J Shoulder Elbow Surg (2016) ■■, ■■–■■

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ORIGINAL ARTICLE

Three-dimensional volume measurement of coracoid graft osteolysis after arthroscopic Latarjet procedure

David L. Haeni, MD[a,*], Gaëtan Opsomer, MD[a], Amit Sood, MD[b], Jeremy Munji, MD[a], Matthieu Sanchez, MD[a], Benoit Villain, MD[a], Gilles Walch, MD[c], Laurent Lafosse, MD[a], Société Française d'Arthroscopie

[a]*Alps Surgery Institute, Annecy, France*
[b]*Department of Orthopedic Surgery, Harvard-Boston Shoulder Institute, Boston, MA, USA*
[c]*Centre Orthopédique Santy, Hôpital Privé Jean Mermoz, Lyon, France*

Background and hypothesis: The Latarjet procedure has been shown to be a reliable method to prevent recurrent anterior shoulder instability. Coracoid bone graft osteolysis is a potential catastrophic complication and can lead to recurrent instability. The purpose of our study is to present a novel quantitative method to measure the amount of coracoid bone osteolysis using 3-dimensional (3D) computed tomography (CT) scan imaging.
Materials and methods: This is a prospective study with 15 patients (16 shoulders) who underwent an arthroscopic Latarjet procedure. Three-dimensional CT scans were obtained at 6 weeks and 6 months. Using volumetric analysis, we quantified the amount of bone loss using our described method. Interobserver reliability and intraobserver reliability were calculated.
Results: On the basis of our new volumetric analysis of the arthroscopic Latarjet procedure using 3D CT scans, we found that the superior half of the coracoid bone graft undergoes a significant amount of osteolysis at 6 months postoperatively. The interobserver reliability and intraobserver reliability were excellent.
Discussion: This study presents a reproducible method to quantify and compare coracoid bone graft osteolysis after an arthroscopic Latarjet procedure. We also developed a description system that may be used for comparison studies. To our knowledge, this is the first method that quantifies the amount of coracoid bone graft osteolysis using more accurate 3D CT scanning.
Conclusion: The 3D analysis we propose is a valid method to measure the amount of coracoid bone graft osteolysis after an arthroscopic Latarjet procedure. Our description system may guide the surgeon regarding possible revision surgery when faced with significant osteolysis of the coracoid bone graft.
Level of evidence: Level IV; Case Series; Diagnostic Study

Keywords: Shoulder; instability; Latarjet; arthroscopy; osteolysis; coracoid graft; 3D volume

The Latarjet procedure,[22] which involves transfer of the coracoid bone with its attached conjoint tendon to the anteroinferior glenoid, has been shown to be a reliable method to prevent recurrent anterior shoulder instability.[6,23,27,28,34]

Institutional review board approval was obtained (Comité d'Ethique de Recherche Clinique Vivalto Santé, CERC-IRB, CERC-VS-2016-02-2).

*Reprint requests: David L. Haeni, MD, Spitalstrasse 21, CH-4031 Basel, Switzerland.

E-mail address: davhae@hotmail.com (D.L. Haeni).

1058-2746/$ - see front matter © 2016 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
http://dx.doi.org/10.1016/j.jse.2016.08.007

Stability is provided by the "triple effect," consisting of the coracoid bone, which restores the anterior-to-posterior glenoid diameter; sling effect from the conjoint tendon; and tension produced within the lower half of the subscapularis, which provides stability to the glenohumeral joint as the arm is brought into abduction and external rotation.[2,9,12,31] The superiority of this procedure in the setting of bone loss, on either the glenoid or humeral side, and poor tissue quality has led surgeons to further develop the Latarjet procedure from its traditional open technique to a more advanced arthroscopic technique.[1,5,13]

Advancements in technique, however, have led to an increased awareness of the Latarjet procedure's associated complications. Complications that have been described include coracoid bone graft osteolysis, prominent hardware or screws, graft malpositioning, and graft nonunion.[3,7,8,10,15,16] All of these complications may lead to persistent anterior instability, stiffness, and/or pain requiring either revision procedures or removal of hardware.

Specifically, osteolysis of the coracoid bone graft[10,17,29] has been previously examined because of its potential catastrophic results with recurrent instability and the need for more complicated revision procedures.[4,24,26,32] Di Giacomo et al[10] were the first authors to use computed tomography (CT) scans to measure the area of bone loss and found that the superficial and medial portions of the proximal end of the graft were most susceptible to resorption.[25] This qualitative observation was confirmed in a recently published study by Zhu et al,[36] who found bone resorption to occur at a high rate 1 year after surgery with resorption occurring more significantly near the superior screw. Their study, similar to the study by Di Giacomo et al,[11] analyzed 2-dimensional (2D) CT scan cuts to grade the amount of bone loss that occurred.

The purpose of our study is to present a more simplistic method to determine the amount of coracoid bone osteolysis using 3-dimensional (3D) CT scans, which more accurately quantify the actual volume of bone loss in a 3D format with the use of volume rendering software.[30] This technique has also allowed us to develop the first 3D volumetric index for coracoid bone graft osteolysis.

Materials and methods

This study was performed at Clinique Générale in Annecy, France. Clinical findings, radiographs, and CT scan data were collected from patients who underwent an arthroscopic Latarjet procedure by use of a previously published technique[21] performed by the senior author from June to November 2014.

Indications for the Latarjet procedure were patient specific, and criteria were similar to those previously published in the literature.[1,13,19,20,28] These included patients with recurrent anterior instability due to glenoid bone loss, associated instability lesions (humeral avulsion of the glenohumeral ligament, anterior labroligamentous periosteal sleeve avulsion, and large Hill-Sachs lesions), and failure of previous stabilization procedures. The exclusion criteria included patients with incomplete clinical or 3D CT scan follow-up.

Radiographs and 3D CT scans (syngo CT; Siemens Healthcare, Erlangen, Germany) were obtained preoperatively to evaluate for bone defects and capsulolabral lesions. Three-dimensional CT scans were then repeated at 6 weeks postoperatively to assess the coracoid bone graft for position (medial, lateral, or flush with the glenoid), fusion, and screw position, as well as at 6 months for coracoid bone graft osteolysis. Follow-up radiographs were not obtained.

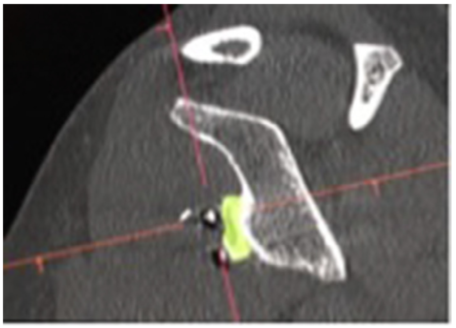

Figure 1 The contour of the bone graft was manually defined in the sagittal plane, and the entire volume (in square centimeters) was automatically generated using our software (syngo.via).

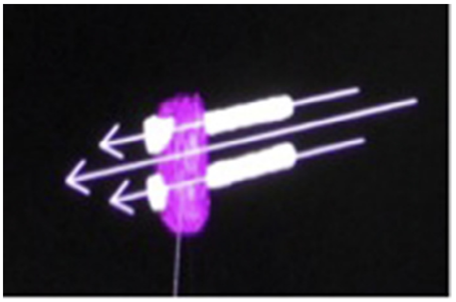

Figure 2 Software (syngo.via)–generated volume rendering of the arthroscopic Latarjet bone graft.

Three-dimensional CT scans were also used at 6 weeks postoperatively and 6 months postoperatively to determine the total coracoid bone graft volume. The bone graft was separated into superior and inferior halves using our 3D software as will be described. The volumes at 6 weeks postoperatively were used as baseline control values and compared with the 6-month postoperative volumes because no coracoid bone graft osteolysis would be expected at 6 weeks postoperatively.

Sagittal images from the CT scans were examined in 0.5-mm cuts to create a volume rendering of the graft (Figs. 1 and 2). The outline of the coracoid graft was manually traced on serial sagittal images as it lay anterior to the glenoid using our software (syngo.via; Siemens Healthcare); it selected the coracoid "bone signal" in the scan, differentiating it from screws and the surrounding joint space or soft tissue. We were then able to establish the "tri-planar" axis of the coracoid in the axial, sagittal, and coronal dimensions by using the core of the 2 graft fixation screws as a reference point. Both screws were placed arthroscopically using a guide (Double Cannula; DePuy Mitek, Raynham, MA, USA) that separates the screws by a set distance of 9 mm. Thus, the sagittal dividing line was placed at a distance of 4.5 mm inferior to the core of the superior screw, which placed the line equidistant from the core of the 2 screws. By using this technique, we were able to determine a line that was able to bisect the coracoid graft and divide the graft into superior and inferior halves.

All measurements were performed by 3 observers (D.L.H., G.O., and J.M.), all of whom are board-certified orthopedic surgeons having completed a shoulder surgery fellowship. All measurements were performed at the same time and on the same day of the week. One observer (D.L.H.) performed every measurement twice after 15 days to determine the intraobserver reliability in addition to the interobserver reliability.

Results

From June to November 2014, data from 15 patients (16 shoulders) who underwent the arthroscopic Latarjet procedure were prospectively collected. The age range of the patients was 19 to 45 years, with a mean age of 28.5 years. There were 11 male shoulders and 5 female shoulders in the study. There were 7 right and 9 left shoulders.

For the total coracoid bone graft volume, the mean at 6 weeks postoperatively was 1.68 cm^3 (SD, 0.77 cm^3; 95% confidence interval [CI], 1.27-2.09 cm^3). At 6 months postoperatively, the mean volume decreased to 1.29 cm^3 (SD, 0.68 cm^3; 95% CI, 0.92-1.64 cm^3). The difference in the total volume of the bone graft at 6 weeks compared with 6 months was not significant, with $P = .128$.

For the superior-half bone graft volume, the mean at 6 weeks postoperatively was 0.89 cm^3 (SD, 0.44 cm^3; 95% CI, 0.62-1.1 cm^3). At 6 months postoperatively, the superior-half bone graft volume decreased to 0.53 cm^3 (SD, 0.33 cm^3; 95% CI, 0.36-0.70 cm^3). This was a significant difference, with $P = .024$.

For the inferior-half bone graft volume, the mean at 6 weeks postoperatively was 0.82 cm^3 (SD, 0.42 cm^3; 95% CI, 0.60-1.04 cm^3). At 6 months postoperatively, the inferior-half bone graft volume decreased to 0.75 cm^3 (SD, 0.43 cm^3; 95% CI, 0.52-0.98 cm^3). The difference between these values was not significant, with $P = .637$.

The intraobserver reliability was excellent, with all measurements taken with values of 0.98 to 0.99. The interobserver reliability was also excellent, with values ranging from 0.94 to 0.98.

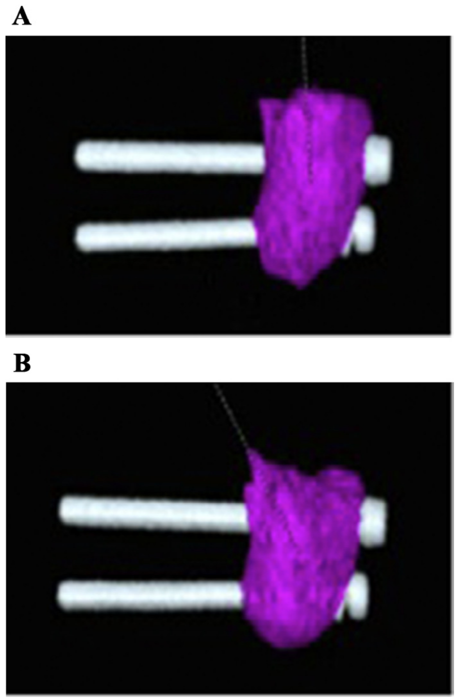

Figure 3 Three-dimensional volume rendering performed at 6 weeks **(A)** and 6 months **(B)** postoperatively showing the notable decrease in the superior volume of the arthroscopic Latarjet graft.

Discussion

On the basis of our new volumetric analysis of the arthroscopic Latarjet procedure using 3D CT scans, we found that the superior half of the coracoid bone graft undergoes a significant amount of osteolysis at 6 months postoperatively (Fig. 3). Our technique uses the 2 parallel screws as a reference point in dividing the coracoid bone graft into superior and inferior volume measurements. The known distance (9 mm) between the 2 parallel screws allows us to determine the center line from which we are able to measure the volume of bone loss in the superior and inferior halves of the coracoid. Using this reproducible method allows us to more accurately compare graft osteolysis at 6 weeks and 6 months after surgery. Although it may be ideal to place both screws exactly centered within the coracoid bone graft in the coronal plane, our technique may still be accurately used in situations in which the screws are placed off-center in the coronal plane within the coracoid graft because our volume–of–bone loss measurements are based on a set location between both screws at a distance of 4.5 mm from the screw heads in the sagittal plane.

The results of this study and its more accurate method of using 3D CT scans to obtain volumetric measurements may be used to develop a Latarjet Osteolysis Index system using the following mathematical expressions: $S_TX\%$ and $I_TX\%$, where *S* refers to the superior part of the coracoid, *I* refers to the inferior part of the coracoid, *T* refers to time after surgery, and *X* refers to the respective percentage of osteolysis from baseline. On the basis of our results, this description system can help compare amounts of osteolysis between different surgeons at different institutions at varying time points if desired.

Previous studies have found similar observations using CT scans. Di Giacomo et al[10] were the first authors to quantify and localize coracoid osteolysis using CT scan analysis. In their study of 26 patients, they found that resorption occurred most frequently within the superior and superficial portions of the graft at a mean follow-up of 17.5 ± 6.7 months with a mean bone loss of 59%. Although they used 3D CT scans to divide the coracoid bone graft into 8 parts, 2D CT cuts were still used to measure the area of bone loss. Our study uses 3D CT scans to perform a volumetric analysis of the coracoid bone graft, which is divided into superior and inferior parts. This method simplifies the number of parts of the bone graft while providing a more accurate measurement of bone loss since volume of bone loss is measured in actual 3D space.

Measurements from axial 2D data, similar to what was performed with the methodology of Di Giacomo et al,[10] are commonly performed in patients with cancer to assess treatment response or disease progression. Hopper et al[18] demonstrated in their study that the 3D method of tumor volume measurement was more accurate and differed significantly from conventional 2D methods of tumor volume determination. They actually found 2D methods to overestimate overall tumor size.

In a recently published study, Zhu et al[36] proposed a new classification system to evaluate the amount of osteolysis after an open Latarjet procedure. In 64 patients, a CT scan was performed 1 year after surgery, and 4 observers performed the qualitative evaluation. The classification system was divided into 4 grades and had good to excellent interobserver and intraobserver reliability.

In our study, we used a 3D approach to calculate coracoid bone graft volume, and we believe that it is a more accurate and better method to assess the volume of the coracoid bone graft. Our method is, to our knowledge, the first that allows a quantification of the amount of osteolysis at a defined time after an arthroscopic Latarjet procedure. This allows us to compare graft osteolysis dynamically through time. This method is also applicable after an open Latarjet procedure if a screw guide is used with placement of parallel screws. Because both screws—and not the graft or the glenoid—are used as a reference, a plane between the 2 screws can easily be defined without significant error.

Failure to fully decorticate the bone graft and glenoid surfaces and insufficient screw compression at the bony interfaces may cause the coracoid bone graft to go on to develop nonunion or fibrous union. However, reasons as to why the superior half of the bone graft either does not heal or goes on to develop osteolysis are still theoretical at this point. Explanations include better bone contact of the inferior half of the bone graft due to the contour of the glenoid, the limited vascular supply to the proximal portion of the graft due to the distal attachment of the conjoint tendon, and stress osteolysis due to the majority of mechanical stresses being applied to the inferior half from the pull of the conjoint tendon and compression from the tensioned inferior half of the subscapularis.

Another reason for osteolysis of the superior half of the bone graft could be related to Wolff's law.[11,14,33,35] According to Wolff's law, bone constantly adapts itself to the external forces, gaining mass in areas of stress and undergoing osteolysis in areas of less stress. The inferior half is subjected to higher stresses by the humeral head compared with the superior half. Correlating this to Wolff's law, the coracoid graft undergoes less stress by the humeral head superiorly compared with inferiorly, thus resulting in resorption of the superior portion of the bone graft.

One cause for pain after a Latarjet procedure is screw prominence, which can lead to irritation of the subscapularis and chondral damage to the humeral head from abutment. This screw prominence can occur if screws are not fully seated or after coracoid bone graft osteolysis. On the basis of our study and the findings of other published data, the superior aspect of the bone graft is most likely to undergo osteolysis with resulting prominence of the superior screw (Fig. 4).

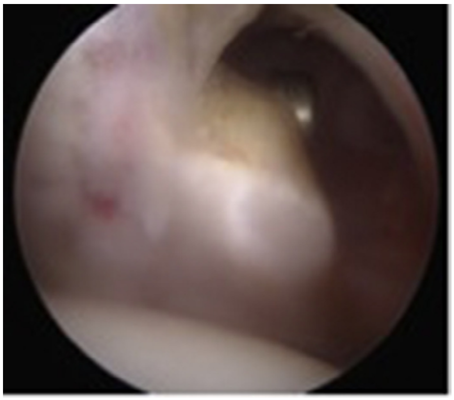

Figure 4 Arthroscopic view of the graft from the lateral portal during arthroscopic screw removal showing significant superior graft lysis and screw prominence compared with the inferior portion of the graft.

Limitations to this study include the fact that we did not examine other parameters that might influence bone graft resorption. Di Giacomo et al[11] showed that bone graft osteolysis is less likely to occur if the Latarjet procedure is performed in patients with larger glenoid bone defects. We were unable to perform an analysis of the influence glenoid bone defects may have on graft resorption because not all patients received preoperative CT scans. It may be valuable in future studies to examine the influence other factors may play in resorption of the bone graft, such as the actual position of placement of the bone graft along the anterior glenoid and screw angulation within the glenoid. Future studies examining such factors may help us to better determine how to prevent or minimize bone graft osteolysis. Given the limited number of patients involved in this study, we are not able to define a specific graft osteolysis percentage that would necessitate screw removal. However, our purpose is to raise awareness of shoulder surgeons regarding coracoid bone graft resorption that occurs around 6 months after the Latarjet procedure and consideration of screw removal in the setting of persistent anterior shoulder pain after performing a volumetric CT scan graft assessment to assess for bone graft osteolysis and resultant screw prominence.

Conclusion

The volumetric measurement assessment we propose is a valid method to determine the exact amount of coracoid bone graft osteolysis after the arthroscopic Latarjet procedure. The Latarjet Osteolysis Index is a helpful descriptive system, but we are not able to define a percentage that may suggest the need for revision surgery and/or screw removal. Future studies are needed for clinical correlation in long-term success of the procedure that may guide the surgeon regarding possible revision surgery when faced with significant osteolysis of the coracoid bone graft.

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. Agneskirchner JD, Lafosse L. Transfer of the coracoid process in recurrent anterior instability of the shoulder joint. The arthroscopic Latarjet procedure. Oper Orthop Traumatol 2014;26:296-306. http://dx.doi.org/10.1007/s00064-011-0052-8
2. Bachy M, Lapner PLC, Goutallier D, Allain J, Hernigou P, Bénichou J, et al. Coracoid process x-ray investigation before Latarjet procedure: a radioanatomic study. J Shoulder Elbow Surg 2013;22:e10-4. http://dx.doi.org/10.1016/j.jse.2013.06.016
3. Balestro J-C, Young A, Maccioni C, Walch G. Graft osteolysis and recurrent instability after the Latarjet procedure performed with bioabsorbable screw fixation. J Shoulder Elbow Surg 2014;24:711-8. http://dx.doi.org/10.1016/j.jse.2014.07.014
4. Boileau P, Richou J, Lisai A, Chuinard C, Bicknell RT. The role of arthroscopy in revision of failed open anterior stabilization of the shoulder. Arthroscopy 2009;25:1075-84. http://dx.doi.org/10.1016/j.arthro.2009.04.073
5. Boileau P, Thélu C-É, Mercier N, Ohl X, Houghton-Clemmey R, Carles M, et al. Arthroscopic Bristow-Latarjet combined with Bankart repair restores shoulder stability in patients with glenoid bone loss. Clin Orthop Relat Res 2014;472:2413-24. http://dx.doi.org/10.1007/s11999-014-3691-x
6. Burkhart SS, De Beer JF, Barth JRH, Cresswell T, Criswell T, Roberts C, et al. Results of modified Latarjet reconstruction in patients with anteroinferior instability and significant bone loss. Arthroscopy 2007;23:1033-41. http://dx.doi.org/10.1016/j.arthro.2007.08.009
7. Butt U, Charalambous CP. Complications associated with open coracoid transfer procedures for shoulder instability. J Shoulder Elbow Surg 2012;21:1110-9. http://dx.doi.org/10.1016/j.jse.2012.02.008
8. Casabianca L, Gerometta A, Massein A, Khiami F, Rousseau R, Hardy A, et al. Graft position and fusion rate following arthroscopic Latarjet. Knee Surg Sports Traumatol Arthrosc 2016;24:507-12. http://dx.doi.org/10.1007/s00167-015-3551-6
9. Degen RM, Giles JW, Johnson JA, Athwal GS. Remplissage versus Latarjet for engaging Hill-Sachs defects without substantial glenoid bone loss: a biomechanical comparison. Clin Orthop Relat Res 2014;472:2363-71. http://dx.doi.org/10.1007/s11999-013-3436-2
10. Di Giacomo G, Costantini A, de Gasperis N, De Vita A, Lin BK, Francone M, et al. Coracoid graft osteolysis after the Latarjet procedure for anteroinferior shoulder instability: a computed tomography scan study of twenty-six patients. J Shoulder Elbow Surg 2011;20:989-95. http://dx.doi.org/10.1016/j.jse.2010.11.016
11. Di Giacomo G, de Gasperis N, Costantini A, De Vita A, Beccaglia MAR, 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. http://dx.doi.org/10.1016/j.jse.2013.10.005
12. Dines JS, Dodson CC, McGarry MH, Oh JH, Altchek DW, Lee TQ. Contribution of osseous and muscular stabilizing effects with the Latarjet procedure for anterior instability without glenoid bone loss. J Shoulder Elbow Surg 2013;22:1689-94. http://dx.doi.org/10.1016/j.jse.2013.02.014
13. Dumont GD, Fogerty S, Rosso C, Lafosse L. The arthroscopic Latarjet procedure for anterior shoulder instability: 5-year minimum follow-up. Am J Sports Med 2014;42:2560-6. http://dx.doi.org/10.1177/0363546514544682
14. Frost HM. A 2003 update of bone physiology and Wolff's law for clinicians. Angle Orthod 2004;74:3-15.
15. 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. http://dx.doi.org/10.1016/j.jse.2014.09.021
16. Gupta A, Delaney R, Petkin K, Lafosse L. Complications of the Latarjet procedure. Curr Rev Musculoskelet Med 2015;8:59-66. http://dx.doi.org/10.1007/s12178-015-9258-y
17. Hamel A, Hamel O, Ploteau S, Robert R, Rogez J-M, Malinge M. The arterial supply of the coracoid process. Surg Radiol Anat 2012;34:599-607. http://dx.doi.org/10.1007/s00276-012-0952-9
18. Hopper KD, Kasales CJ, Eggli KD, TenHave TR, Belman NM, Potok PS, et al. The impact of 2D versus 3D quantitation of tumor bulk determination on current methods of assessing response to treatment. J Comput Assist Tomogr 1996;20:930-7.
19. Hovelius L, Sandström B, Saebö M. One hundred eighteen Bristow-Latarjet repairs for recurrent anterior dislocation of the shoulder prospectively followed for fifteen years: study II-the evolution of dislocation arthropathy. J Shoulder Elbow Surg 2006;15:279-89. http://dx.doi.org/10.1016/j.jse.2005.09.014
20. Hovelius L, Sandström B, Sundgren K, Saebö M. One hundred eighteen Bristow-Latarjet repairs for recurrent anterior dislocation of the shoulder prospectively followed for fifteen years: study I—clinical results. J Shoulder Elbow Surg 2004;13:509-16. http://dx.doi.org/10.1016/j.jse.2004.02.013
21. Lafosse L, Boyle S. Arthroscopic Latarjet procedure. J Shoulder Elbow Surg 2010;19(Suppl):2-12. http://dx.doi.org/10.1016/j.jse.2009.12.010
22. Latarjet M. Treatment of recurrent dislocation of the shoulder. Lyon Chir 1954;49:994-7 [in French].
23. Leroux T, Wasserstein D, Veillette C, Khoshbin A, Henry P, Chahal J, et al. Epidemiology of primary anterior shoulder dislocation requiring closed reduction in Ontario, Canada. Am J Sports Med 2014;42:442-50. http://dx.doi.org/10.1177/0363546513510391
24. 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. http://dx.doi.org/10.1016/j.arthro.2014.04.005
25. Magarelli N, Milano G, Sergio P, Santagada DA, Fabbriciani C, Bonomo L. Intra-observer and interobserver reliability of the "Pico" computed tomography method for quantification of glenoid bone defect in anterior shoulder instability. Skeletal Radiol 2009;38:1071-5. http://dx.doi.org/10.1007/s00256-009-0719-5
26. Mauro CS, Voos JE, Hammoud S, Altchek DW. Failed anterior shoulder stabilization. J Shoulder Elbow Surg 2011;20:1340-50. http://dx.doi.org/10.1016/j.jse.2011.05.003
27. McMahon PJ, Yang BY, Chow S, Lee TQ. Anterior shoulder dislocation increases the propensity for recurrence: a cadaveric study of the number of dislocations and type of capsulolabral lesion. J Shoulder Elbow Surg 2013;22:1046-52. http://dx.doi.org/10.1016/j.jse.2012.11.013
28. 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. http://dx.doi.org/10.1016/j.jse.2014.02.015
29. Moroder P, Blocher M, Auffarth A, Hoffelner T, Hitzl W, Tauber M, et al. Clinical and computed tomography-radiologic outcome after bony glenoid augmentation in recurrent anterior shoulder instability without significant glenoid bone loss. J Shoulder Elbow Surg 2014;23:420-6. http://dx.doi.org/10.1016/j.jse.2013.07.048
30. Puri L, Wixson RL, Stern SH, Kohli J, Hendrix RW, Stulberg SD. Use of helical computed tomography for the assessment of acetabular osteolysis after total hip arthroplasty. J Bone Joint Surg Am 2002;84:609-14.

31. Schulze-Borges J, Agneskirchner JD, Bobrowitsch E, Patzer T, Struck M, Smith T, et al. Biomechanical comparison of open and arthroscopic Latarjet procedures. Arthroscopy 2013;29:630-7. http://dx.doi.org/10.1016/j.arthro.2012.12.003
32. Tauber M, Resch H, Forstner R, Raffl M, Schauer J. Reasons for failure after surgical repair of anterior shoulder instability. J Shoulder Elbow Surg 2004;13:279-85. http://dx.doi.org/10.1016/j.jse.2004.01.008
33. Turner CH. Functional determinants of bone structure: beyond Wolff's law of bone transformation. Bone 1992;13:403-9.
34. Walch G, Charret P, Pietro-Paoli H, Dejour H. Anterior recurrent luxation of the shoulder. Postoperative recurrences. Rev Chir Orthop Reparatrice Appar Mot 1986;72:541-55 [in French].
35. Wolf JH. Julis Wolff and his "law of bone remodeling". Orthopade 1995;24:378-86 [in German].
36. Zhu Y-M, Jiang C-Y, Lu Y, Li F-L, Wu G. Coracoid bone graft resorption after Latarjet procedure is underestimated: a new classification system and a clinical review with computed tomography evaluation. J Shoulder Elbow Surg 2015;24:1782-8. http://dx.doi.org/10.1016/j.jse.2015.05.039