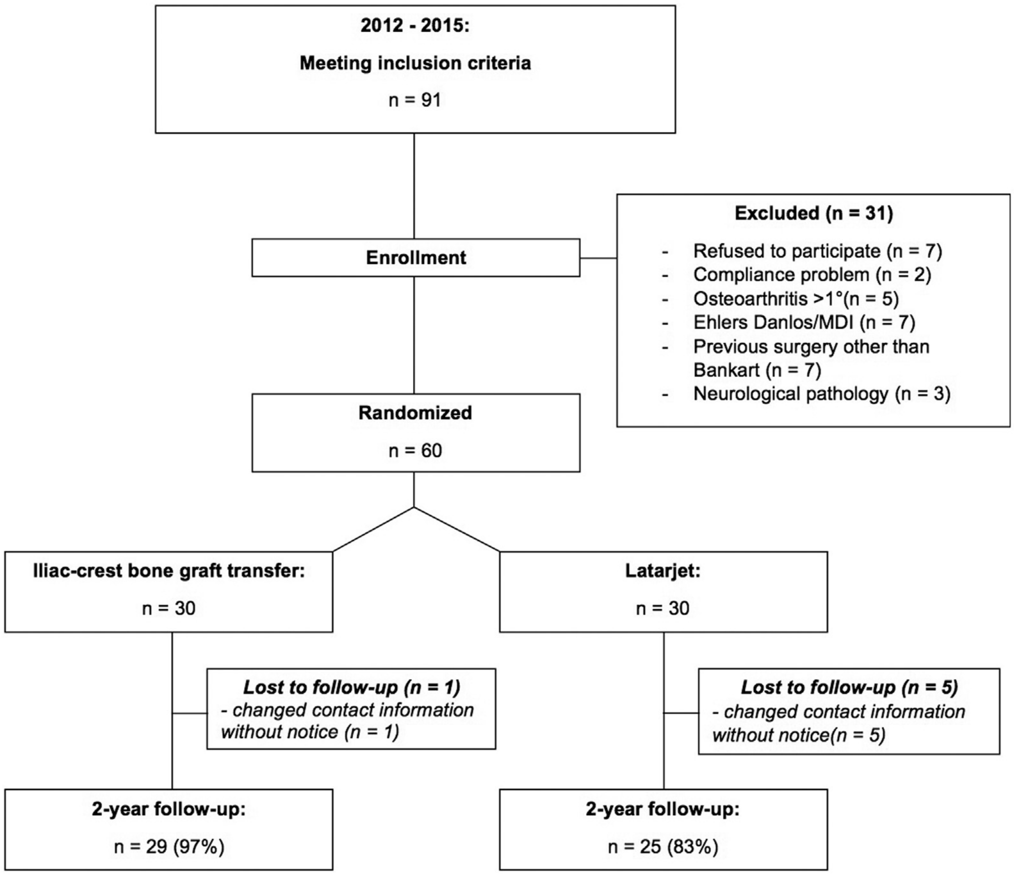

Figure 1 Flowchart of trial. *MDI*, multidirectional instability.

Both trial sites are referral centers for shoulder surgery. Two surgeons per center completed the interventions. All 4 surgeons are specialized shoulder surgeons with extensive experience performing both techniques. The postoperative period of sling immobilization, as well as the rehabilitation protocol, was the same for both interventions.

Clinical outcome assessment

Baseline examination before surgery included the following: a pathology-specific medical history (number of dislocations, time since first dislocation, cause of dislocation, previous surgical stabilization, and bilateral affection); instability testing including the apprehension test[50] and relocation test[33]; hyperlaxity assessment using the Beighton score[7]; standardized clinical scores in terms of the Western Ontario Shoulder Instability (WOSI) index (main outcome measurement),[32,38] Rowe score,[49] Subjective Shoulder Value (SSV),[27] Athletic Shoulder Outcome Scoring System (ASOSS) value,[57] numeric pain rating scale (from 0 to 10),[31] shoulder-specific work activity level (from 0 to 2), and shoulder-specific sports activity level (from 0 to 7); abduction strength assessment using a dynamometer; and assessment of range of motion using a goniometer. Internal rotation capacity was recorded as the highest vertebral level a patient could reach with the hand of the affected side on his or her back.

Longitudinal follow-up examinations were performed 6, 12, and 24 months after surgery, including the WOSI index (main outcome measurement), Rowe score, SSV, ASOSS score (if the shoulder-specific sports activity level at baseline was >4), numeric pain rating scale, level of satisfaction with surgery (from 0 to 5), abduction strength, and range of motion, as well as recording of any adverse events including assessment of the recurrence of instability with the following parameters: dislocation, subluxation, apprehension positive (apprehension test and relocation test), and apprehension negative. Because of increased awareness triggered by our preliminary findings and other newly published findings,[15] the following secondary outcome parameters were added to the protocol at the final follow-up time point: internal and external rotation assessment in 90° of abduction using a goniometer; internal and external rotation strength assessment in 0° of abduction, neutral rotation, and 90° of elbow flexion using a dynamometer; and scapular dyskinesis evaluation according to Kibler.[36] These parameters do not fulfill the same quality requirements as the prespecified primary or secondary outcome parameters mentioned earlier and therefore should be considered only tertiary.

Radiologic outcome assessment

Patients underwent preoperative, postoperative, and follow-up CT examinations using a CT scanner with a 0.625-mm slice

Table I Comparison of preoperative group characteristics

	ICBGT	Latarjet procedure	*P* value
Age, mean ± SD (range), yr	29 ± 9 (18-57)	31 ± 8 (18-47)	.446
Sex, n	28 M/2 F	28 M/2 F	>.999
No. of instability episodes, mean ± SD (range)	19 ± 19 (3-80)	16 ± 18 (2-80)	.263
Period of instability, mean ± SD (range), mo	67 ± 65 (5-264)	85 ± 57 (5-228)	.100
Cause of instability: major trauma/moderate trauma, n	29/1	27/3	.612
Bilateral instability: yes/no, n	24/6	22/8	.542
Beighton score for hyperlaxity (range, 0-7), n			.229
0	13	19	
1	6	2	
2	6	5	
3	1	0	
4	3	4	
5	0	0	
6	1	0	
7	0	0	
No. of previous soft-tissue stabilization attempts			.954
0	17	15	
1	8	13	
2	3	2	
3	2	0	
Shoulder-specific work activity level (range, 0-2), n			.396
0	21	18	
1	8	10	
2	1	2	
Shoulder-specific sport activity level (range, 0-7), n			.102
0	2	2	
1	0	0	
2	2	2	
3	4	6	
4	6	12	
5	5	3	
6	4	3	
7	7	2	

ICBGT, iliac crest bone graft transfer; *SD*, standard deviation; *M*, male; *F*, female.

thickness. All measurements and plane reconstructions were accomplished using a plane-reconstruction plug-in for Impax EE R20 (version III; Agfa HealthCare, Mortsel, Belgium). The glenoid defect area was calculated according to the validated Pico method[6,9] on standardized en face views of 3-dimensional reconstructions of the CT scans according to the previously published spoon technique.[46] In addition, glenoid depth, diameter, and version were measured in the standardized axial imaging plane according to a previously published method that features high reliability.[44] The glenoid track concept was used to identify on-track and off-track Hill-Sachs defects on 3-dimensional CT scans as described by Di Giacomo et al.[20]

Statistics

Prior to the beginning of the study, a power analysis based on the minimal clinically important difference of the main outcome measurement (WOSI index, 10.4%),[37,38] a power of 80%, and an expected follow-up rate of 88% was performed. During the trial, data were collected on report forms and later entered into spreadsheets for further analysis. Group characteristics and outcome variables were tested for normal distribution using the Kolmogorov-Smirnov test. For group comparisons at the different time points, the Mann-Whitney *U* test, *t* test, χ^2 test, or Fisher exact test were used. All reported tests were 2-tailed, and $P < .05$ was considered statistically significant.

In this randomized trial, all enrolled patients were allocated according to the randomization sequence and received the assigned intervention along with the postoperative treatment. Therefore, the intention-to-treat analysis corresponds to a per-protocol analysis in this trial.

Results

Both groups showed no significant differences regarding their preoperative characteristics (Table I).

Clinical outcome

At no follow-up time point did the WOSI index (main outcome measurement) show a statistically significant

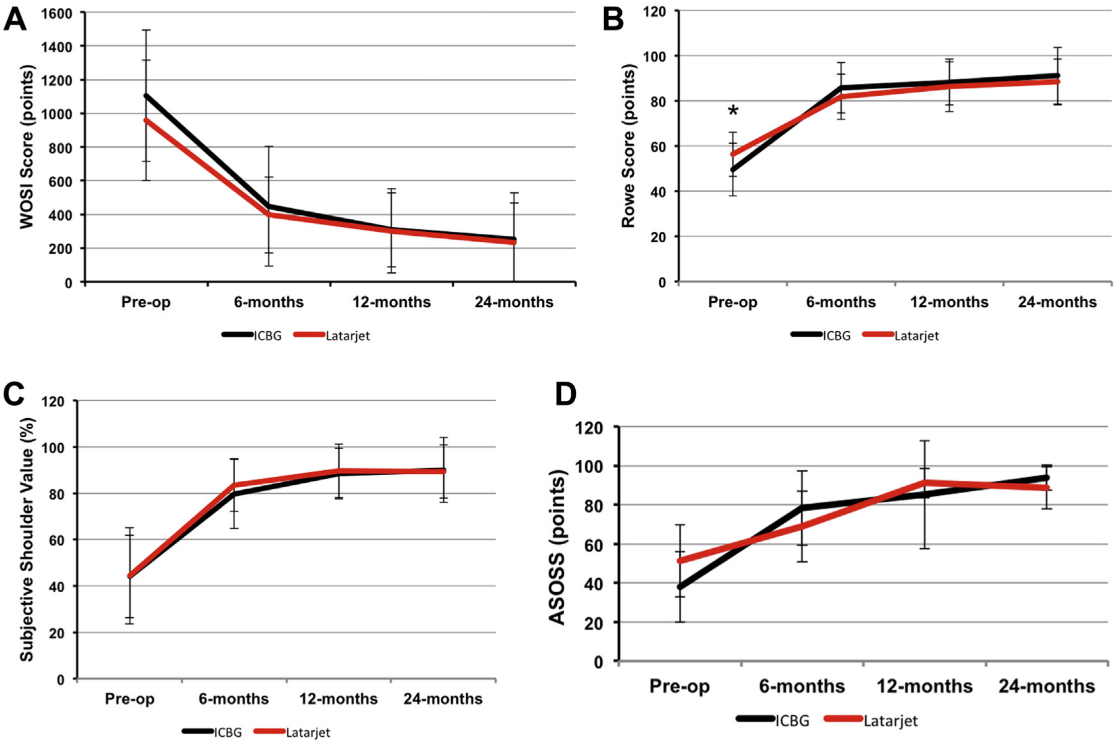

Figure 2 Longitudinal comparison of Western Ontario Shoulder Instability (*WOSI*) index (main outcome measurement) **(A)**, Rowe score **(B)**, Subjective Shoulder Value **(C)**, and Athletic Shoulder Outcome Scoring System (*ASOSS*) score **(D)** at different time points between patients receiving an iliac crest bone graft transfer (*ICBG*) and patients receiving a Latarjet procedure. Statistically significant differences are marked (*). *Pre-op*, preoperatively.

difference between the 2 groups (Fig. 2, *A*). Similarly, both procedures did not significantly differ regarding the Rowe score, SSV, or ASOSS score at any follow-up time point except for the preoperative Rowe score ($P = .005$) (Fig. 2, *B-D*).

Although no statistically significant differences between the 2 groups were found regarding abduction and external rotation at any time, internal rotation capacity was better in the ICBGT group at 6 months ($P = .001$), 12 months ($P = .002$), and 24 months ($P = .013$) (Fig. 3, *A-C*). Similarly, external rotation at 90° of abduction showed no difference between groups, whereas internal rotation at 90° of abduction was significantly different at 24 months' follow-up ($P = .044$) (Fig. 3, *D*). No significant difference in the longitudinal abduction strength follow-up or the internal and external rotation strength assessment at final follow-up was noted between the 2 groups (Fig. 4).

No dislocation was recorded after either type of surgery within the monitored period. A single postoperative traumatic subluxation event occurred in 2 patients (6.7%) in the ICBGT group and 1 patient (3.3%) in the Latarjet group. The apprehension and relocation tests, without any history of postoperative instability episodes, were positive in 3 patients (10.0%) in the ICBGT group and 2 patients (6.7%) in the Latarjet group. No statistically significant differences were observed regarding the stability parameters. Complications in the ICBGT group included 8 sensory disturbances around the scar of the donor site (26.7%) and 2 cases of superficial wound infection at the donor site (6.7%), as well as 1 graft fracture (3.3%) 1 year after surgery due to a bicycle fall with subsequent graft reunion and without residual subjective or objective instability. Complications in the Latarjet group included 1 nonunion of the graft without clinical consequence (3.3%), 1 case of screw irritation requiring revision surgery (3.3%), and 1 case of postoperative hematoma without the need for surgical revision (3.3%). Scapular dyskinesis was noted in 4 patients (13%) after the Latarjet procedure and 1 patient (3%) after ICBGT at final follow-up. No significant differences were noted between the ICBGT group and Latarjet group regarding the pain level (0.3 ± 0.8 vs. 0.4 ± 0.5, $P = .180$) and satisfaction level (4.8 ± 0.8 vs. 4.9 ± 0.3, $P = .812$).

Radiologic outcome

Analysis of the CT scans revealed a significantly increased postoperative glenoid augmentation effect of the ICBGT in terms of increased surface area ($P = .001$), reduced defect area ($P = .003$), increased diameter ($P = .009$), increased depth ($P = .034$), and higher retroversion ($P = .002$) compared with the Latarjet procedure. However, at 12 and

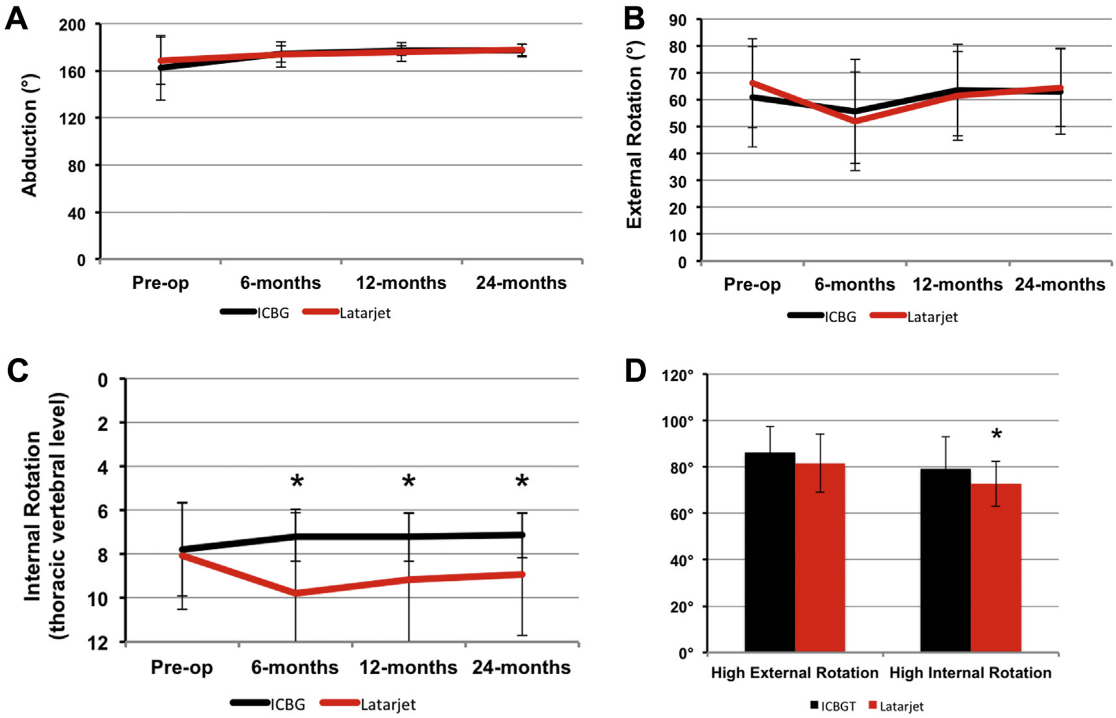

Figure 3 Longitudinal comparison of range of motion in abduction **(A)**, external rotation **(B)**, and internal rotation **(C)** at different time points between patients receiving an iliac crest bone graft transfer (*ICBG*) and patients receiving a Latarjet procedure. **(D)** External rotation and internal rotation in 90° of abduction were compared at the 24-month follow-up. Statistically significant differences are marked (*). *Pre-op*, preoperatively.

24 months' follow-up, only the defect area was significantly lower in the ICBGT group ($P = .023$ and $P = .030$, respectively); all other parameters showed no statistically significant difference (Fig. 5).

Before surgery, off-track Hill-Sachs lesions were found in 83% of patients in the ICBGT group and 68% of those in the Latarjet group ($P = .206$). After surgery, the percentage of patients with off-track defects was reduced to 14% in the ICBGT group and 28% in the Latarjet group ($P = .310$).

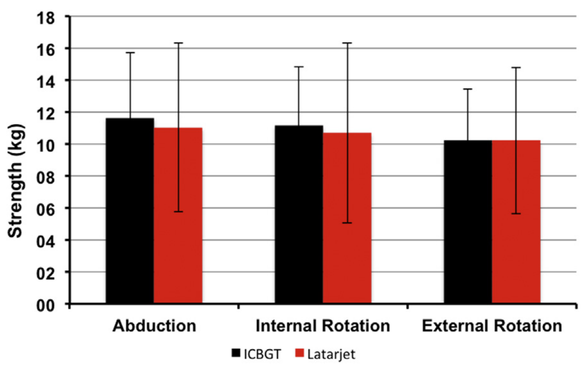

Figure 4 Comparison of abduction, internal rotation, and external rotation strength at the 24-month follow-up time point between patients receiving an iliac crest bone graft transfer (*ICBGT*) and patients receiving a Latarjet procedure. No significant differences were noted.

Follow-up CT scans revealed an off-track defect in 28% of ICBGT patients and 20% of Latarjet patients ($P = .516$).

Discussion

The main finding of our study is that the ICBGT and the Latarjet procedure did not show any significant difference regarding the main outcome measurement (WOSI index) at any of the observed time points after surgery. Thus, our study hypothesis was not confirmed. Similarly, no difference was seen in the Rowe score, SSV, or ASOSS score. Even though no other randomized comparative trials are available, similar findings have been published in 2 level III matched-cohort studies: 1 comparing the Latarjet procedure with the J-bone graft technique (ICBGT)[15] and the other comparing the Latarjet procedure with the distal tibia allograft procedure (which can be considered a derivative technique of the ICBGT).[25]

The longitudinal recording of range of motion showed no difference in abduction and external rotation; however, internal rotation was shown to be significantly worse by 2 to 3 vertebral levels on average after the Latarjet procedure than after ICBGT at 6, 12, and 24 months' follow-up. A significant difference in internal rotation capacity by a mean of 6° was also found in 90° of abduction. Although the causes thereof remain speculative, a possible explanation is the permanent split of the subscapularis by the

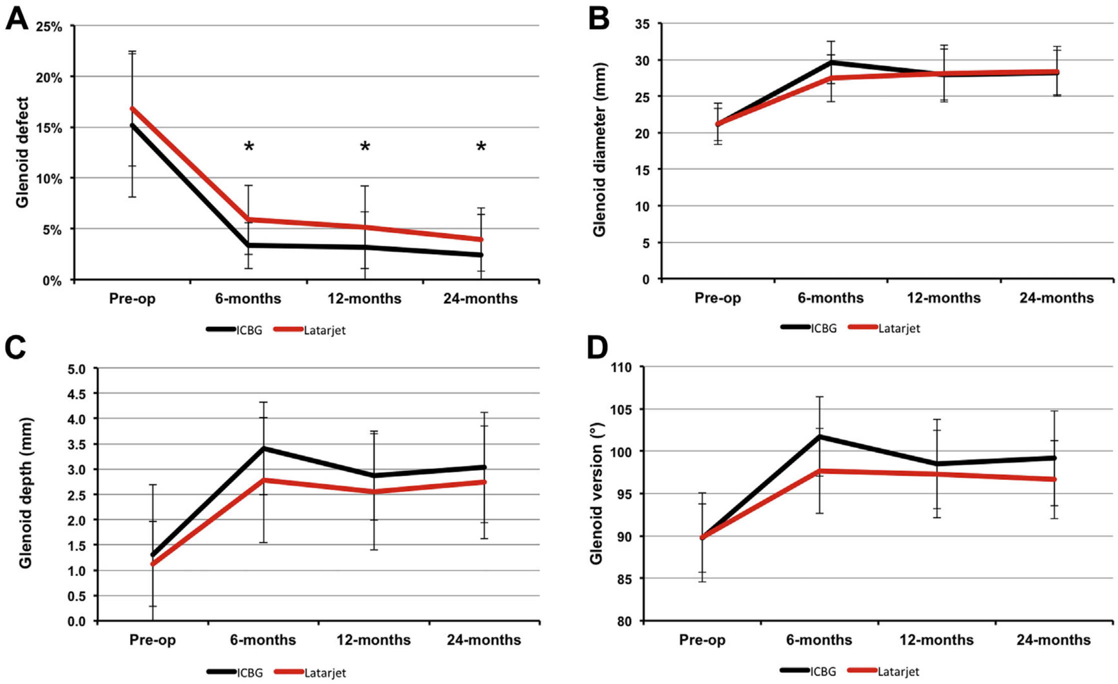

Figure 5 Longitudinal comparison of glenoid defect area **(A)**, glenoid diameter **(B)**, glenoid depth **(C)**, and glenoid retroversion **(D)** between patients receiving an iliac crest bone graft transfer (*ICBG*) and patients receiving a Latarjet procedure. Statistically significant differences are marked (*). *Pre-op*, preoperatively.

conjoined tendon with possible structural affection or movement restriction of the muscle and tendon. For example, a biomechanical study on the sling effect after the Latarjet procedure revealed a significant loss of general rotation capacity in 90° of abduction if the conjoined tendon was loaded instead of unloaded. Although the trend was similar in adduction of the arm, no statistically significant difference was found.[28] Another possible explanation might be the larger number of prior open Bankart repairs in the Latarjet group (n = 4) than in the ICBGT group (n = 1), which might have negatively affected the subscapularis musculotendinous unit muscle.[53] This difference, however, was not statistically significant (P = .353) and average preoperative internal rotation capacity in both groups was very similar, which makes this explanation unlikely. An interesting finding was that the strength measurements at final follow-up showed no significant differences between the Latarjet and ICBGT groups. A case-control study with isokinetic comparison of the strength of patients after the Latarjet procedure revealed a combined internal and external rotation strength deficit and reduced endurance 1 year after surgery compared with the healthy, contralateral side.[16] However, Edouard et al showed that this weakness might already be present preoperatively[23] and that, 6 months after the Latarjet procedure, patients recover their preoperative rotation strength.[22] Similarly, other studies found no internal rotation strength difference between the operated side and nonoperated side after the Latarjet procedure as long as a subscapularis split instead of an L-shaped tenotomy was performed.[24,48] However, as in our study, internal rotation strength measurement accomplished in a functional position of 0° of abduction, neutral rotation, and 90° of elbow flexion or even in a belly-press position does not specifically isolate the subscapularis activity from the other strong internal rotators.

No statistically significant difference was noted between groups regarding postoperative stability. This reflects the results of previous case series reports that showed the high rate of stabilization success of both procedures even in the long term.[1,10,18,29,42,45,54,55]

Although the shoulder-related adverse event rate was very low in the ICBGT group (n = 1, 3.3%), donor site–related adverse events were rather frequent, mostly involving sensory disturbances around the scar (n = 8, 26.7%). These issues resulting from harvesting bone graft from the iliac crest are well known[4,14,21] and are a primary reason for the increased reports on alternative techniques using allografts or other donor sites.[25,41,51,59,62,66] Although the Latarjet procedure shows a clear advantage because of the lack of additional donor-site morbidity, shoulder joint–related adverse events can occur, including graft nonunion and screw irritation with the necessity for removal (n = 2, 6.7%). These adverse events have also been well described in the literature[13,30] and are a primary reason for the investigation of alternative fixation techniques using resorbable material or suture buttons.[5,8] Although our trial seems to show a disadvantage of the

Latarjet procedure compared with the ICBGT in this regard, it must be considered that the J-bone graft is only an implant-free subgroup of the family of ICBGTs and that similar implant-related problems might be observed with non–implant-free ICBGT techniques. Finally, the extra-anatomic nature of the Latarjet procedure with release of the pectoralis minor tendon, transposition of the conjoined tendons, and a permanent split of the subscapularis could be a matter of concern as it might lead to scapular dyskinesis[15] and make revision surgery more complicated.[63] However, the data collected in this study are not suitable to support or disprove these concerns.

The CT scans revealed a larger glenoid augmentation effect of the ICBGT immediately after surgery. Whereas the Latarjet graft size is limited by the extent of the coracoid process,[39] the graft size of the ICBGT is limited by the dimensions of the iliac crest, which typically offers a larger bone stock. Nonetheless, remodeling processes as previously described for the ICBGT[43,44] and Latarjet procedure[19] attenuate this difference over time with a comparable bony augmentation effect of both procedures with the exception of slightly but significantly smaller coverage of the glenoid defect area in the Latarjet group. The burden of preoperative off-track Hill-Sachs lesions seemed to be slightly higher in the ICBGT group; however, the difference was not significant. Either procedure successfully transformed off-track Hill-Sachs lesions into on-track Hill-Sachs lesions in most patients. It is interesting to note that both patients who experienced subluxation after the ICBGT had off-track Hill-Sachs defects before and after surgery whereas the 1 patient in the Latarjet group showed an on-track defect before and after surgery. However, the number of patients with recurrent instability episodes was too small to find any associations with remnant glenoid defects or persisting off-track Hill-Sachs lesions.

Limitations

Because of the strict inclusion and exclusion criteria, a homogeneous study population was created and the comparison of both interventional groups showed comparable preoperative clinical and radiographic parameters, offering reassurance regarding the effectiveness of the randomization procedure. Although this is necessary to ensure comparability, it also limits the applicability of the presented conclusions to selected cases. In addition, external validity is compromised to a certain extent by the fact that both procedures were performed by 4 highly specialized shoulder surgeons, which theoretically might have a positive impact on the outcome and reduce the risk of complications.

The moderately lower final follow-up rate in the Latarjet group (83%) than in the ICBGT group (97%) paired with the inability to reach the patients lost to follow-up raises the potential for attrition bias. However, the follow-up rates at the 6- and 12-month time points were comparably high in both groups (97% vs. 97% and 93% vs. 97%, respectively) with no differences compared with the 24-month time point regarding the superiority of one intervention over the other in the various outcome measures.

An orthopedic resident not involved in the interventions assessed outcome parameters at each institution. Owing to the nature of both interventions, blinding of the patients was not possible and blinding of the outcome examiners was not feasible. This lack of blinding creates the risk of bias. However, this risk is reduced by the fact that the main outcome measurement is a patient-reported subjective score.

Conclusion

The Latarjet and ICBGT procedures for the treatment of anterior shoulder instability with glenoid bone loss showed no difference in clinical and radiologic outcomes except for significantly better internal rotation capacity in the ICBGT group. Both procedures resulted in a different spectrum of complications, with donor-site sensory disturbances being frequently noted in the ICBGT group.

Disclaimer

The authors, their immediate families, and any research foundations 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. Allain J, Goutallier D, Glorion C. Long-term results of the Latarjet procedure for the treatment of anterior instability of the shoulder. J Bone Joint Surg Am 1998;80:841-52.
2. An VV, Sivakumar BS, Phan K, Trantalis J. A systematic review and meta-analysis of clinical and patient-reported outcomes following two procedures for recurrent traumatic anterior instability of the shoulder: Latarjet procedure vs. Bankart repair. J Shoulder Elbow Surg 2016;25:853-63. https://doi.org/10.1016/j.jse.2015.11.001
3. Anderl W, Pauzenberger L, Laky B, Kriegleder B, Heuberer PR. Arthroscopic implant-free bone grafting for shoulder instability with glenoid bone loss: clinical and radiological outcome at a minimum 2-year follow-up. Am J Sports Med 2016;44:1137-45. https://doi.org/10.1177/0363546515625283
4. Auffarth A, Schauer J, Matis N, Kofler B, Hitzl W, Resch H. The J-bone graft for anatomical glenoid reconstruction in recurrent post-traumatic anterior shoulder dislocation. Am J Sports Med 2008;36:638-47. https://dx.doi.org/10.1177/0363546507309672

5. Balestro JC, Young A, Maccioni C, Walch G. Graft osteolysis and recurrent instability after the Latarjet procedure performed with bioabsorbable screw fixation. J Shoulder Elbow Surg 2015;24:711-8. https://doi.org/10.1016/j.jse.2014.07.014
6. 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.
7. Baum J, Larsson LG. Hypermobility syndrome—new diagnostic criteria. J Rheumatol 2000;27:1585-6.
8. Boileau P, Gendre P, Baba M, Thélu CE, Baring T, Gonzalez JF, et al. A guided surgical approach and novel fixation method for arthroscopic Latarjet. J Shoulder Elbow Surg 2016;25:78-89. https://doi.org/10.1016/j.jse.2015.06.001
9. 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. https://doi.org/10.1177/0363546512458247
10. Bouju Y, Gadea F, Stanovici J, Moubarak H, Favard L. Shoulder stabilization by modified Latarjet-Patte procedure: results at a minimum 10 years' follow-up, and role in the prevention of osteoarthritis. Orthop Traumatol Surg Res 2014;100:S213-8. https://doi.org/10.1016/j.otsr.2014.03.010
11. Burkhart SS, De Beer JF. Traumatic glenohumeral bone defects and their relationship to failure of arthroscopic Bankart repairs: significance of the inverted-pear glenoid and the humeral engaging Hill-Sachs lesion. Arthroscopy 2000;16:677-94.
12. Bushnell BD, Creighton RA, Herring MM. Bony instability of the shoulder. Arthroscopy 2008;24:1061-73. https://doi.org/10.1016/j.arthro.2008.05.015
13. Butt U, Charalambous CP. Complications associated with open coracoid transfer procedures for shoulder instability. J Shoulder Elbow Surg 2012;21:1110-9. https://doi.org/10.1016/j.jse.2012.02.008
14. Calori GM, Colombo M, Mazza EL, Mazzola S, Malagoli E, Mineo GV. Incidence of donor site morbidity following harvesting from iliac crest or RIA graft. Injury 2014;45(Suppl 6):S116-20. https://doi.org/10.1016/j.injury.2014.10.034
15. Carbone S, Moroder P, Runer A, Resch H, Gumina S, Hertel R. Scapular dyskinesis after Latarjet procedure. J Shoulder Elbow Surg 2016;25:422-7. https://doi.org/10.1016/j.jse.2015.08.001
16. Caubère A, Lami D, Boileau P, Parratte S, Ollivier M, Argenson JN. Is the subscapularis normal after the open Latarjet procedure? An isokinetic and magnetic resonance imaging evaluation. J Shoulder Elbow Surg 2017;26:1775-81. https://doi.org/10.1016/j.jse.2017.03.034
17. de Beer JF, Roberts C. Glenoid bone defects—open Latarjet with congruent arc modification. Orthop Clin North Am 2010;41:407-15. https://doi.org/10.1016/j.ocl.2010.02.008
18. Deml C, Kaiser P, van Leeuwen WF, Zitterl M, Euler SA. The J-shaped bone graft for anatomic glenoid reconstruction: a 10-year clinical follow-up and computed tomography-osteoabsorptiometry study. Am J Sports Med 2016;44:2778-83. https://doi.org/10.1177/0363546516665816
19. Di Giacomo G, de Gasperis N, Costantini A, De Vita A, Beccaglia MA, Pouliart N. Does the presence of glenoid bone loss influence coracoid bone graft osteolysis after the Latarjet procedure? A computed tomography scan study in 2 groups of patients with and without glenoid bone loss. J Shoulder Elbow Surg 2014;23:514-8. https://doi.org/10.1016/j.jse.2013.10.005
20. Di Giacomo G, Itoi E, Burkhart SS. Evolving concept of bipolar bone loss and the Hill-Sachs lesion: from "engaging/non-engaging" lesion to "on-track/off-track" lesion. Arthroscopy 2014;30:90-8. https://doi.org/10.1016/j.arthro.2013.10.004
21. Dimitriou R, Mataliotakis GI, Angoules AG, Kanakaris NK, Giannoudis PV. Complications following autologous bone graft harvesting from the iliac crest and using the RIA: a systematic review. Injury 2011;42(Suppl 2):S3-15. https://doi.org/10.1016/j.injury.2011.06.015
22. Edouard P, Beguin L, Degache F, Fayolle-Minon I, Farizon F, Calmels P. Recovery of rotators strength after Latarjet surgery. Int J Shoulder Surg 2012;33:749-55. https://doi.org/10.1055/s-0031-1298001
23. Edouard P, Degache F, Beguin L, Samozino P, Gresta G, Fayolle-Minon I, et al. Rotator cuff strength in recurrent anterior shoulder instability. J Bone Joint Surg Am 2011;93:759-65. https://doi.org/10.2106/JBJS.I.01791
24. Elkousy H, Gartsman GM, Labriola J, O'Connor DP, Edwards TB. Subscapularis function following the Latarjet coracoid transfer for recurrent anterior shoulder instability. Orthopedics 2010;33:802. https://doi.org/10.3928/01477447-20100924-08
25. Frank RM, Romeo AA, Richardson C, Sumner S, Verma NN, Cole BJ, et al. Outcomes of Latarjet versus distal tibia allograft for anterior shoulder instability repair: a matched cohort analysis. Am J Sports Med 2018;46:1030-8. https://doi.org/10.1177/0363546517744203
26. Giannakos A, Vezeridis PS, Schwartz DG, Jany R, Lafosse L. All-arthroscopic revision Eden-Hybinette procedure for failed instability surgery: technique and preliminary results. Arthroscopy 2017;33:39-48. https://doi.org/10.1016/j.arthro.2016.05.021
27. Gilbart MK, Gerber C. Comparison of the Subjective Shoulder Value and the Constant score. J Shoulder Elbow Surg 2007;16:717-21. https://doi.org/10.1016/j.jse.2007.02.123
28. Giles JW, Boons HW, Elkinson I, Faber KJ, Ferreira LM, Johnson JA, et al. Does the dynamic sling effect of the Latarjet procedure improve shoulder stability? A biomechanical evaluation. J Shoulder Elbow Surg 2013;22:821-7. https://doi.org/10.1016/j.jse.2012.08.002
29. Gordins V, Hovelius L, Sandström B, Rahme H, Bergström U. Risk of arthropathy after the Bristow-Latarjet repair: a radiologic and clinical thirty-three to thirty-five years of follow-up of thirty-one shoulders. J Shoulder Elbow Surg 2015;24:691-9. https://doi.org/10.1016/j.jse.2014.09.021
30. Griesser MJ, Harris JD, McCoy BW, Hussain WM, Jones MH, Bishop JY, et al. Complications and re-operations after Bristow-Latarjet shoulder stabilization: a systematic review. J Shoulder Elbow Surg 2013;22:286-92. https://doi.org/10.1016/j.jse.2012.09.009
31. Haefeli M, Elfering A. Pain assessment. Eur Spine J 2006;15(Suppl 1):S17-24. https://doi.org/10.1007/s00586-005-1044-x
32. Hofstaetter JG, Hanslik-Schnabel B, Hofstaetter SG, Wurnig C, Huber W. Cross-cultural adaptation and validation of the German version of the Western Ontario Shoulder Instability index. Arch Orthop Trauma Surg 2010;130:787-96. https://doi.org/10.1007/s00402-009-1033-3
33. Jobe FW, Kvitne RS, Giangarra CE. Shoulder pain in the overhand or throwing athlete. The relationship of anterior instability and rotator cuff impingement. Orthop Rev 1989;18:963-75.
34. Kalogrianitis S, Tsouparopoulos V. Arthroscopic iliac crest bone block for reconstruction of the glenoid: a fixation technique using an adjustable-length loop cortical suspensory fixation device. Arthrosc Tech 2016;5:e1197-202. https://doi.org/10.1016/j.eats.2016.07.007
35. Kany J, Codanda B, Croutzet P, Guinand R. Arthroscopic congruent-arc shoulder bone-block for severe glenoid bone defect: preliminary report. Orthop Traumatol Surg Res 2017;103:441-6. https://doi.org/10.1016/j.otsr.2016.11.023
36. Kibler WB. The role of the scapula in athletic shoulder function. Am J Sports Med 1998;26:325-37.
37. Kirkley A, Griffin S, Dainty K. Scoring systems for the functional assessment of the shoulder. Arthroscopy 2003;19:1109-20. https://doi.org/10.1016/j.arthro.2003.10.030
38. Kirkley A, Griffin S, McLintock H, Ng L. The development and evaluation of a disease-specific quality of life measurement tool for shoulder instability. The Western Ontario Shoulder Instability Index (WOSI). Am J Sports Med 1998;26:764-72.
39. Ljungquist KL, Butler RB, Griesser MJ, Bishop JY. Prediction of coracoid thickness using a glenoid width-based model: implications for bone reconstruction procedures in chronic anterior shoulder

instability. J Shoulder Elbow Surg 2012;21:815-21. https://doi.org/10.1016/j.jse.2011.10.006

40. Longo UG, Loppini M, Rizzello G, Ciuffreda M, Maffulli N, Denaro V. Latarjet, Bristow, and Eden-Hybinette procedures for anterior shoulder dislocation: systematic review and quantitative synthesis of the literature. Arthroscopy 2014;30:1184-211. https://doi.org/10.1016/j.arthro.2014.04.005
41. Mascarenhas R, Raleigh E, McRae S, Leiter J, Saltzman B, MacDonald PB. Iliac crest allograft glenoid reconstruction for recurrent anterior shoulder instability in athletes: surgical technique and results. Int J Shoulder Surg 2014;8:127-32. https://doi.org/10.4103/0973-6042.145269
42. Mizuno N, Denard PJ, Raiss P, Melis B, Walch G. Long-term results of the Latarjet procedure for anterior instability of the shoulder. J Shoulder Elbow Surg 2014;23:1691-9. https://doi.org/10.1016/j.jse.2014.02.015
43. Moroder P, Hirzinger C, Lederer S, Matis N, Hitzl W, Tauber M, et al. Restoration of anterior glenoid bone defects in posttraumatic recurrent anterior shoulder instability using the J-bone graft shows anatomic graft remodeling. Am J Sports Med 2012;40:1544-50. https://doi.org/10.1177/0363546512446681
44. 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. https://doi.org/10.1016/j.jse.2013.03.006
45. Moroder P, Plachel F, Becker J, Schulz E, Abdic S, Haas M, et al. Clinical and radiological long-term results after implant-free, autologous, iliac crest bone graft procedure for the treatment of anterior shoulder instability. Am J Sports Med 2018;46:2975-80. https://doi.org/10.1177/0363546518795165
46. 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. https://doi.org/10.1016/j.arthro.2017.08.234
47. Nebelung W, Reichwein F, Nebelung S. A simplified arthroscopic bone graft transfer technique in chronic glenoid bone deficiency. Knee Surg Sports Traumatol Arthrosc 2016;24:1884-7. https://doi.org/10.1007/s00167-014-3025-2
48. Paladini P, Merolla G, De Santis E, Campi F, Porcellini G. Long-term subscapularis strength assessment after Bristow-Latarjet procedure: isometric study. J Shoulder Elbow Surg 2012;21:42-7. https://doi.org/10.1016/j.jse.2011.03.027
49. Rowe CR, Patel D, Southmayd WW. The Bankart procedure: a long-term end-result study. J Bone Joint Surg Am 1978;60:1-16.
50. Rowe CR, Zarins B. Recurrent transient subluxation of the shoulder. J Bone Joint Surg Am 1981;63:863-72.
51. Sanchez M, Klouche S, Faivre B, Bauer T, Hardy P. Acromial J-bone graft on the acromion for surgical treatment of glenohumeral instability: an anatomical study. Shoulder Elbow 2017;9:272-8. https://doi.org/10.1177/1758573217693809
52. Scheibel M, Kraus N, Diederichs G, Haas NP. Arthroscopic reconstruction of chronic anteroinferior glenoid defect using an autologous tricortical iliac crest bone grafting technique. Arch Orthop Trauma Surg 2008;128:1295-300. https://doi.org/10.1007/s00402-007-0509-2
53. Scheibel M, Nikulka C, Dick A, Schroeder RJ, Popp AG, Haas NP. Structural integrity and clinical function of the subscapularis musculotendinous unit after arthroscopic and open shoulder stabilization. Am J Sports Med 2007;35:1153-61. https://doi.org/10.1177/0363546507299446
54. Schroder DT, Provencher MT, Mologne TS, Muldoon MP, Cox JS. The modified Bristow procedure for anterior shoulder instability: 26-year outcomes in Naval Academy midshipmen. Am J Sports Med 2006;34:778-86. https://doi.org/10.1177/0363546505282618
55. Singer GC, Kirkland PM, Emery RJ. Coracoid transposition for recurrent anterior instability of the shoulder. A 20-year follow-up study. J Bone Joint Surg Br 1995;77:73-6.
56. Steffen V, Hertel R. Rim reconstruction with autogenous iliac crest for anterior glenoid deficiency: forty-three instability cases followed for 5-19 years. J Shoulder Elbow Surg 2013;22:550-9. https://doi.org/10.1016/j.jse.2012.05.038
57. Stein T, Linke RD, Buckup J, Efe T, von Eisenhart-Rothe R, Hoffmann R, et al. Shoulder sport-specific impairments after arthroscopic Bankart repair: a prospective longitudinal assessment. Am J Sports Med 2011;39:2404-14. https://doi.org/10.1177/0363546511417407
58. Taverna E, D'Ambrosi R, Perfetti C, Garavaglia G. Arthroscopic bone graft procedure for anterior inferior glenohumeral instability. Arthrosc Tech 2014;3:e653-60. https://doi.org/10.1016/j.eats.2014.08.002
59. Tokish JM, Fitzpatrick K, Cook JB, Mallon WJ. Arthroscopic distal clavicular autograft for treating shoulder instability with glenoid bone loss. Arthrosc Tech 2014;3:e475-81. https://doi.org/10.1016/j.eats.2014.05.006
60. Valenti P, Maroun C, Wagner E, Werthel JD. Arthroscopic Latarjet procedure combined with Bankart repair: a technique using 2 cortical buttons and specific glenoid and coracoid guides. Arthrosc Tech 2018;7:e313-20. https://doi.org/10.1016/j.eats.2017.09.009
61. Warner JJ, Gill TJ, O'Hollerhan JD, Pathare N, Millett PJ. Anatomical glenoid reconstruction for recurrent anterior glenohumeral instability with glenoid deficiency using an autogenous tricortical iliac crest bone graft. Am J Sports Med 2006;34:205-12. https://doi.org/1177/0363546505281798
62. Weng PW, Shen HC, Lee HH, Wu SS, Lee CH. Open reconstruction of large bony glenoid erosion with allogeneic bone graft for recurrent anterior shoulder dislocation. Am J Sports Med 2009;37:1792-7. https://doi.org/1177/0363546509334590
63. Willemot LB, Elhassan BT, Sperling JW, Cofield RH, Sánchez-Sotelo J. Arthroplasty for glenohumeral arthritis in shoulders with a previous Bristow or Latarjet procedure. J Shoulder Elbow Surg 2018;27:1607-13. https://doi.org/10.1016/j.jse.2018.02.062
64. Yamamoto N, Muraki T, Sperling JW, Steinmann SP, Cofield RH, Itoi E, et al. Stabilizing mechanism in bone-grafting of a large glenoid defect. J Bone Joint Surg Am 2010;92:2059-66. https://doi.org/10.2106/JBJS.I.00261
65. Young AA, Maia R, Berhouet J, Walch G. Open Latarjet procedure for management of bone loss in anterior instability of the glenohumeral joint. J Shoulder Elbow Surg 2011;20:S61-9. https://doi.org/10.1016/j.jse.2010.07.022
66. Zhao J, Huangfu X, Yang X, Xie G, Xu C. Arthroscopic glenoid bone grafting with nonrigid fixation for anterior shoulder instability: 52 patients with 2- to 5-year follow-up. Am J Sports Med 2014;42:831-9. https://doi.org/10.1177/0363546513519227