Anterior and posterior glenoid bone augmentation options for shoulder instability: state of the art

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ABSTRACT

Bony lesions are highly prevalent in anterior shoulder instability and can be a significant cause of failure of stabilisation procedures if they are not adequately addressed. The glenoid track concept describes the dynamic interaction between the humeral head and glenoid defects in anterior shoulder instability. It has been beneficial for understanding the role played by bone defects in this entity. As a consequence, the popularity of glenoid augmentation procedures aimed to treat anterior glenoid bone defects; reconstructing the anatomy of the glenohumeral joint has risen sharply in the last decade. Although bone defects are less common in posterior instability, posterior bone block procedures can be indicated to treat not only posterior bony lesions, attritional posterior glenoid erosion or dysplasia but also normal or retroverted glenoids to provide an extended glenoid surface to increase the glenohumeral stability. The purpose of this review was to analyse the rationale, current indications and results of surgical techniques aimed to augment the glenoid surface in patients diagnosed of either anterior or posterior instability by assessing a thorough review of modern literature. Classical techniques such as Latarjet or free bone block procedures have proven to be effective in augmenting the glenoid surface and consequently achieving adequate shoulder stability with good clinical outcomes and early return to athletic activity. Innovations in surgical techniques have permitted to perform these procedures arthroscopically. Arthroscopy provides the theoretical advantages of lower morbidity and faster recovery, as well as the identification and treatment of concomitant pathologies.

INTRODUCTION

Clinical problem and biomechanics of bone defects in shoulder instability

Bony lesions are common in shoulder instability, and numerous investigations have demonstrated that they can be a significant cause of failure of stabilisation procedures if they are not properly addressed.[1] As the prevalence of anterior shoulder instability is much more common than the posterior one, most of the biomechanical studies have focused on bony lesions in anterior shoulder instability. A set of bony lesions in anterior shoulder instability is a glenoid bone loss and a Hill-Sachs lesion. In the series of recurrent anterior dislocation of the shoulder reported by Kurokawa *et al*, 86% had a bony defect of the glenoid, and 94% had a Hill-Sachs lesion.[2] In total, 81% of them had both lesions, which is called a 'bipolar lesion'. These bony lesions are intimately related to shoulder instability. Regarding the bony lesions of the glenoid, the critical size of bone loss is known to be 25% of the glenoid width.[3–6] Recently, Shaha *et al* followed up their military patients after arthroscopic Bankart repair and found recurrent instability was the problem when a bone loss was greater than 20% of the glenoid width.[7] Less than 20%, recurrence was not an issue, but the Western Ontario Shoulder Instability Index (WOSI) score was significantly worse in those with the glenoid bone loss between 13.5% and 20% than in those less than 13.5%. They called a bony defect sizing of 13.5%–20% a subcritical bone loss. Yamamoto *et al* found 25% was the critical bone loss, and 17%–25% was the subcritical bone loss.[8] The subcritical bone loss may likely change, depending on the patient's risks of recurrence.

A glenoid bone loss causes shoulder instability in the mid-range of motion. As the mid-range stability depends solely on the depth of the glenoid, the risk of instability can be determined by the glenoid alone. On the contrary, a Hill-Sachs lesion is related to the end-range stability together with the glenoid. The risk of instability caused by a Hill-Sachs lesion depends not only on the Hill-Sachs lesion but also on the glenoid. A Hill-Sachs lesion, which causes no instability when the glenoid is intact, may cause instability if there is a bone loss on the glenoid side[9] (figure 1). This tells us that the risk of Hill-Sachs lesion cannot be determined by the size of the Hill-Sachs lesion alone. It needs to be assessed together with the glenoid. How can this be assessed in the clinical setting? One method is to use a dynamic examination during surgery. However, this must be performed after the Bankart repair. Before the Bankart repair, the shoulder is unstable anteriorly, and the Hill-Sachs lesion approaches the anterior rim of the glenoid quite easily. This phenomenon might be misinterpreted as an engaging Hill-Sachs lesion. If the dynamic examination is performed after the Bankart repair, the Hill-Sachs lesion does not come closer to the anterior rim of the glenoid because the humeral head is stabilised and well centred on the glenoid socket. If the Hill-Sachs lesion engages even after the Bankart repair, it is a 'true engaging Hill-Sachs lesion', which needs to be treated. However, most surgeons perform a dynamic examination at the very beginning of the surgery before Bankart repair, which makes them misinterpret a non-engaging Hill-Sachs lesion as an engaging Hill-Sachs lesion. Thus, if a dynamic examination is to be used, it must be performed after the Bankart repair. The problem of using dynamic examination is it helps us decide whether the remplissage should be added or not only after the

Bankart repair. Performing remplissage after the Bankart repair is technically demanding because the head does not come anteriorly, and as a result, inserting suture anchors into the Hill-Sachs lesion is difficult to perform. To avoid this difficulty, we would like to know whether the remplissage is necessary or not before the Bankart repair. For this purpose, the dynamic examination is useless. Therefore, another method, a glenoid track concept, is recommended.[10] The glenoid moves along the posterior border of the articular surface of the humeral head when the arm is moved along the posterior end range of motion. This track on the humeral head created by the glenoid is called the glenoid track. To avoid misinterpretation of dynamic examination and misuse of remplissage, a new terminology of 'on-track'/'off-track' lesion was introduced to replace 'engaging'/'non-engaging' lesion.[11] In order to assess the bony lesions accurately, preoperative 3D CT imaging is recommended. There are two methods to estimate the size of bony defect of the glenoid: best-fit circle method and the contralateral comparison method. The contralateral method to use the contralateral glenoid as a reference is more reliable than the best-fit circle method.[12] Since bilateral shoulders are within the CT gantry, CT images of bilateral shoulders are available. We only need to ask the radiologist to create 3D images of bilateral glenoids and humeral heads. There is no need to scan the patient twice. If a Hill-Sachs lesion stays on the glenoid track, it is an on-track lesion, and it is stable. The width of the glenoid track is 84% in cadaveric shoulder[10] and 83% in live shoulders.[13] We use this 83% value in our daily practice. However, this value changes with the change of the range of motion. The glenoid track width is wider if the shoulder is stiff, and it is narrower if the shoulder is hypermobile. A relationship was found between the active range of motion in horizontal extension in the sitting position and the glenoid track width as follows: $Y=-0.49X+90$, where Y is the glenoid track width (%) and X is the active range of motion in horizontal extension in the sitting position (°).[14] Using this conversion can provide a better assessment of the glenoid track width of each individual. More recently, a sort of 'subcritical zone' in the glenoid track was found. The glenoid track would be divided into four zones, and if a Hill-Sachs lesion is located in the most medial one-fourth, the WOSI score of the patients was less satisfactory than those in the remaining three-fourths of the glenoid track.[15] The former is called 'peripheral track', and the latter is called 'central track' (figure 2).

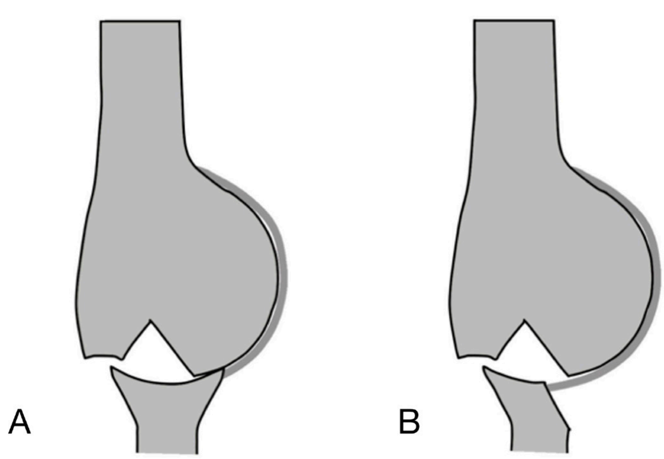

Figure 1 Risk of Hill-Sachs lesion. (A) This Hill-Sachs lesion is entirely covered by the glenoid at the end range of motion. Thus, this Hill-Sachs lesion does not cause instability. (B) The same Hill-Sachs lesion can cause instability if there is a bone loss on the glenoid side (adapted from Itoi[9]).

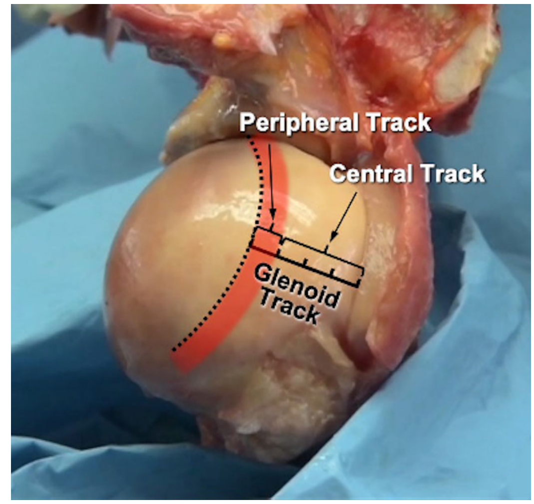

Figure 2 Peripheral track and central track (adapted from Itoi[16]).

If a Hill-Sachs lesion extends medially into the peripheral track, the WOSI score is less satisfactory. If a patient is very active and at high risk of recurrence, this peripheral-track lesion should be considered as an off-track lesion for treatment selection.[16] Now that we know there are a subcritical glenoid bone loss and a peripheral-track Hill-Sachs lesion, treatment selection for patients who have either one or the other or both should be based on the risks of the patients.

Posterior shoulder instability is clearly different from anterior instability, not only the direction of instability but also clinical presentations and pathological findings. Out of 200 patients in the matched cohort analysis, Bernhardson *et al* reported 95% of patients who underwent anterior stabilisation had a dislocation or subluxation event, and their chief complaint was instability, whereas 78% of those who underwent posterior stabilisation had no single acute injury, and their chief complaint was pain.[17] According to a recent study of the Multicenter Orthopaedic Outcomes Network database, bone and cartilage lesions were observed in 54/271 patients (19.9%) with posterior instability at the time of surgical treatment.[18] Glenoid bone loss was observed in 3 patients (1.1%), and reverse Hill-Sachs lesion was observed in 16 patients (5.9%). Judging from these data, the prevalence of bony lesions in patients with posterior instability is much less common compared with anterior instability. Another study in which they examined 40 patients with recurrent posterior instability with confirmed bone loss demonstrated that a bone loss was located posteriorly, and almost 60% of them had a low-grade bone loss (<10%) and only 5% had a high-grade bone loss (≥20%).[19] Only a couple of biomechanical studies have been reported regarding the role of bone loss in posterior instability. In a cadaveric study, Nacca *et al* created a posterior glenoid bone loss stepwise, repaired the reverse Bankart lesion and measured the posterior stability.[20] This was very similar to what Yamamoto *et al* did in their anterior stability study.[21] Their study showed that a posterior glenoid bone loss equal to or greater than 20% of the glenoid width remained unstable after isolated, reverse Bankart repair. Considering the glenoid shape with its inferior two-thirds similar to a circle, it is understandable that almost the same critical size was obtained in the posterior bone loss. The same group created a 40% bone loss and reconstructed either with a distal tibial allograft or scapular spine autograft.[22] They found both methods of bone graft could restore stability, and there was no significant difference between them.

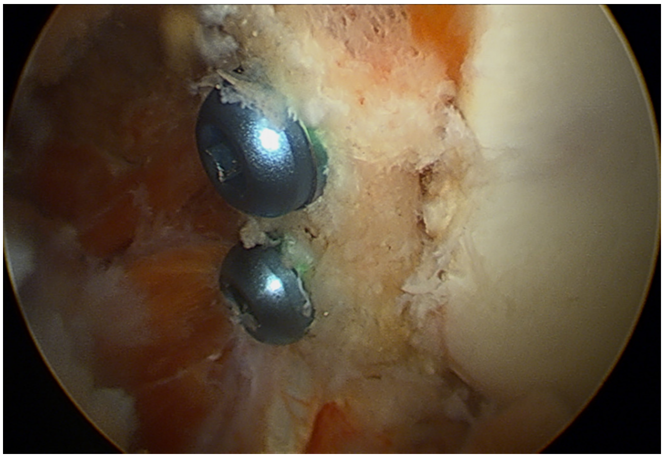

Figure 3 Intraoperative imaging of an arthroscopic Latarjet (left shoulder). The coracoid process has been transferred to the anteroinferior glenoid neck and fixed with two screws.

Glenoid version is another issue to be considered in posterior instability. It can be assessed by CT scan with the conventional method described by Friedman *et al*[23] or the vault version technique, according to Matsumura *et al*.[24] The traditional way takes into account the line between the anterior and posterior glenoid rim and the scapular axis defined as the line connecting the root of the scapular spine and the midpoint of the glenoid line. Based on the concept that the scapular body shape may influence the conventional method, Matsumura defined the 'glenoid vault measuring technique' to better address the glenoid face version. The glenoid face has an average between −2° and −10° of retroversion.[25] Several studies have reported an increased glenoid retroversion in patients suffering from posterior instability compared with healthy individuals.[26–28] The dominant arm has an increased retroversion compared with the opposite side.[26] Thus far, there is no definitive glenoid version cut-off from where the version has a significant influence on the surgical results. However, based on their high complication rates, the glenoid open wedge osteotomies are indicated only when the retroversion is over −15°. For patients with a glenoid retroversion lower than that, a posterior bone block is preferred.[29]

Main articles: reviews, state of the art and current concepts

Over the past decades, several reviews have been published about the management of glenoid defects in shoulder instability. As time has progressed, reviews have moved from patient selection criteria to arthroscopic surgical techniques.

CURRENT STATE OF THE ART

Anterior and posterior glenoid augmentation options

For acute lesions of the glenoid, direct repair of the fracture can be performed. In patients with chronic shoulder instability and glenoid defects, there is generally no fragment to be reattached, and several techniques to reconstruct the glenoid using different types of grafts have been proposed.

Open Latarjet

Michel Latarjet described in 1954 a coracoid bone block technique to prevent recurrent dislocations.[30] He suggested transferring the horizontal limb of the coracoid process to the anteroinferior edge of the glenoid and fixing it with a screw.[31] This intervention became quickly accessible in France, where it represented an alternative to open Bankart. In 1958, Helfet described a similar technique that he named Bristow procedure regarding his mentor, who had initially described the technique.[32] In the initial Bristow technique, the coracoid graft was smaller and attached to the anterior edge of the glenoid and capsule with sutures. This intervention, a long time assimilated to Latarjet, is therefore different, in particular not allowing a solid initial bone-to-bone fixation. This perhaps explains the disparity in the results of the two interventions, which were sometimes confused and probably the low success rate of the 'Latarjet' procedure in North America. Accordingly, the term Bristow-Latarjet should no longer be used to avoid confusion.

The technique of Latarjet remained faithful to its initial description in France and was particularly popularised by Patte *et al*[33] and then Walch *et al*.[34] This technique has since been shown to be reliable in the treatment of anterior shoulder instabilities with numerous series presenting good or excellent results.[35] The biomechanical basis for its effectiveness, even if it remains controversial, is based on the concept of the 'triple locking' effect. The coracoid graft restores the anatomy of the glenoid. The coraco biceps creates a hammock effect with the lower portion of the subscapularis tendon, and the repair of the capsule achieves an additional Bankart effect. The hammock effect is likely predominant in the stabilisation mechanism.[36]

Since its description, various technical modifications have been proposed to improve its effectiveness or to facilitate the surgical technique. Although the initial technique proposed a vertical incision of the subscapularis to be plicated at the end of the intervention, a horizontal incision to preserve the integrity and the function of the subscapularis muscle is preferred. The fibres are separated longitudinally, usually between the proximal two-thirds and the distal third. There is some consensus on removing a sufficiently large portion of the distal part of the coracoid process with an osteotomy made at the 'knee' level of the process.

The position of the graft on the glenoid has been discussed. Still, the majority of surgeons agree to recommend a fixation between 4 and 5 O'clock while being perfectly aligned with the

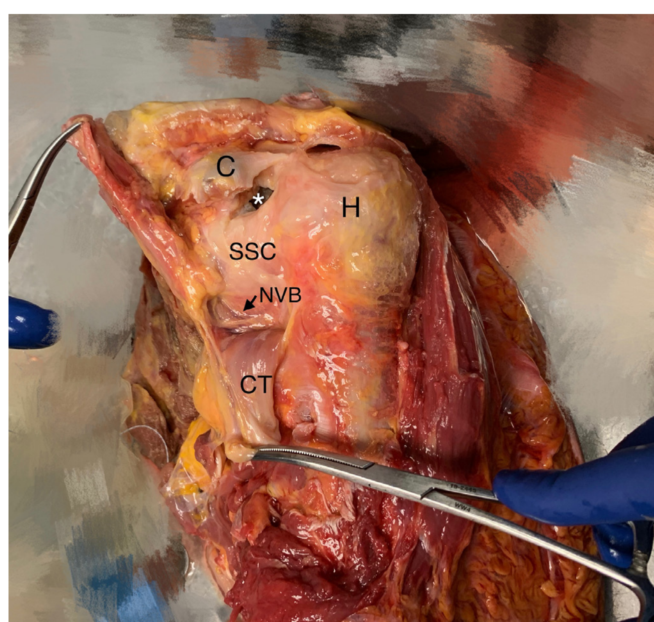

Figure 4 Anatomical dissection of the Halifax portal (white asterisk) that is far away from the NVB and the SSC. C, coracoid; CT, conjoint tendon; H, humeral head; NVB, neurovascular bundle; SSC, subscapularis.

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anterior glenoid edge and, above all, to avoid being too lateral.[37] A position below 5 o'clock causes a risk of recurrence with dislocation of the humeral head above the graft. The orientation of the coracoid process can be flat in most common cases, allowing extensive bone contact to promote consolidation. Some surgeons proposed in the past a standing position. More recently, it has been recommended to place the graft on the side according to the congruent arc technique to improve the restoration of the glenoid surface since the curve of the rotated coracoid fits well with the curve of the glenoid remnant.[38]

The fixation, initially one screw proposed by Latarjet, is now carried out more often by two screws, possibly cannulated or more recently by an endobutton, and some have recommended mini plates to improve the fixation. The use of two screws is now widely accepted, although it has not been proven that they cause less non-union than a single compression screw or endobutton. On the other hand, they involve, especially if the diameter is large, an additional risk of fracture of the coracoid process. Conversely, a too-small diameter poses a risk of displacement of the graft.[39]

The capsulotomy is conventionally performed vertically, but others propose a horizontal capsulotomy to improve the adjustment of tension during the capsular repair. Finally, it is accepted as an essential point that this capsular repair must be carried out in external rotation of the humerus to avoid a limitation of external rotation. Some older series have likely shown mobility restrictions due to the failure of this capsular repair technique. At the same time, the fact that capsular repair could improve the results of the Latarjet on stability remains to be discussed.[40]

The outcomes after the Latarjet procedure are very good or even excellent, with reported recurrence rates around 2%.[35 41] Rehabilitation can be immediate and rapid due to the solid bone fixation and capsular repair in external rotation. The rate of return to sport is also excellent and can be achieved after 3 or 4 months, depending on the type of sport. Comparative Latarjet versus Bankart studies show a clear advantage for Latarjet, especially if there is a bone deficit.[42]

However, the surgical technique can be challenging and requires a learning curve. Some series have reported a rate of complications up to 30%, including minor and major complications.[43] There is an intraoperative neurological risk, particularly for the musculocutaneous nerve, since the point of entry into the coracobrachialis muscle is located between 5.0 and 5.5 cm from the tip of the coracoid. This potential risk has motivated monitoring studies of neurological activity during the surgical procedure.[44]

The screws may bend. They can also rupture, and this usually occurs when there is a non-union of the coracoid.[43] Finally, osteolysis is a well-known complication, especially on the proximal portion of the graft, probably less stressed mechanically than its distal portion.[45] It does not necessarily compromise the result on the stability of the shoulder. A voluminous coracoid process or excessively large hardware can cause irritation or even damage to the subscapularis tendon, as well as humeral head cartilage in case of prominent lateral material.

The limitation of external rotation has been considered a matter of concern after the Latarjet procedure. It currently seems certain that the Latarjet, performed according to the recent technical recommendations, has demonstrated better respect of external rotation than soft tissue techniques.[46]

As with Bankart, the risk of long-term osteoarthritis is difficult to assess because recurrent shoulder dislocations also develop cartilage lesions. However, it has been shown that too lateral placement of the coracoid graft leads to an increased risk of degenerative lesion.[35] Conversely, the overly medial positioning of the coracoid process increases the risk of recurrent instability.

The Latarjet procedure can be proposed in recurrent anterior dislocations or subluxations, particularly if there is a bone deficit, glenoid or humeral, with or without constitutional hyperlaxity. This technique can entirely compensate a deficiency of 20%–25% of the anterior edge of the glenoid. The bone effect of this surgery makes it possible to widen the glenoid surface and prevent a Hill-Sachs lesion from engaging on the anterior glenoid edge in abduction, external rotation. The conjoint tendon makes a sling effect with the inferior part of the subscapularis tendon. It is also possible that the hammock effect prevents excessive anterior translation of the humeral head. It can be performed for revision after the failure of soft tissue surgery. However, this surgery is not anatomical, and it is more invasive than Bankart surgery.

The fact remains that more than 60 years after the initial description by Latarjet, this surgical procedure, which has generally retained the same initial concept, is an excellent technique in the therapeutic arsenal of any shoulder surgeon. Perfectly indicated when there is a bone deficit, either unipolar or bipolar, it has also shown its effectiveness in contact athletes, even in the absence of significant bone lesions, as they have an increased risk of recurrence after simple Bankart.

Arthroscopic Latarjet

Arthroscopic treatment of anterior shoulder instability allows multiple options that can specifically address the different anatomical underlying lesions. Among these, the Latarjet procedure is regarded as an excellent procedure to treat anterior shoulder instability in patients with glenoid bone loss. Based on the positive experience of arthroscopic treatment of shoulder instability, first, Lafosse and Boyle[47] and, later, Boileau *et al*[48] proposed arthroscopic Latarjet, combining the excellent results reported with the open approach with the advantages of arthroscopy, and developed specific tools and implants to perform the arthroscopic anatomical glenoid reconstruction. Although not widely used by the orthopaedic community, the reports on the technique since it was published more than a decade ago provide evidence of the efficiency, safety, surgeon's comfort and cost of arthroscopic Latarjet.[47 49]

In addition to the usual benefits of arthroscopic treatment, such as lower morbidity and faster recovery than open surgery, arthroscopic surgery in coracoid transfer procedures provides other theoretical advantages, including the possibility of achieving a more precise positioning of the graft, as well as the identification and treatment of concomitant pathologies (figure 3). Clinical results in terms of shoulder stability and clinical outcomes have been as satisfactory as those of open Latarjet.[50] However, comparative studies have failed to find a higher precision in coracoid graft nor in fixation device positioning compared with open surgery, with a higher tendency to position the coracoid more laterally with arthroscopic technique.[51] Randelli *et al* published a systematic review of the reported results of both open and arthroscopic Latarjet and concluded that the healing rate was superior and the cost was lower with the open procedure. Despite this finding, there were no differences in the reported incidence of other complications, and the recurrence rate after the arthroscopic technique was lower.[52]

The general interest shown by orthopaedic surgeons on arthroscopic Latarjet for anterior shoulder instability is clear. Yet, the use of the procedure has not expanded among the orthopaedic community, notwithstanding its theoretical advantages over open surgery. The main reason for not performing the procedure likely relies on the fact that it constitutes a highly demanding procedure indicated in a limited number of patients with anterior shoulder instability. In this sense, several studies have analysed the learning curve of the arthroscopic Latarjet technique and confirmed that it follows the same pattern as other arthroscopic procedures.[53] However, a large volume of cases is recommended to accomplish the procedure in a reasonable time.[54]

Free bone block procedures for anterior instability

Despite the excellent results obtained by the technique of Latarjet in shoulder instability, North American surgeons are slower to implement the method in their practices due to the higher complication rates associated with open surgery to perform a subscapularis split and transferred coracoid graft.[55 56] Additionally, revising a failed open Latarjet remains a challenge due to the change in native shoulder anatomy by rerouting the conjoint tendon.[57] Compared with open Latarjet, the arthroscopic Latarjet techniques have been developed to allow surgeons to treat concomitant pathologies that would otherwise be missed and be a more similar treatment to the arthroscopic Bankart repair.[47] However, it has a long learning curve[58] and related concerns regarding high complication rates, risks to neurovascular structures while splitting the subscapularis[59] and the potential difficulty of performing a revision surgery.[60]

Bony augmentation has evolved rapidly in the last few decades and is well accepted as a salvage procedure for failed Latarjet.[60] Eden in Germany and Hybinette in France pointed out for the first time the importance of bony lesions in the pathoanatomy of anterior shoulder instability and proposed anterior glenoid bone block technique using autologous iliac crest bone graft.[61] Based on this idea, Provencher *et al*[62] described an open technique of glenoid reconstruction using fresh distal tibial allograft in patients with a minimum of 15% glenoid bone loss that ensured appropriate graft sizing, thereby overcoming the limitations inherent to using a coracoid autograft. Since the technique does not require retouring of the subscapularis, it has been named anatomical glenoid reconstruction. A subsequent study[63] showed that the anatomical glenoid reconstruction technique using fresh distal tibial allograft has excellent clinical outcomes and minimal graft resorption at an average follow-up of 45 months. However, the inherent disadvantages of an open technique, including the potential difficulty of revising a failed open surgery, remain a concern.

To avoid open surgery and to decrease severe neurovascular complications, arthroscopic anatomical glenoid reconstruction using a free bone block was developed. While Taverna *et al*[64] and Kraus *et al*[65] in Europe described the technique using iliac crest bone graft, Wong and Urquhart in America used the advantages of distal tibial allograft.[66] The technique of arthroscopic anatomical glenoid reconstruction described by Wong and Urquhart uses a novel far medial portal, also known as the Halifax portal, with an inside-out technique to allow for safe passage of the bone graft and for screws to be placed parallel to the glenoid and perpendicular to the glenoid defect.[66] To create the Halifax portal, a switching stick is placed from the posterior cannula, parallel to the glenoid, superior to the subscapularis and lateral to the conjoint tendon before advancing the switching stick through the deltopectoral muscle fibres and to the skin. This uses the same superficial and deep intervals of the deltopectoral approach to the glenohumeral joint except, instead of detaching or splitting the subscapularis, the subscapularis is retracted inferiorly to expose the anterior rim of glenoid. This technique uses the Halifax portal for graft insertion and fixation, which minimises the risk of neurovascular complications by avoiding a subscapularis split.[66] The safety of the Halifax portal for arthroscopic anatomical glenoid reconstruction has been demonstrated in a cadaveric study showing minimal risk to neurovascular structures by keeping the conjoin tendon and subscapularis intact during the procedure[67] (figure 4). The learning curve of arthroscopic anatomical glenoid reconstruction using the Halifax portal has also been studied and has been found to be shorter compared with the arthroscopic Latarjet.[68] The safety profile and short-term radiographical outcomes of the arthroscopic anatomical glenoid reconstruction also showed excellent clinical and radiographical outcomes without any complications, neurovascular injuries and adverse events.[69]

Arthroscopic anatomical glenoid reconstruction has recurrence rates comparable to the Latarjet while minimising complications.[70 71] In a retrospective study performed by Wong *et al*, the radiographical and clinical results of the arthroscopic anatomical glenoid reconstruction and Latarjet groups were comparable at the minimum 2-year follow-up. Specifically, arthroscopic anatomical glenoid reconstruction using distal tibial allograft had a similar bony union but higher resorption than Latarjet; however, there was no statistically significant difference in the final graft surface area, the size of grafts and the anteroposterior

Box 1 Key articles on glenoid augmentation options for shoulder instability

1. Yamamoto *et al*[10] described for the first time the glenoid track concept showing the dynamic interaction between the humeral head and glenoid defects in anterior shoulder instability.
2. This concept was further evolved into the on-track/off-track concept for clinical use by Di Giacomo *et al.*[11]
3. Latarjet[30] proposed transferring the coracoid process to the anteroinferior glenoid neck for the treatment of anterior shoulder instability.
4. Allain *et al*[35] reported excellent results at long-term follow-up of the Latarjet procedure for anterior shoulder instability.
5. Longo *et al*[42] performed a systematic review of glenoid augmentation techniques for anterior shoulder instability, demonstrating that they are associated with a lower rate of recurrence when compared with the Bankart repair. Still, the Eden-Hybinette has a higher percentage of postoperative osteoarthritis and recurrence than Latarjet.
6. Lafosse and Boyle[47] described for the first time the technique of all arthroscopic Latarjet and reported satisfactory results in a preliminary series of patients.
7. Eden and Hybinette[61] underlined the importance of bony lesions in the pathoanatomy of anterior shoulder instability. They proposed an anterior glenoid bone block technique using iliac crest graft to restore the anatomy of the glenoid.
8. Taverna *et al*[64] and Scheibel *et al*[65] described in Europe the technique of arthroscopic anatomical glenoid reconstruction using iliac crest bone graft.
9. Wong and Urquhart[66] published in North America the technique of arthroscopic anatomical glenoid reconstruction using a frozen distal tibial allograft.
10. Lafosse *et al*[82] described the technique of arthroscopic posterior bone block using iliac tricortical bone graft fixed with two screws.

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Box 2 Validated outcome measures and classifications

- Rowe score.[95]
- Western Ontario Shoulder Instability Index.[96]
- Oxford Shoulder Instability Score.[97]
- Melbourne Instability Shoulder Scale.[98]
- Simple Shoulder Test.[99]
- Shoulder Rating Questionnaire.[100]
- Subjective Shoulder Value.[101]
- Single Assessment Numeric Evaluation.[102]
- American Shoulder and Elbow Surgeons score.[103]

dimensions of the reconstructed glenoids between the two groups. Besides, there was no significant difference in terms of recurrence rate and subluxations between the two groups at a minimum follow-up of 2 years.[70] The arthroscopic anatomical glenoid reconstruction group had a decreased step deformity than the Latarjet group, which could lead to a slower progression of osteoarthritis. These short-term findings suggest that arthroscopic anatomical glenoid reconstruction using distal tibial allograft may be used as an alternative to Latarjet.

Furthermore, this concept is strengthened by the findings of a recent randomised controlled trial.[72] This level 1 study showed that the clinical outcomes of the bone reconstruction procedures are similar to those of the Latarjet for recurrence. The sling effect of the conjoint tendon in Latarjet is not necessary when a bony reconstruction is performed in patients with glenoid bone loss.[72]

Glenoid bone augmentation for posterior shoulder instability

Posterior shoulder instability constitutes about 4%–10% of the shoulder instability cases. This incidence can increase by up to 24% of the military population. Athletes performing collision sports with the arm in forward flexion and internal rotation are at risk of developing posterior instability. Also, posterior instability is a relatively common finding in patients where their glenoid dysplasia predisposes to the problem.[73–77]

A well-designed rehabilitation programme for muscle strengthening, improving proprioception, and sometimes sport swing modification is the mainstay of treatment for patients who suffer from posterior instability. After the failure of the conservative treatment, surgical repair or reconstructions are indicated. Since severe bone abnormalities are less common in posterior instability, arthroscopic extensive posterior and inferior labrum repair with suture anchors and capsular plication is the usual treatment of choice for patients without critical bone loss or severe glenoid dysplasia. Satisfactory outcomes have been reported with this technique, even in revision cases.[78]

When present, the bone deficiency in posterior instability may be located at the humerus as an impression fracture (reverse Hill-Sachs) or at the glenoid side. The humeral impaction fracture can be treated with bone grafting or the Mc Laughlin subscapularis transfer.[79] Glenoid bone loss is a well-accepted risk factor for failure after arthroscopic stabilisation of anterior glenohumeral instability, but there are few reports of its influence on posterior instability soft tissue repairs. The posterior glenoid bone loss is addressed with posterior bone block grafting. This technique is mainly indicated in cases of posterior bony Bankart lesions, attritional posterior glenoid erosion or dysplasia. Based on the reported relatively high recurrence rate of soft tissue repairs, some surgeons add a posterior bone block despite the absence of bone deficiency or dysplasia. The rationale of the bone graft

Box 3 Key Issues of patient selection

- CT scan or MRI 3D reconstructions allow an accurate determination of glenoid and humeral bone loss.
- The glenoid track concept combines the dynamic impact during the arc of motion of glenoid and humeral bone defects. The concept of the grey zone of the 'peripheral track' has been added to the previously described on-and-off track Hill-Sachs humeral bone loss.
- The tripolar challenge of patient selection for glenoid bone augmentation procedures is glenoid and humeral bone loss, soft tissue quality and contact sport.
- The glenoid 'critical bone loss' where bone augmentations are deemed indicated is 20%. The cases where between 13.5% and 20% of glenoid bone is missed are defined as 'subcritical bone loss', where the sports activity level plays a role in decision making.
- For posterior shoulder instability, a bone loss of more than 20% of the glenoid face or glenoid dysplasia and retroversion of more than 10° are essential factors to add a bone augmentation. In cases with more than 15° of retroversion, an open wedge osteotomy may be needed.

in these circumstances, where the real problems are capsular laxity and poor soft tissue quality, is to extend the glenoid track for stability and not an anatomical repair.[80 81] In the setting of posterior bone loss or glenoid retroversion, posterior bone block augmentation is required. The most popular graft choices are iliac crest bone graft, distal tibial allograft and scapular spine autograft. Bone graft using tricortical iliac crest autograft around 2.5 cm long × 1 cm wide × 1 cm thick is the preferred option in the literature.[70] The iliac crest bone graft has the advantages of excellent bone quality for healing but the downside of local harvest morbidity. This drawback is not a concern with the distal tibial allograft or the scapular spine autograft. Nacca *et al* reported good augmentation effect in cadaveric models with distal tibial allograft and scapular spine autograft, and this is the reason why many surgeons preferred these graft options.[22]

The surgical procedure can be performed through a classic open posterior approach or arthroscopically assisted. The classic posterior open glenoid bone graft augmentation is performed through a posterior transdeltoid approach. With the patient in lateral decubitus, the deltoid is divided from the acromion spine in line with the muscle fibres between the posterior and medial thirds. The rotator cuff is split between the infraspinatus and teres minor insertion sites. After a glenoid based T-shape capsulotomy, the bone block is positioned at the cartilage level; therefore, the graft extends the glenoid surface. The labrum is repaired at the anatomical position, leaving the graft extra-articular. Posterior–inferior capsular plication is performed, depending on the status of capsular laxity.

Potential advantages of the arthroscopic technique are as follows: (1) it allows addressng other complementary intra-articular pathology such as SLAP; (2) it warrants a better capsule–labrum final reconstruction; (3) it has better cosmetic results; and (4) it prevents partial deltoid muscle insufficiency, which can be seen after open access. With the patient positioned in lateral decubitus or beach chair position, the scope is located at the anterior–superior portal. The labrum and capsule are preserved with a

Box 4 Essential and/or typical features of the open or arthroscopic Latarjet, the anterior arthroscopic bone block, and open or arthroscopic posterior bone augmentation

Open or arthroscopic Latarjet
- Harvest a large coracoid graft with a right-angle saw or burr.
- Split the inferior third of the subscapularis with the tip of a scissor from the muscle belly to lateral.
- Fully decorticate the lower or medial face of the coracoid graft and the anterior glenoid neck.
- Place the graft between 3 and 5 o'clock position at or 2 mm medial to the glenoid edge.
- Use two canulated screws or endobuttons for stable fixation.
- Repair the capsule with the arm in external rotation.

Anterior arthroscopic bone block
- Place the anterior Halifax portal with an 'inside-out' technique parallel to the glenoid face, proximal to the subscapularis and lateral to the conjoined tendon.
- Double-barreled cannulas for steady control of the graft (iliac crest or distal tibial allograft).
- Deliver the graft through the rotator interval over the subscapularis in internal rotation to relax the tendon and to make the lower location of the graft easier.

Open or arthroscopic posterior bone augmentation
- Deliver the posterior bone block splitting the infraspinatus and the teres minor.
- Inside-out portals with a trocar parallel to the glenoid face help to fix the graft at the right location.
- Repair the capsule and labrum to keep the graft extra-articular.

Box 5 Tips and tricks
- Neurovascular: musculocutaneous, axillary and suprascapular nerves are the surrounding structures at risk.
- Graft non-union with bent or broken screws.
- Osteolysis or reabsorption of the proximal part of the grafts with prominent hardware.
- Decreased range of motion.
- Long-term degenerative changes and osteoarthritis.

vertical capsulotomy. Two traction cinches are used to hold them during the posterior glenoid neck debridement. A 3 cm posterior skin incision at the level of the glenoid equator is performed. Special pins and double-barreled cannulas are used to have steady control of the graft. The graft is delivered through a split between the infraspinatus and teres minor muscles. After ensuring its right position with an anterior insertion of switching stick across the joint plane, the graft is fixed to the glenoid with two cannulated screws.[82] The bone block can be also be secured with two suture anchors with mattress double pulley technique or adjustable buttons.[83] Arthroscopic labrum repair and capsular plication with two or three suture anchors is an essential final step of the procedure and keeps the posterior bone block extra-articular.[27 83]

To date, only a few studies in the literature accurately establish which bone defects should be treated with bony augmentation procedures and the exact correlation between the percentage of bone loss and risk of dislocation in clinical circumstances.[29] Both Mauro *et al*[84] and Galvin *et al*[85] reported that even though the patients with posterior instability usually have an increased glenoid retroversion, this issue has no influence in the surgical outcome of a soft tissue repair. On the other hand, bone loss and a narrow glenoid width have a significant impact on increasing the failure rates of posterior labrum repairs. According to Hines *et al*, the average bone loss in patients with posterior instability is 7.3% (range 0%–21.5%). He reported one-third of the patients did not present any bone loss. Another third suffered a mild bone deficit of less than 13.5%. Twenty-eight per cent of the patients showed a bone loss between 13.5% (defined as 'subcritical bone loss') and 20%. Even though these findings did not influence the clinical outcomes, they had a significant impact on the return to sports and full military duty.[77] Struck *et al* reported in a small group of patients (n=15) a comparison between short and long follow-up and concluded that the posterior bone block has reliable results even in the long run.[81] Servien *et al* reviewed 21 patients treated with posterior bone block for posterior instability. Twelve shoulders had glenoid fractures or posterior glenoid erosion. The average retroversion was 9.6° (range 1°−21°). Ten patients presented reverse Hill-Sachs anterior humeral lesions. With an average follow-up of 6 years, they reported a recurrence of instability rate of 14%. With regard to the postoperative X-rays, 16 were normal; 4 showed osteoarthritis (19%); and 1 had bone graft lysis.[25] Barbier *et al* reported eight entirely traumatic posterior instability cases who underwent posterior deltoid detachment and posterior bone block. All patients had a healed bone block in proper position and considered themselves cured. The competition players return to their previous sport to a lower level, but the occasional leisure ones did not. Five patients out of the eight still referred pain at the latest follow-up.[75]

Clavert *et al* published the clinical and radiological outcomes of a multicentre study of 66 patients (mean follow-up of 3.7 years) with posterior instability treated with open or arthroscopic posterior bone block. In 86% of the cases, iliac crest and 14% of the acromion spine were used as autograft. Reverse Bankart lesion was found in 59% of the patients and reversed Hill-Sachs in 3%. The pain and functional scores improved significantly after the procedure. Eighty-five per cent of the patients were satisfied or very satisfied with the results. With regard to radiological findings, 35% of the patients had an intact graft; 31% had partial lysis; and 33% had significant lysis of the posterior bone block. There was no significant clinical effect of the radiological bone block resorption. Failures, defined as real dislocations, instability episodes or subluxations, reached 12%.[86]

Cerciello *et al* performed a systematic review of 13 papers, including 182 patients with 73 months follow-up. He concluded that bone grafting is a reliable option for posterior instability with low recurrence rates, but these outcomes deteriorate with time. Moreover, bone graft lysis and glenohumeral osteoarthritis were present in at least one-third of the patients.[87]

More recently, some authors described encouraging outcomes with arthroscopic techniques.[88 89] Lafosse *et al* described the arthroscopic procedure with the same instruments of the Latarjet.[82 90] Smith *et al* also reported good early results of the arthroscopic technique fixing the graft with two screws. Twenty-four patients with a mean follow-up

Box 6 Major pitfalls and complications of glenoid bone augmentations

- There are more glenoid bone defects in shoulder instability than believed.
- Addressing bone defects is a key to avoid recurrence after shoulder stabilisation surgeries.
- Bone defects in anterior shoulder instability should not be considered as humeral or glenoid sided independent problems but as the two sides of the same bipolar lesion.
- It is widely accepted that patients with >20% glenoid bone loss should be treated with glenoid augmentation techniques.
- Patients with between 13.5% and 20% glenoid bone loss are suggested to be treated with anatomical glenoid reconstruction procedures in the future due to the reported unsatisfactory functional scores that resulted from soft tissue procedures.
- Latarjet is still considered as the gold standard procedure for anterior glenoid reconstruction due to excellent long-term results.
- Despite the excellent results, the acceptance of Latarjet outside Europe is slow due to its non-anatomical nature, long learning curve, high complication rates and the potential difficulty of performing a revision surgery.
- New arthroscopic and less invasive glenoid reconstruction procedures using bone grafts have been developed in the last two decades and have shown a short learning curve, excellent clinical and radiographical outcomes, including good graft union, low recurrence rate and low complications.
- Both Latarjet and free bone block procedures have been described to be carried out arthroscopically and allow to treat either anterior or posterior glenoid bone defects.
- Based on the advantages and excellent outcomes, it is expected that anatomical glenoid reconstruction will gain more popularity in the future.

of 26 months had a significant clinical improvement of the Rowe and WOSI scores with a 12.5% recurrence rate.[91] With a quite long mean follow-up of 18 years (range 13–23 years), Meuffels *et al* found osteoarthritis in all his patients (n=11), but 36% of them had shown degenerative changes preoperatively.[92]

Overall, the results of glenoid bone augmentation to treat posterior instability are good, with a relatively low recurrence rate and a significant improvement in the outcome scores.[93] However, reviewing the literature, we found that it seems these results deteriorate in the long term, and degenerative changes are a shared concern.[94] When a bony augmentation procedure is considered, patients should be extensively counselled regarding high rates of degenerative joint disease.

Because of significant heterogeneity in the clinical outcomes reported to date, further research will be necessary to define the long-term clinical results of posterior bone augmentation in the setting of posterior instability with glenoid bone loss or retroversion.

FUTURE PERSPECTIVES AND GEOGRAPHICAL VARIATIONS

Recent studies have shown that the prevalence of glenoid bone defects in shoulder instability is higher than believed.[7] The importance of addressing bone defects to prevent recurrences after surgical stabilisation has been made clear.[1] Nowadays, it is considered that bone defects in anterior shoulder instability should not be regarded as humeral or glenoid sided independent problems, but as the two sides of the same bipolar lesion that interact in the instability process as described by the glenoid track concept.[2 8–11 13–15] Concerning the size of the glenoid bone defect to be addressed, it has been considered traditionally that those involving more than 20% of the articular surface should be treated with glenoid augmentation techniques.[7] However, patients with subcritical glenoid bone loss sizing 13.5%–20% of the glenoid surface achieve significantly lower functional scores when treated with soft tissue procedures, leading to the conclusion that anatomical glenoid reconstruction procedures should be considered as a treatment option more often for anterior shoulder instability in the future.[1 7 8] Latarjet is still considered the gold standard procedure to reconstruct anterior glenoid defects according to the excellent long-term results reported.[35] Despite these advantages, the acceptance of the Latarjet technique outside Europe is slow since it is regarded as a non-anatomical repair with a long learning curve[58–60] and because it also raises concerns regarding potential complications.[59] Due to these theoretical drawbacks, anatomical glenoid reconstruction using free bone grafts have been suggested with satisfactory clinical results.[65] New arthroscopic and less invasive techniques of glenoid reconstruction using bone procedures have been developed in the last two decades, furnishing the possibility of achieving a more precise positioning of the graft and the identification and treatment of concomitant pathologies, in addition to less morbidity and faster recovery.[27 47 48 64–66 69 82] Both techniques—Latarjet and free bone block procedures—have been described to be carried out arthroscopically and allow to reconstruct either anterior and posterior glenoid bone defects. Arthroscopic glenoid reconstruction techniques have been shown to have a similar safety profile and better outcome in the treatment of glenoid bone loss compared with arthroscopic Bankart.[47 49 69 70] They also follow a short learning curve and show excellent short-term clinical and radiographical outcomes, including good graft union, minimal resorption and lowered recurrence rate, while minimising complications.[68 70 71] As a consequence of their advantages and proven satisfactory results, an increase in the application of arthroscopy for glenoid reconstruction is expected.

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