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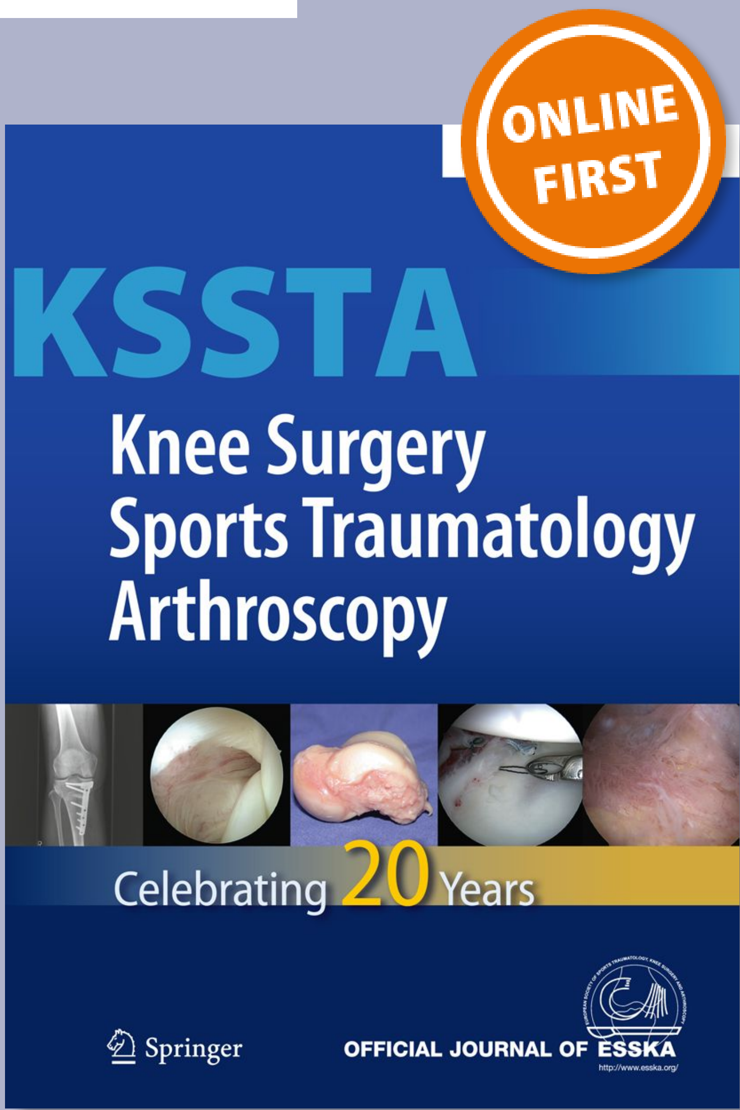

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SHOULDER

Arthroscopic management of anterior shoulder instability with glenoid bone defects

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Abstract Bony deficiency of the anterior glenoid rim may significantly contribute to recurrent shoulder instability. Today, based on clinical and biomechanical data, a bony reconstruction is recommended in patients with bone loss of greater than 20–25 % of the glenoid surface area. Recent advances in arthroscopic instruments and techniques presently allow minimally invasive and arthroscopic reconstruction of glenoid bone defects and osteosynthesis of glenoid fractures. This article underlines the role of glenoid bone deficiency in recurrent shoulder instability, provides an update on the current management regarding this pathology and highlights the modern techniques for surgical treatment. Therefore, it can help orthopaedic surgeons in the treatment and decision-making when dealing with these difficult to treat patients in daily clinical practice.
Level of evidence V.

Keywords Shoulder instability · Anterior glenoid rim fracture · Bony Bankart lesion · Arthroscopic Latarjet procedure · Arthroscopic glenoid bone grafting · Bony Bankart Bridge technique

Introduction

The incidence of anterior glenoid rim fractures, so-called bony Bankart lesions after shoulder dislocations ranges from 4 to 70 % in the literature with a higher prevalence in males [43]. It has been shown that bony deficiency of the anterior glenoid rim does significantly contribute to recurrent instability [7] and has higher failure rates after arthroscopic soft tissue repairs [10]. Glenoid fractures [5] in acute shoulder dislocations and attritional bone loss in more chronic cases are the primary aetiologies. The region of bone loss is typically between 2:30 and 4:20 on the clock

Frank Martetschläger and Tobias M Kraus contributed equally to this work.

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face of a right shoulder [44]. Because of unsatisfactory clinical outcomes after soft tissue repairs [10], and biomechanical evidence supporting bony reconstruction [23, 55], bone grafting is recommended for at risk patients with bone loss of greater than 20–25 % of the glenoid surface area. These procedures have typically been performed through a deltopectoral approach, using either a free bone graft for reconstruction, such as the iliac crest, [3, 52] or a local bone graft by harvesting and transferring the coracoid process [4, 19, 20, 31, 57].

Although technically challenging, recent advances in arthroscopic instruments and techniques presently allow arthroscopic reconstruction of glenoid bone defects [25, 35, 37, 42] and osteosynthesis of glenoid fractures [5]. The purpose of this article is to provide an update on the management of anterior glenoid bone defects and to show the latest treatment options for treating glenoid bone defects in patients with shoulder instability.

Classification

Glenoid bone defects come in various forms. In 1998, these injuries were classified by Bigliani et al. [7] into 3 types. Type I represents an avulsion fracture with attached capsule, type II is a medially displaced fragment malunited to the glenoid rim and type III is an erosion of the glenoid. Type III lesions are further subdivided into type IIIA lesions with less than 25 % deficiency of the glenoid diameter and type IIIB with more than 25 % deficiency (Fig. 1).

Biomechanical background

In a cadaveric study published in 2000, Itoi et al. [23] found osseous defects with a width of at least 21 % of the glenoid length lead to significant decreases in shoulder stability. These findings are supported by another cadaveric study that also found a significant decrease of anterior stability when there was an anterior osseous defect that was equal to or greater than 20 % of the glenoid length [55]. In 2002, Gerber and Nyffeler [17] reported on a relationship between the defect size and the overall size of the glenoid. They came up with a ratio and showed that when the length of the glenoid bone deficiency, as measured in the sagittal plane, was greater than the radius of the glenoid, resistance to dislocation was reduced by 30 % as compared to the intact state. Furthermore, Greis et al. [18] found that bone defects increase contact stresses, which may predispose to premature arthritis. They found that bone loss of 20 % of the diameter of the glenoid approximately doubled the mean contact pressure in the anterior-inferior quadrant and increased peak pressures by 50–100 %.

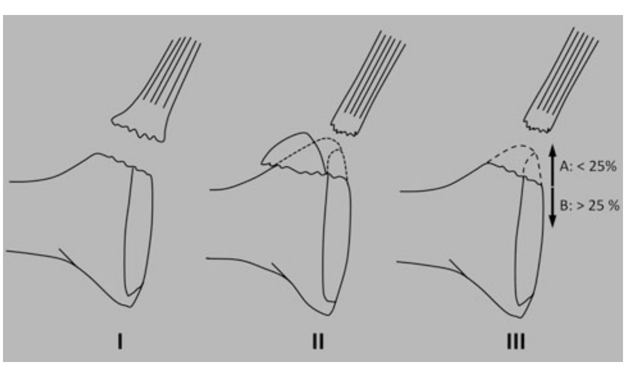

Fig. 1 Classification of bony Bankart lesions according to Bigliani et al. [7]. *I* avulsion fracture with attached capsule, *II* medially displaced fragment malunited to the glenoid rim, *III* erosion of the glenoid with less (*A*) or more (*B*) than 25 % deficiency of the glenoid diameter

Since the convex humeral head and the concave glenoid and labrum are basic necessities for concavity compression [30], clinically relevant glenoid or humeral (Hill-Sachs lesion) bone loss can disturb this biomechanical relationship and therefore contribute to shoulder instability. Yamamoto et al. [56] recently attempted to quantify the impact of humeral-sided bone loss and how this affects combined lesions of both the humerus and the glenoid. The critical size of a Hill-Sachs lesion was quantified and they found that Hill-Sachs lesions that extend medially into the glenoid track had a higher risk of engagement or dislocation.

However, there remains a paucity of biomechanical data to specifically determine the contributions of the glenoid and humeral bone loss in combined lesions.

Evaluation

Clinical evaluation

A thorough history and physical examination are mandatory to establish a diagnosis of glenohumeral instability. The number of prior dislocations, activities that cause apprehension or dislocation, any previous trauma and prior surgical interventions are basic questions during anamnesis of instability patients. In athletic patients also, the type of sports performed—overhead, contact or high risk such as American Football or Rugby as well as the level of sports performed as competition or leisure—should be taken into consideration as proposed in the Instability Severity Index Score (ISIS). This score was developed by Balg and Boileau [4] in order to help during decision-making whether and open or arthroscopic stabilization technique should be used. Besides involvement in competitive (2 points) or contact sports (1 point), further risk factors for recurrent instability were defined: patient age under 20 years at the time of surgery (2 points), shoulder hyperlaxity (1 point), a Hill-Sachs lesion present on an anterior–posterior radiograph of the shoulder in external rotation (2 points) and loss of the sclerotic inferior glenoid contour (2 points). On the basis of this score, patients with over 6 points out of 10 have a high recurrence risk and the authors recommend a Bristow–Latarjet procedure.

The common clinical tests include anterior apprehension, relocation test, anterior release and anterior drawer tests, which can demonstrate anterior instability as compared to the contralateral shoulder. With the Gagey test and the Shoulder-Hyper-Abduction-Radiologic test (SHART), two further tools can be used to assess a concomitant ligamentous laxity of the inferior capsule [16, 24]. For the provocative tests, the examiner should assess the patient's sense of apprehension rather than pain to increase the reliability of the examination [14]. To assess multidirectional instability, the patient is tested for global ligamentous laxity and the sulcus sign is evaluated. A patient is to be estimated hyperlax with an external rotation of more than 85° in neutral position. The examination is performed in both the standing and supine positions to appreciate the degree of instability and to help the patient relax.

A thorough and bilateral clinical examination should be repeated preoperatively under anaesthesia to assess the amount of laxity and translation in addition to a possible crepitation suggesting bony lesions [34]. This examination under anaesthesia allows a more objective measure of stability, translation and how easily the humerus locks out over the glenoid rim [14]. Furthermore, it helps the experienced surgeon to estimate the amount of re-established stability during the surgical procedure.

Radiologic evaluation

A true anteroposterior view, internal and external rotation views, an axillary lateral view, a scapular Y view and an apical oblique view are obtained in all patients with clinical signs for instability [13]. The West Point view is useful to assess for glenoid bone loss, and a Stryker notch view is useful to look for associated Hill-Sachs lesion. With the Bernageau view, bone loss of the glenoid can be detected and accurately estimated [6, 39]. When bone loss is suspected, either computerized tomography (CT) or magnetic resonance imaging (MRI) should be considered to more accurately quantify bone loss. Three-dimensional (3D) reconstructions might be of utility to better comprehend complex defects. In a recent study, Chuang et al. [15] showed that a 3D CT scan is an excellent tool for preoperative planning and predicting the requirement of a bone grafting procedure. In 2011, Nofsinger et al. used 3D CT scans to confirm that the inferior portion of the glenoid contour could be approximated to a true circle with remarkably low variability (Fig. 2). However, Magarelli et al. [33] recently reported excellent agreement between 3D and 2D CT scans for measuring bone loss, thus they concluding that two measurements could be considered interchangeable. The main advantage of this 'circle' methodology is that scanning of the contralateral shoulder is no longer necessary to calculate the defect size.

Arthroscopic evaluation

Arthroscopic evaluation is mandatory to confirm the severity of the osseous defect noted on imaging studies. In acute cases, the osseous fragment is typically covered by the surrounding labral and ligamentous complex. The bone fragment in acute bony Bankart fractures is usually displaced with the labrum and the labrum remains attached to the fragment. Detachments of the superior labrum and capsular tears have been reported and should be excluded [47]. The diagnostic process is followed by an arthroscopic measurement of the glenoid bone loss. Burkhart et al. [12] described using the glenoid 'bare spot' as a reference for the geometric centre of the inferior glenoid. In a normal shoulder, the distance from the bare spot to the anterior and

Fig. 2 3D CT scan of a left shoulder showing anterior-inferior bone loss. The normal glenoid completely fills the circle. The anterior *red area* represents the amount of bone loss

posterior glenoid rim should be equal distance with the normal distance from the bare spot to the anterior and posterior rims being about 12 mm (diameter of the circle is approximately 24 mm). A probe can be used to measure the amount of missing bone both anteriorly and inferiorly and to estimate the percentage of glenoid bone loss (Fig. 3).

Since a large Hill-Sachs lesion can also contribute to recurrent instability, the posterosuperior aspect of the humeral head is examined under direct visualization. Dynamic evaluation can also be helpful. Engagement of the Hill-Sachs lesion at the glenoid rim with abduction and external rotation can portend an increased risk for recurrence and may lower the threshold for treatment, particularly when it is combined with a glenoid defect.

Surgical treatment

Indications and arthroscopic techniques

Currently, operative treatment is recommended in patients with symptomatic instability in the presence of glenoid bone loss [14]. Clinical [10] and biomechanical [18, 23, 55]

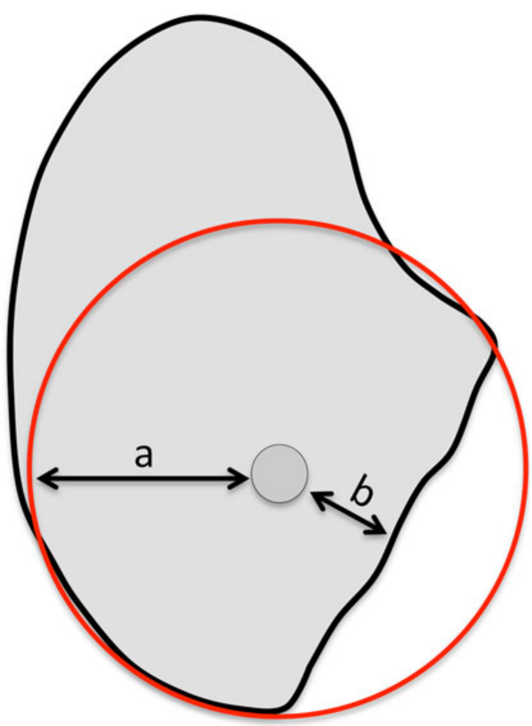

Fig. 3 Schematic drawing of the arthroscopic measurement of glenoid bone loss according to Burkhart et al. [12]. Since the inferior glenoid can be assumed a true circle, the distances from the bare spot (*inner gray circle*) to the anterior and posterior glenoid rim should be equal. The distances are measured with a calibrated probe. If *b* measures ½ of *a*, a 25 % bone loss is present

studies support reconstruction of the bony glenoid in cases with greater than 20–25 % bone deficiency of the inferior glenoid diameter. However, the patients' activity level, status of the humerus, and the number of recurrent dislocations should be carefully considered and can lower the threshold for bony reconstruction.

If there is bone loss of less than 20–25 %, an arthroscopic Bankart repair alone can usually be performed. In cases with a concurrent engaging Hill-Sachs lesion, the surgeon might want to add a remplissage procedure in order to augment stability [26]. An arthroscopic remplissage was first described by Wolf and Pollack [54] in 2004, using the infraspinatus tendon to fill the Hill-Sachs lesion. In a recent study, Boileau et al. [9] reported on 47 patients after arthroscopic Hill-Sachs remplissage in combination with a Bankart repair after a mean follow-up of 24 months. 98 % of the patients showed a stable shoulder, 90 % were able to return to sport and 68 % returned to the same level as preoperatively.

As mentioned above, the situation becomes more complicated in patients with greater than 20–25 % bone loss. For avulsion fractures with a single fragment present, bony reconstruction can be achieved by direct refixation of the fragment, using screws or anchors [25, 35, 43, 48, 58]. In the setting of a fragmented bony Bankart fracture, which is not reparable or in cases with attritional bone loss, the glenoid may require reconstruction using either arthroscopic or mini-open techniques such as the Bristow [5, 8], Latarjet [29, 57] or free bone graft techniques (allograft and autograft) [37, 45, 50]. The following section will highlight the current concepts for the reconstruction of the glenoid and highlight the details of the various techniques.

Arthroscopic suture anchor repair

Several different techniques have already been described for arthroscopic suture anchor repair of bony Bankart lesions. Porcellini et al. [42] reported on an arthroscopic reconstruction using a modified Bankart technique with single anchors leading one limb of the suture through the capsule and around the fragment. More recent techniques used a 2- or 3-point fixation of the fragment achieved by anchors placed medial and lateral to the fragment [25, 35, 58]. Millett et al. [35] described a suture anchor technique that compressed the bone back into its fracture site and called the technique the 'Bony Bankart Bridge'. A high anterosuperior and an accessory anterior-inferior portal are established, and a 70° arthroscope is used to visualize the neck of the glenoid, medial to the fracture. Instruments are placed through both anterior portals to mobilize the bony Bankart and the entire IGHL, which is typically attached to the fragment, as a sleeve of continuous tissue, inferiorly to the 6 o'clock position. Next, the fractured surface of the bony fragment is prepared by the use of shaver in order to enhance healing. An elevator is used to reduce the fracture piece, so that the first anchor can be placed medially to the fragment on the glenoid neck. In case of small fragments, only one medial anchor is necessary, which is placed in the midportion (sagittal plane) of the fracture. For larger fragments, two medial anchors are used. Both limbs of the suture are passed through the soft tissues, medial to the bony fragment, using a 45° curved shuttling device (SutureLasso, Arthrex, Naples FL), and shuttled out the anterior-inferior cannula. Next, a suture anchor is placed just inferior to the bony fracture piece on the glenoid rim. This anchor secures the labrum and IGHL complex, inferior to the fragment. The medial suture limb is passed through the IGHL complex, shifting the IGHL complex and labrum superiorly and medially tightening the axillary pouch. The size of the shift is controlled with a grasper through the anterosuperior portal. Large bony pieces may require two medial anchors. The two free limbs of the medial suture anchor are fed into a 3.5-mm knotless anchor (Bio-push lock Arthrex, Naples, FL) and the appropriate tension for fracture reduction as well as the optimal position for the lateral fixation anchor on the glenoid face is assessed. A drill hole is placed on the glenoid face at the cartilage-fracture margin followed by inserting the anchor into the drill hole while the sutures are tensioned. By doing so, the bony fragment is compressed back into its donor bed and an arthroscopic osteosynthesis is achieved. Security of the reconstruction is tested with a probe, and the free limbs are cut flush with the lateral anchor. In addition, the superior capsule, labrum and middle glenohumeral ligament are repaired superior to the bony repair if necessary. Depending on the size of the bony Bankart lesion, this procedure can be repeated several times. Figure 4 illustrates the procedure, and Fig. 5 shows an intraoperative example.

Arthroscopic bone graft repair

Mochizuki et al. [37] were described an all-arthroscopic bone grafting technique for anterior glenoid bone loss. They harvested two cylindrical bone grafts from the lateral site of the acromion and transplanted them into the Bankart lesion by the use of suture anchors. Scheibel et al. [45] described an arthroscopic iliac crest bone grafting procedure. For this technique, an anterior-inferior working portal through the rotator interval and an anterosuperior viewing portal behind the biceps tendon are used. Furthermore, a deep anterior-inferior portal is established through the inferior subscapularis (SSC). 8.25 mm translucent twist-in cannulas are inserted in the anterior-inferior

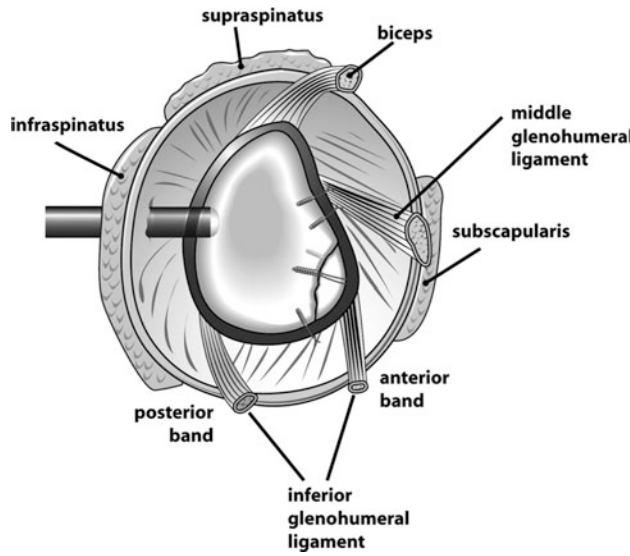

Fig. 4 Final Bony Bankart Bridge repair with reduced bony Bankart piece, repaired labrum, and shifted capsule and IGHL complex. (Reprinted from Arthroscopy, 25/1, Peter J Millett, Sepp Braun, The 'Bony Bankart Bridge' procedure: a new arthroscopic technique for reduction and internal fixation of a bony Bankart lesion, pp 102–105, Copyright (2009), with permission from Elsevier)

and deep anterior-inferior portal and a 6-mm cannula is utilized in the posterior portal. The bone graft is harvested from the iliac crest as described by Warner et al. [52] and shaped using an oscillating saw to restore the inferior glenoid morphology. Through the anterior-inferior portal, the capsulolabral complex is mobilized medially beyond the 6 o'clock position. Next, the bony surface is debrided with a burr or shaver until a bleeding bone bed is created on which to place the graft. After removing the cannula from the anterosuperior portal, the graft can be placed intra-articularly using a clamp for insertion. After correct positioning of the graft and examining the graft–joint line relationship by the use of a hooked probe or Wisinger rod, the graft is temporarily fixed with K-wires. Two K-wires are inserted in line through the anterior-inferior and the deep anterior-inferior portal. After a final control of the correct positioning, these K-wires are then overdrilled and two 2.7–3.7 mm cannulated bio-compression screws are inserted for final fixation of the graft. If necessary, the graft can be polished to match the native glenoid using a small burr. Two anchors, one placed superiorly and one inferiorly to the graft, are used to reattach the capsulo-ligamentous tissue, hence completing the repair (Fig. 5) (Fig. 6).

Taverna et al. [50] also described the arthroscopic bone grafting technique and evaluated feasibility and results in ten cadaveric shoulders. They reported on good results for the last 5 shoulders concluding that the learning curve did not appear to be steep.

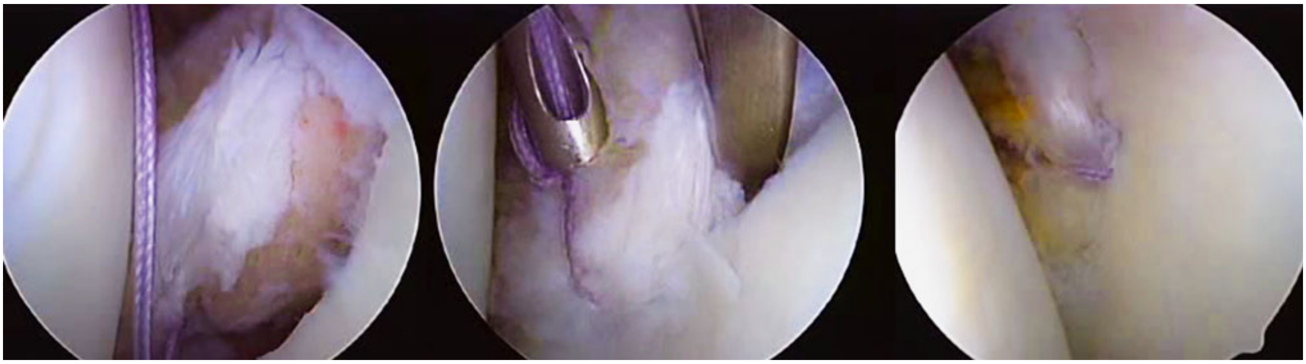

Fig. 5 Right shoulder viewing from posterior with 70° scope. *Left* debrided bony fragment. *Middle* the fragment is reduced by the use of a grasper and the sutures are tied. *Right* completed arthroscopic osteosynthesis using the 'Bony Bankart Bridge' technique

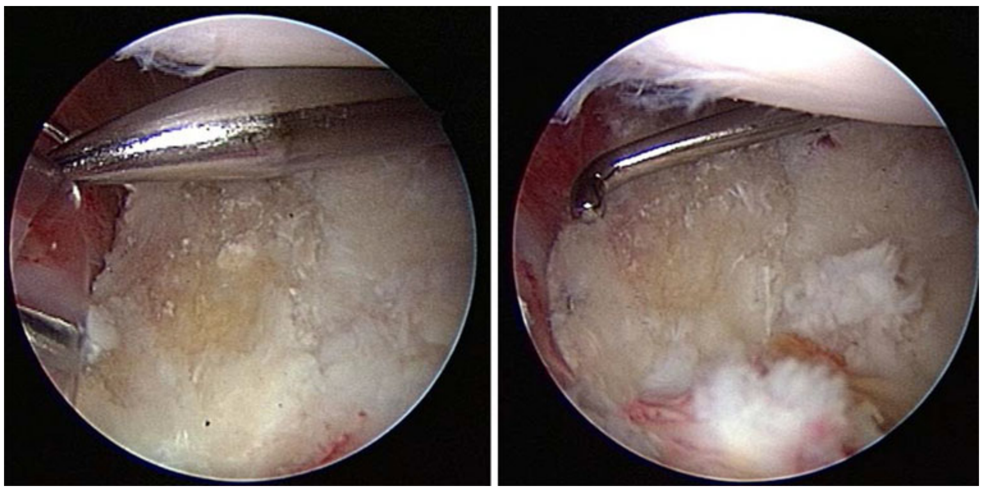

Fig. 6 Intraoperative view of a right shoulder through the anterosuperior portal showing arthroscopic bone graft repair. *Left* after placing the graft in position, it is temporarily fixed using K-wires. The position of the graft relative to the joint line is established using a standard Wisinger rod. *Right* The final construct after screw insertion reveals a reconstructed anterior-inferior bony glenoid. (Reprinted from Arch Orthop Trauma Surg, 128(11), Marcus Scheibel et al., Arthroscopic reconstruction of chronic anterior-inferior glenoid defect using an autologous tricortical iliac crest bone grafting technique, pp 1295–1300, Copyright (2007), with permission from Springer)

Mini-open and arthroscopic coracoid transfer: Latarjet procedure

The Latarjet procedure uses the coracoid process as a local bone graft and its attached conjoint tendons as soft tissue stabilization [4, 29, 57].

This technique has shown excellent results with a very low rate of recurrent instability, high patient satisfaction [5, 11, 57] as well as low translation in biomechanical testing [53]. Positioning of the coracoid graft, however, is crucial for firstly the triple locking of the shoulder, meaning (1) the osseous graft itself which increases the anterior–posterior glenoid diameter, (2) the sling effect of the attached conjoint tendons through the subscapularis muscle and (3) the ligamentous capsular reinforcement with the coracoacromial ligament [21]. The Latarjet operation itself and the placement of the coracoid graft requires advanced technical skill and can be challenging in muscular young athletes with robust musculature.

This is important to recognize because the long-term success of the procedure strongly depends on the correct positioning of the bone graft, flush to the articular surface (Fig. 7). Too lateral a position or improper screw placement may cause cartilage defect on the humeral head and an early onset of osteoarthritis in the shoulder [2, 21]. Too medial a position is associated with higher recurrence rates of shoulder instability [32].

Arthroscopic Latarjet procedure Lafosse et al. [27, 29] were the first authors to publish an all-arthroscopic coracoid transfer. In this technique, 5 major stages for the procedure are described. Exposure is achieved at the glenoid by debridement and resection of the anterior labrum and middle glenohumeral ligament. The coracoid is

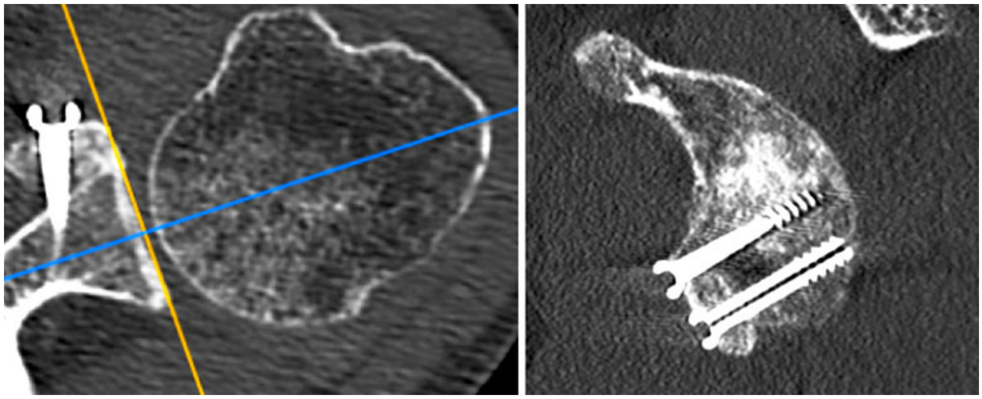

Fig. 7 Left shoulder, post-operative CT scan after the Latarjet procedure. *Left* axial view, the yellow line indicates flush positioning of the coracoid graft, the blue line a well-centred status. *Right* sagittal view, two parallel screws are used for fixation of the graft

prepared through the anterior portal under arthroscopic vision. The rotator interval is opened and the conjoint tendon is released from the pectoralis minor on both sides. Next, the coracoid is drilled and osteotomized. The inferior side of the coracoid is decorticated, and the coracoid is drilled with two lag holes for screw fixation. Two sutures are passed in order to shuttle the coracoid before it gets osteomized creating a graft length of about 2–2.5 cm. In the fourth stage, an anterior-inferior portal through the subscapularis tendon is created to allow for the coracoid transfer and its fixation. The graft is then transferred and fixed with its inferior side to the glenoid. In the final stage, the coracoid transplant is reduced to the glenoid and scapular neck under direct visualization through the anterior portal. In case of a lateral positioning of the graft, a burr should be used to obtain a flush alignment.

Mini-open Latarjet procedure In the mini-open procedure as published by Young and Walch [57], after a 5 cm delto-pectoral incision, the graft is created by osteotomy of the distal 2–2.5 cm of the coracoid process with an angulated saw. The insertion of the pectoralis minor tendon is also detached. The coracoid bone graft then gets decorticated on the inferior surface. The subscapularis muscle and tendon are split at the junction of the middle and distal thirds. The subscapularis is classically left attached laterally, although it can be reflected as advocated by Burkhart [11]. The coracoid bone graft is then transplanted along with the conjoined tendons to the anterior glenoid rim. Careful preparation of the anterior glenoid is important to aid in osteosynthesis as well. The coracoid graft is fixed with two screws and may be held provisionally with a dedicated guide (Arthrex Inc., Naples, FL) or fixed indirectly as described by Walch [51]. Again, it is important that the graft is positioned no less than 2 mm from the glenoid cartilage. In the classic manner, the coracoid is laid lengthwise (lying position) with the inferior side facing the glenoid and held in place with 2 parallel bicortical screws (Fig. 7). Alternatively, the graft may be rotated and positioned in the congruent arc or standing position as described by Burkhart and DeBeer [10]. The remaining stump of the coracoacromial ligament is then sutured to the capsule in order to reinforce the soft tissues.

Post-operative rehabilitation

Post-operatively, the shoulder is immobilized in a sling. Passive range of motion exercises start the first day after surgery. However, for each patient, an individualized rehabilitation protocol has to be established in close collaboration between the surgeon and the physiotherapist. The decisive factors to be considered are the estimated overall stability of the repair, the size of the bony lesion that was addressed, other concomitant procedures, and the overall health and goals of the patient. The progression of therapy and return to activity is determined by the aforementioned patient-specific factors.

Outcomes

Several studies are published in the literature, which report on clinical outcome after arthroscopic treatment for patients with glenoid bone loss. In 2007, Mologne et al. [38] published a follow-up of 21 patients who underwent arthroscopic anchor stabilization for bony deficiency of the anterior-inferior glenoid (20–30 % bone loss) with a mean follow-up of 34 months. They reported 2 patients (9.5 %) with recurrent subluxation and 1 (4.8 %) that sustained a recurrent dislocation requiring revision. Patients with a bony fragment did better than those with attritional bone loss. The same year, long-term follow-up (at least 4 years) results of 65 patients who underwent arthroscopic reconstruction using a modified Bankart technique were presented by Porcellini et al. [43]. Only 2 patients (3.1 %) showed a traumatic redislocation. Lafosse et al. [27] published the clinical results after arthroscopic Latarjet procedure in 2010, showing 91 % excellent and 9 % good clinical outcome scores at 26 months of follow-up. However, only 35 % of the patients were available for clinical review. There is a paucity of the literature on arthroscopic bone grafting with only case reports in the literature [37, 45]. Therefore, reliable data on the clinical outcome of this technique are lacking.

In general, longer-term studies are needed to give us a better perspective regarding patient satisfaction, outcomes, complications and durability after arthroscopic treatments for instability in patients with severe bone loss. It will also be interesting to compare those longer-term arthroscopic studies to the results of mini-open procedures that have already been published [40].

Risks and pitfalls

According to several authors, complication rates following arthroscopic procedures to address bony deficiency are low [8, 27, 28, 38, 46, 48]. However, common surgical complications such as infection, bleeding, neurovascular damage and anaesthetic risks exist and should be explained to the patient. Furthermore, hardware problems, such as loosening, or impingement or graft resorption can occur [49]. The pitfalls of the presented techniques are particularly amplified with arthroscopic management, which requires advanced skill. Correct portal placement is of great importance since an adverse location might complicate the procedure or even render it completely unsuccessful. Insufficient mobilization of the capsuloligamentous complex can also make correct graft placement or reduction of the fragment difficult. Mobilization should always be performed carefully in order to avoid neurological damage.

Discussion

In the modern era of arthroscopic shoulder surgery, improvements in surgical technique, instrumentation and implants now allow surgeons to perform nearly all procedures for instability through an arthroscopic approach. However, despite the promising short-term results [1, 27, 38, 41, 48], more long-term data are necessary to clarify the value of these techniques.

In the meantime, shoulder surgeons should not forget the principles or methods of the open techniques, which have historically provided good and reliable results [3, 21, 22, 40]. In many cases, the open procedures remain the gold standard, especially when the appropriate equipment or the technical experience, instrumentation, or expertise are lacking. Furthermore, in some settings, conversion to an open procedure may be needed particularly during the learning curve or in revision cases, with distorted anatomy or when visualization becomes challenging. As arthroscopic techniques continue to evolve, the surgical approach should be considered carefully based on not only the surgeon's level of comfort and skills but also the spectrum of pathology that may be encountered in these types of cases [36].

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