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Innovative Approaches in the Management of Shoulder Instability: Current Concept Review

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Abstract

Purpose of Review This article summarises the latest innovations and concepts in the management of shoulder instability associated with glenoid bone loss.

Recent Findings The management of shoulder instability has undergone significant evolution in the last century with rapid strides being made in the last few decades due to the transition from open to arthroscopic techniques allowing management of pathological entities which were previously untreatable. However, there is no consensus on treatment methods, especially in the presence of glenoid bone loss. The complication profile associated with non-anatomic glenoid bony reconstruction procedures has triggered research for alternate techniques using free bone grafts. Open Latarjet procedure continues to be the gold standard in the face of glenoid bone loss; however, arthroscopic anatomic glenoid reconstruction with bone block grafts is gaining in popularity and is associated with excellent short-term clinico-radiologic outcomes.

Summary Arthroscopic anatomic glenoid reconstruction using bone grafts has been proposed as an alternative to the complex all-arthroscopic Latarjet procedure with excellent short-term results, minimal complications and a relatively easier learning curve. Capsular reconstruction has emerged as option for the management of instability with poor quality or absent capsular tissue. Future long-term outcome studies and randomised comparative trials will determine if these innovations stand the test of time.

Keywords Shoulder instability · Arthroscopy · Innovations · Arthroscopic anatomic glenoid reconstruction · Arthroscopic Latarjet · Capsular reconstruction

Introduction

Shoulder instability encompasses a wide spectrum from subluxation to frank dislocation with a high prevalence affecting mainly the young, active population with a significant impact on the quality of life [1, 2]. With an incidence of 23.9/100,000 person-years, anterior shoulder instability is a common problem [3]. Several aspects in the management of anterior shoulder instability continue to be controversial with a lack of consensus on treatment protocols especially in the face of glenoid and/or humeral head bone loss [4].

Arthroscopic techniques have enormously altered the landscape of shoulder stabilization surgery [5]. Although shoulder arthroscopy was first introduced by Samuel Burman in 1931, it was only in 1980 that the first arthroscopic stabilization procedure was described [5, 6]. Since then, rapid strides have been made and increasingly sophisticated arthroscopic techniques have been published which continue to evolve constantly (Table 1).

Bankart [7] described his paradigm-shifting eponymous lesion (or 'the essential lesion') in 1923 and his experience of suturing the labrum to the glenoid rim with silkworm gut sutures through a deltopectoral, subscapularis-splitting approach in four cases with no recurrences [7]. The earliest 'arthroscopic' Bankart repair technique (using staples between the Bankart lesion and the nearby subscapularis muscle and capsule) was first described in 1980 by Johnson [8]. Morgan and Bodenstab [9] published their case series of arthroscopic Bankart repair using transglenoid suture fixation of anterior

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Table 1 Major milestones in the timeline of anterior shoulder instability management

Year	Authors	Procedure
1923	Arthur S.B. Bankart	Description of 'the essential lesion' and open labral repair to glenoid rim
1932	Samuel Hybinette	Autologous iliac crest bone graft transfer to anterior scapular neck
1940	Harold A. Hill, Maurice D. Sachs	Hill–Sachs lesion description
1954	Michel Latarjet, Albert Trillat	Coracoid transfer procedure
1980	Lanny Johnson	First description of arthroscopic shoulder stabilization by capsular stapling
1990–91	Stephen Snyder, Eugene Wolf	Use of suture anchors in arthroscopic Bankart repair
2000	Stephen s Burkhart	Engagement concept for Hill–Sachs lesion
2004–2008	Eugene M. Wolf, Robert J. Purchase	Arthroscopic HSL remplissage
2007	Laurent LaFosse	Arthroscopic Latarjet procedure
2008	Ettore Taverna, Markus Scheibel	Arthroscopic iliac crest bone graft procedure
2008	Matt Provencher	Open anatomic glenoid reconstruction with distal tibia allograft
2015	Ivan Wong	Arthroscopic anatomic glenoid reconstruction with distal tibia allograft with Bankart repair (subscapularis-sparing approach)
2018	Ivan Wong	Arthroscopic anterior capsular reconstruction using acellular human dermal allograft

labrum. Use of suture anchors for labral repair was popularised Wolf and Snyder in the early 1990s [5, 10].

The open coracoid transfer procedure to augment the anterior glenoid was introduced by the French surgeon Michel Latarjet in 1954 [11]. It addresses instability due to glenoid bone loss (GBL) by a 'triple locking mechanism': bone surface augmentation, 'hammock effect' secondary to subscapularis lowering with the conjoined tendon and capsular reattachment to the coracoacromial ligament (CAL) [11]. The open Latarjet procedure has shown very satisfying long-term results with a low recurrence rate [12, 13].

The current indications for open coracoid transfer are controversial; the procedure is usually reserved for cases with GBL more than 20–30% although some European centres use the technique for GBL as low as 10% [4]. Recent comparative studies indicate that primary Latarjet has a reduced risk of recurrence compared to arthroscopic Bankart repair [14, 15]. The all-arthroscopic Latarjet (AL) procedure was described separately by the French surgeons Boileau and LaFosse [16, 17]. However, this procedure has limited popularity because of the difficult surgical technique, complex arthroscopic anatomy, steep learning curve and the high chances of complications, particularly nerve injuries (brachial plexus, musculocutaneous and axillary nerves) [18, 19•].

Arthroscopic anatomic glenoid reconstruction (AAGR) using bone grafts is the latest addition to the ever expanding arsenal and has been associated with good results, low recurrence rates, minimal complications, relatively easier learning curve and is increasingly gaining in popularity in the last decade [20•, 21–23]. The AAGR technique described by Wong and Urquhart [24•], which spares the subscapularis and also allows for a Bankart capsulolabral repair for added stability, could be established as a better alternative to the AL procedure in the near future.

The purpose of this review is to discuss novel, innovative strategies which have revolutionised the surgical management of anterior shoulder instability and is likely to influence our approach in the future.

All-Arthroscopic Latarjet Procedure

The open Latarjet procedure is the current gold standard of care in anterior instability cases with significant GBL and in contact sport athletes [12, 13, 25]. The arthroscopic Latarjet (AL) procedure appears to be a natural evolution of this procedure; it retains all the advantages of open Latarjet procedure albeit with the additional advantages of a minimally invasive technique.

The first descriptions of the AL procedure were all from France. Laurent LaFosse et al. [16] described an all-arthroscopic technique of performing the Latarjet procedure in 2007. The coracoid process is carefully exposed arthroscopically through the rotator interval. The osteotomised fragment is then transported to the anterior glenoid through a horizontal split in the subscapularis. Pascal Boileau et al. [17] in 2010 published their technique of performing the AL procedure with a Bankart repair posterior to the bone block (arthroscopic Bankart-Bristow-Latarjet procedure) using six portals (five anterior portals and one posterior portal) in the beach chair position. The procedure was performed without conversion to open technique in 41 out of 47 patients with no neurovascular injuries or recurrences in short-term follow-up [17].

Lewington et al. [26] in 2015 described the AL technique in the lateral decubitus position with the advantage of better visualization of the glenoid than in the beach chair position. The labrum and anterior capsule are excised to allow for a horizontal split of the subscapularis. Two top hat washers are inserted into the coracoid process after releasing the attachment of pectoralis minor and CAL. The coracoid process is then osteotomised and attached to a double-barrel cannulated Bristow-Latarjet Instability Shoulder system (DePuy Mitek) and brought out to the anterior glenoid surface through the subscapularis split (Figs. 1 and 2). The graft is then fixed to the glenoid rim using 2 cannulated, titanium screws [26].

Smaller skin incision, relatively lesser surgical morbidity, more accurate graft positioning and the ability to simultaneously treat multiple, concurrent pathologies in the shoulder at the time of the surgery are some of the advantages of the AL procedure [27, 28].

Mid-term data with a minimum 5-year follow-up was published by LaFosse et al. in 2014 for 64 of the 89 patients in the

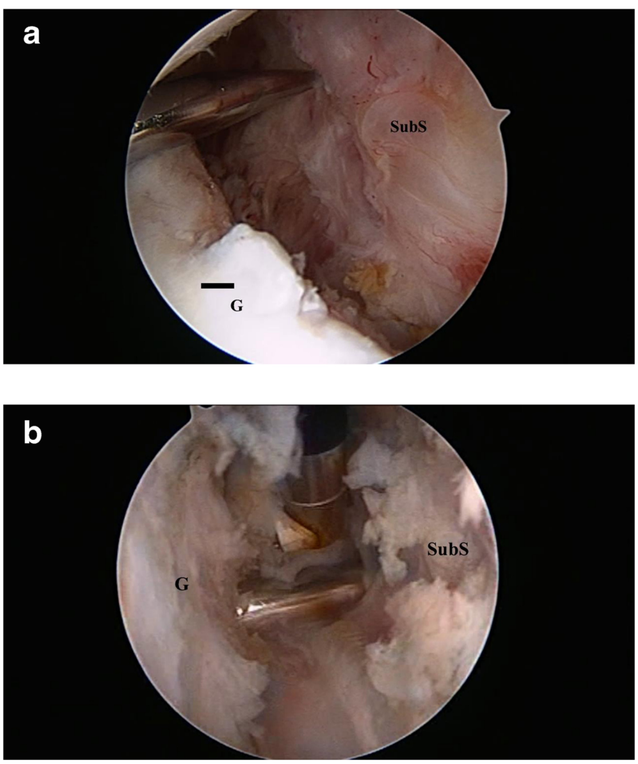

Fig. 1 **a** View from the lateral portal with the glenoid (G) visible in the foreground after debridement of the rotator interval. The switching stick is introduced through the posterior portal and is used to pierce the subscapularis (SubS) halfway between the anterior and inferior margins, lateral to the conjoined tendon. **b** Under direct vision from the lateral portal, the subscapularis (SubS) is then split with an ablator (StarVac 90) laterally and medially, with the ablator working from the inferior portal. This is performed both anteriorly and posteriorly to the subscapularis through the rotator interval

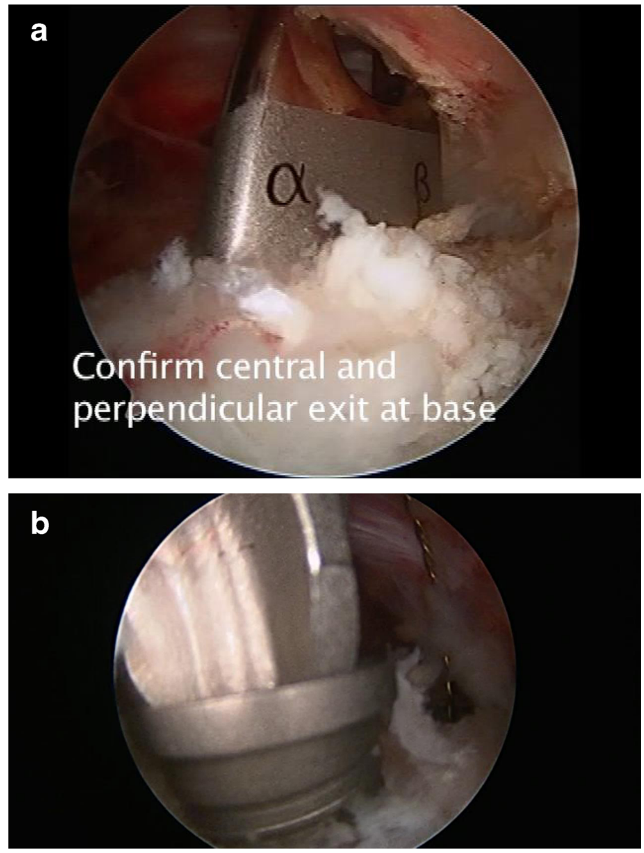

Fig. 2 **a** Coracoid process (CP) visualized through anteroinferior portal. The pectoralis minor tendon has been taken down, and a new coracoid portal has been established directly over the CP to place the α-β coracoid drill guide. **b** Two 1.5-mm K-wires have been drilled at the midline of the coracoid, 1 cm proximal to the tip. A step drill has been used prior to a tap for insertion of top-hat washers that secure fixation into the CP. **c** Viewing from the anteroinferior portal, the base of the CP is circumferentially decorticated with a round burr. **d** With the arthroscope in the anteroinferior portal, a curved osteotome is inserted from the coracoid portal and used to osteotomise the base of the CP

original cohort. Only one case with recurrence of instability (1.59%) in the form of subluxations was noted; there was no case with a frank dislocation after surgery [29]. Boileau et al. [30] reported only 1 dislocation out of 70 cases at a mean follow-up of 35 months. The coracoid graft healed in 73% of the cases ($n = 51$) with a non-union rate of 14% ($n = 14$) and graft resorption in the remaining 7% cases ($n = 5$). However, the graft non-union and resorption in their series did not compromise shoulder stability although an association with persistent apprehension and lesser return to sport was noted [30].

Castricini et al. [31] evaluated the learning curve and preliminary results linked with the transition from open to the AL procedure in their first 30 patients. They observed that the learning curve is roughly 15 cases for experienced shoulder surgeons. Operative times reduced significantly in the last 15 patients (99 min) compared to the first 15 cases (132 min)

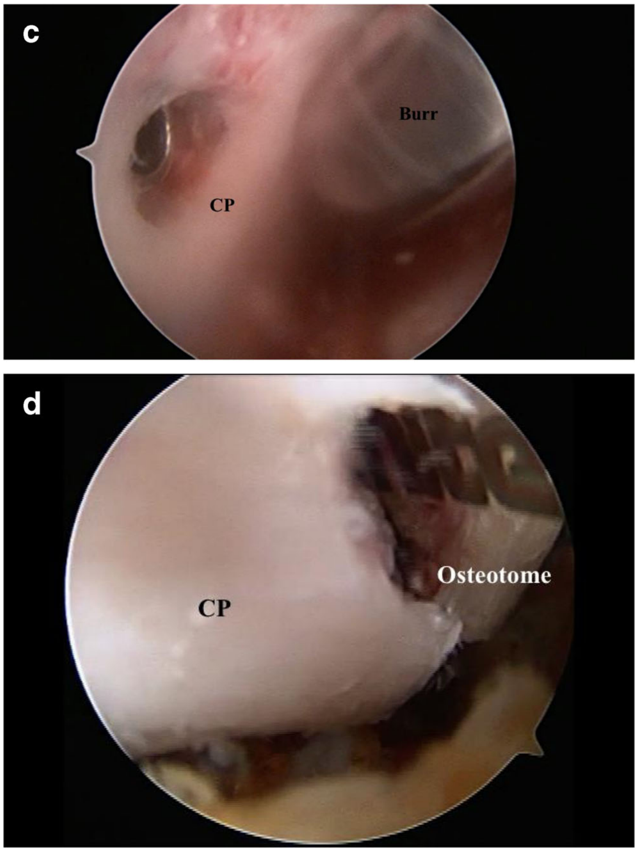

Fig. 2 (continued)

[31]. Cunningham et al. [32] reviewed 36 open Latarjet procedures and 28 AL procedures performed by a single surgeon with comparable age, sex ratio and pre-operative Instability Severity Index Scores (ISIS). Mean operative time was 82 ± 24 min for the open group and 146 ± 51 min for the arthroscopic group. They noted that 20 AL procedures were necessary to achieve equal operative times as an open procedure and 10 AL procedures were necessary to overcome the need for conversion to an open procedure. A higher complication rate, screw placement inaccuracy, persistent apprehension and recurrence rate was noted with the AL technique although clinical outcomes and satisfaction rates were similar to that of the open technique [32].

In comparison to the open technique, AL also has excellent clinical outcomes and less graft resorption rates [28]. However, the arthroscopic technique has not been widely accepted as it is technically challenging and invariably associated with a steep learning curve; advanced arthroscopy skills, sound anatomical knowledge and familiarity with arthroscopic instruments is a pre-requisite to perform this procedure. In case of failure, the revision surgery becomes even more challenging in view of the disrupted normal anatomy [18, 22•, 33]. Compromised glenoid bone stock, issues with metalwork and screws and/or pre-existing anchors and scar formation (especially around neurovascular structures) with associated increase in chances of neurovascular injuries are some of the technical challenges linked with a revision after a failed Latarjet procedure [34].

Open Anatomic Glenoid Reconstruction with Allograft

Provencher et al. [35] have described a technique of anatomic glenoid reconstruction (AGR) utilizing fresh distal tibial osteochondral allograft (DTA) in the beach chair position in patients with a minimum of 15% GBL using a modified deltopectoral approach and a subscapularis split for joint visualization. They noted clinically stable joints with excellent functional outcomes and minimal graft resorption at an average follow-up of 45 months ($n = 27$ patients). There were no cases of recurrent instability. One patient had a superficial infection with *Propionibacterium acnes* and underwent graft removal followed by revision with DTA. A mean allograft healing rate of 89% (range 80 to 100%) was observed on CT analysis at an average of 1.4 year follow-up [20•].

Although the 'sling effect' due to the transfer of the conjoined tendon in the Latarjet procedure is not reproduced, free bone graft transfer has the advantage of being an anatomic reconstruction compared to a non-anatomic reconstruction of the anatomy seen in Latarjet procedure. They also noted that reconstruction with a DTA would be optimal for larger glenoid bone defects [20•]. Sanchez et al. [36] also reported the use of this technique in revision of a failed Latarjet procedure. Frank et al. [37] conducted a prospective matched cohort study comparing the Latarjet procedure to AGR with fresh DTA and noted similar clinical outcomes and recurrence rates at nearly 4 years follow-up.

Arthroscopic Anatomic Glenoid Reconstruction with Autograft

Taverna et al. [38] and Scheibel et al. [39] have described an arthroscopic technique of anatomically reconstructing the glenoid using a tricortical iliac crest bone autograft in the beach chair position using biocompression screws and a capsulolabral repair. Scheibel's team reported no dislocations at a mean follow-up of 20.6 months in 15 patients with 100% consolidation of graft on post operative CT analysis [40].

Fortun et al. [41] described a technique of arthroscopic iliac crest autograft augmentation without disturbing the subscapularis in the lateral decubitus position with an additional Bankart capsulolabral repair making the graft extra-articular and decreasing the chances of long-term OA associated with non-articular iliac crest grafts (Fig. 3). Donor site morbidity after iliac crest graft harvest is the most important disadvantage of this procedure [41, 42]. Although these grafts can be matched to the glenoid contour, concerns for

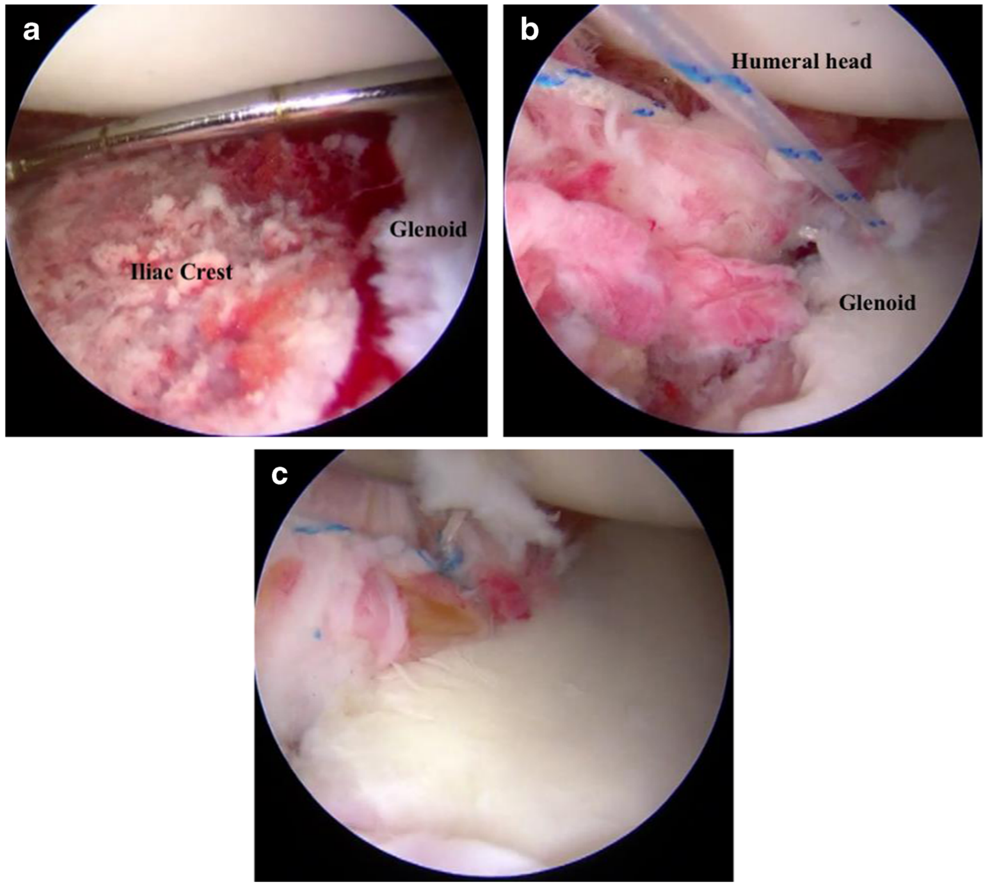

Fig. 3 View of left shoulder through anterior-superior portal in the lateral decubitus position. **a** Positioning of the iliac crest autograft 1 to 2 mm medial to the anterior glenoid rim. **b** Standard arthroscopic Bankart repair. **c** Final inspection shows a well-centred humeral head with anterior capsulolabral repair making the graft extra-articular

osteoarthritis in the long-term remains as the iliac crest graft lacks articular cartilage [43].

Tokish et al. [44] recently described an arthroscopic technique of augmenting glenoid with distal clavicular osteochondral autograft. They use a 3-cm horizontal incision over the subcutaneous border of the acromioclavicular joint and excise the distal 6 to 8 mm of the clavicle which is identical to the traditional Mumford procedure. They recently published a controlled laboratory study of 27 fresh-frozen cadaver specimens to compare the width of the coracoid graft with the distal clavicle graft and also to compare the thickness of the articular cartilage of the distal clavicle with the native glenoid [45]. They noted that the clavicular graft was able to reconstruct 44% of the glenoid diameter compared to 33% for the coracoid graft ($p < 0.001$). However, the articular cartilage of the glenoid was found to be significantly thicker than the clavicle cartilage (1.4 mm thicker; $p < 0.001$) [45]. Apart from the donor-site morbidity, the size of the clavicle graft, soft bone quality and shape mismatch with native glenoid are other limiting factors of this technique. The clinical importance of the increased restoration of glenoid width compared to coracoid graft is also questionable. The cartilage microanatomy and radius of curvature are also important variables that come into play apart from cartilage thickness. Also, as there are no standardised instruments or jigs for graft harvest, the bone cuts tend to be variable [45]. Clinical and biomechanical studies are needed in the future to evaluate the role of this procedure in the management of shoulder instability.

Arthroscopic Anatomic Glenoid Reconstruction with Allograft

Wong and Urquhart [24•] described an AAGR technique using a DTA in the lateral decubitus position that spares damage of the subscapularis muscle as well as allows for an additional capsulolabral repair with an inferior to superior shift of the capsulolabral complex to restore bony and soft tissue anatomy of the shoulder. Paladini et al. [46] noted weakness in the isometric subscapularis muscle strength following AL procedure at an average follow-up of 45 months. The AAGR procedure described by Wong may circumvent this problem by sparing the subscapularis muscle. This technique is also safer with much lesser risk of injury to neurovascular structures, has a faster learning curve and requires just one additional portal.

Apart from the standard posterior, anterosuperior and anterior portals, a far-medial portal called the 'Halifax portal' is created though an inside-out technique parallel to the glenoid surface, superior to the subscapularis and lateral to the conjoined tendon (to avoid damage to the neurovascular structures) to facilitate graft passage [47]. A frozen, non-irradiated DTA is the preferred allograft choice. The posterolateral corner of the DTA is used as it best replicates the native glenoid contour and provides three cortical surfaces for better fixation and strength [20•, 24•, 35]. The dimensions of the bone block are customised according to the size of the defect measured intraoperatively (generally 10 mm in AP dimension, 20 mm in superior-inferior dimension and 15 mm in thickness). A double barrel cannula (DePuy Mitek, Raynham, MA) is then attached to the graft similar to the AL technique [26] described before and the graft is introduced into the shoulder joint through the Halifax portal using a Wissinger rod from the posterior portal to retract the subscapularis muscle inferiorly [24•]. The subscapularis is reduced back to its native position after fixation of the graft with two compression screws and a Bankart capsulolabral repair is performed using all-suture anchors to provide an additional soft tissue restraint, thus making the bone block extra-articular (Fig. 4) [24•].

Amar et al. [21] studied 42 patients who underwent this procedure for the safety profile and short-term radiographic outcomes. They noted an excellent safety profile with no intraoperative complications (neurovascular injuries, adverse events, bleeding and infections). Graft healing on CT analysis at a mean radiographic follow-up of 6.31 months was 100% for 31 out of 42 patients. Wong et al. [48] reported short-term clinical outcomes with follow-up of up to 4 years (mean follow-up of 2 years) in 44 patients noted excellent clinical outcomes, good graft positioning and healing rates on CT analysis with a recurrence rate of 3% (1 out of 44 patients). Moga et al. [47] performed a cadaveric study to evaluate the safety of the Halifax portal and noted mean distances of 50.79 ± 13.69 mm from the musculocutaneous nerve, 46.28 ± 9.64 mm from the axillary nerve, 6.71 ±

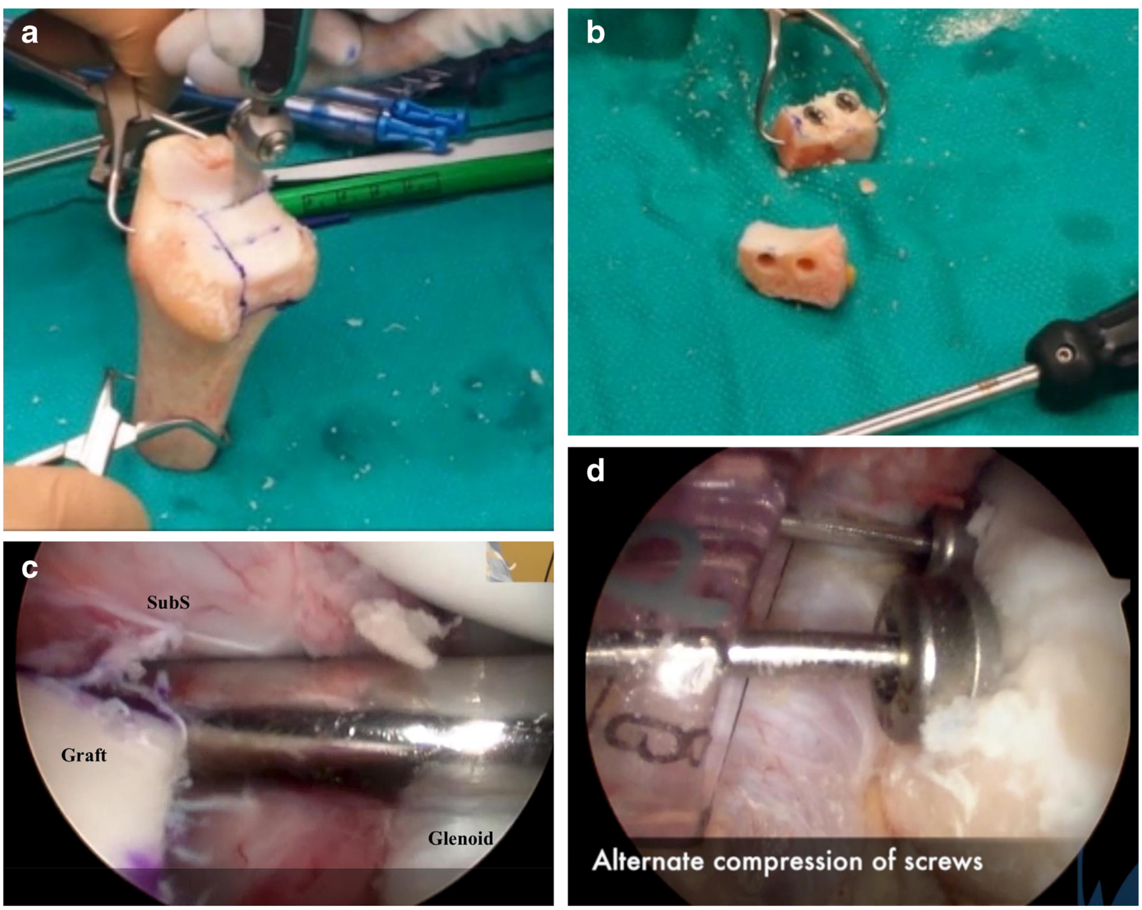

Fig. 4 **a** Graft preparation from distal tibial allograft using a microsagittal saw to fashion the graft from the posterolateral corner of the tibia. **b** Graft after drilling, tapping and placement of top hat washers. **c** A Wissinger rod placed in the posterior portal is used to shift the subscapularis inferiorly allowing the graft to be placed without splitting the subscapularis. **d** Guide wires are placed to temporarily affix the graft in proper position on the glenoid before drilling and placing the cannulated screws which are then tightened in an alternate fashion

8.52 mm from the cephalic vein and 48.52 ± 7.22 mm from the subclavian artery and vein. The axillary and musculocutaneous nerves were found to be safe distances away from the Halifax portal compared to other portal safety studies from the literature [47].

Wong et al. [22•] conducted a retrospective cohort study to radiologically compare the size, shape, healing and resorption of coracoid autograft to the distal tibial allograft in 48 consecutive patients: 12 patients with AL procedure and 36 patients with AAGR procedure. Although the graft resorption rate in the AAGR group was higher compared to the AL group (odds ratio 7; $p = 0.008$), the DTA used in the AAGR cohort had a similar bone union rate to the coracoid autograft with no significant differences in final graft surface area, graft size, anteroposterior dimensions of the reconstructed glenoid and recurrence rates (Fig. 5) [22•].

Wong and colleagues have also recently published a cohort study comparing the learning curves of AAGR and AL procedures [19•]. Two cohorts of AAGR and AL procedures with 27 patients each were compared with respect to operative times and accuracy of graft placement. Each cohort was divided into three chronological sectors of nine patients each to assess the changes in operative time and graft positioning accuracy over successive clusters. It was observed that the operative time of the AAGR procedure was significantly faster in all three time clusters compared to the AL procedure. Desired graft placement (lower third of the glenoid) in the AAGR cohort was identified more commonly across all three clusters: 67% of cases in the early cluster (compared to 56% in AL group), with the rate increasing to 100% for the middle and late clusters (compared to 78% in the AL group). Besides being a faster technique, the AAGR was also observed to be a easier procedure to learn with more standardised reproducibility [19•].

Suture buttons can be used in place of screws for fixation of the allograft [42]. McNeil et al. [49] described a technique of using free labral suture as a traction suture and securing the graft with round endobuttons (Smith & Nephew). This traction suture can be used for additional augmentation of the Bankart repair at the end. Non-rigid fixation with endobuttons may lead to lower re-operation rates. By avoiding the placement of screws through the glenoid and preserving the native anatomy of the glenoid, the complexity of future surgery, if required, is decreased (Fig. 6) [49].

Capsular Reconstruction

In soft tissue pathologies where a capsulolabral repair is not possible either due to absent or poor quality capsular tissue and/or excessively patulous capsule, or in revision

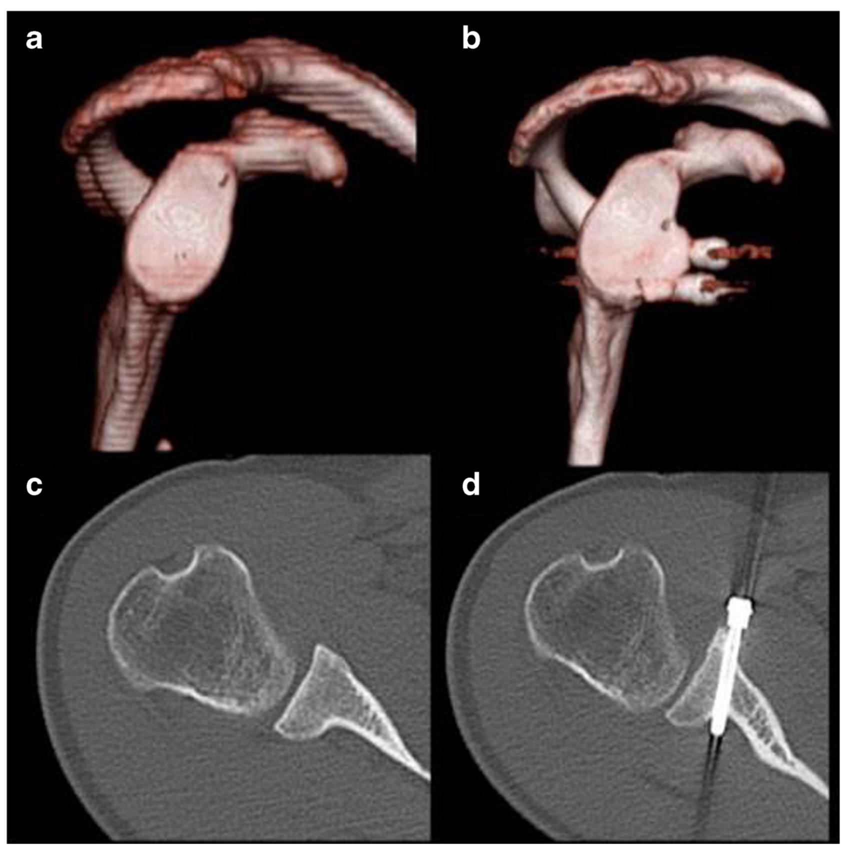

Fig. 5 Pre- and post-operative comparative CT images showing allograft healing after AAGR procedure

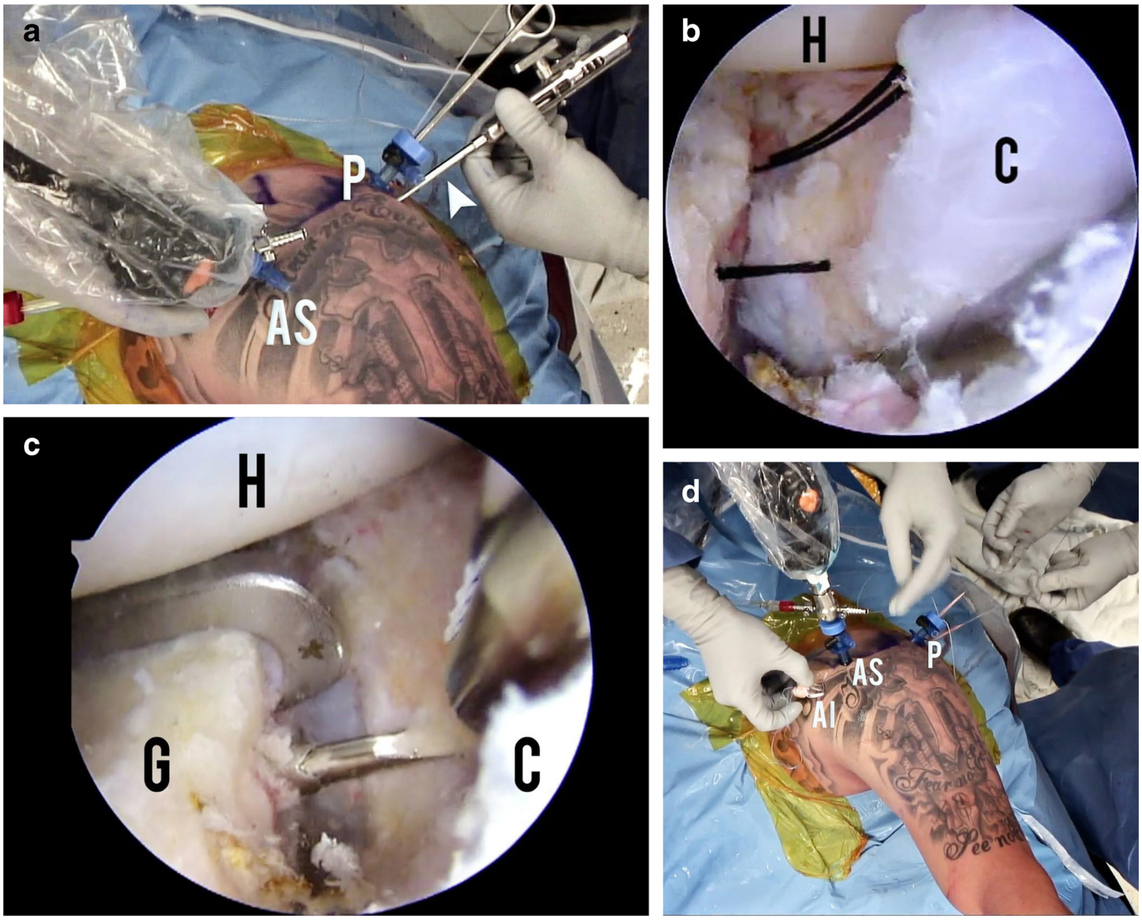

Fig. 6 **a** Bullet drill guide positioned posteriorly (left shoulder). **b** Drilling of the transglenoid tunnel. **c** Monofilament passed through the transglenoid tunnel. **d** A tensioner (white arrow) is used to secure the graft with a force of 100 N

scenarios without significant GBL, anterior glenohumeral capsular reconstruction (ACR) can be a good alternative to restore stability. Various techniques have been described for ACR using different autografts and allografts [50, 51]. ACR techniques using hamstring autografts/allografts have been shown to decrease anterior instability but are associated with decreased ROM compared to opposite shoulder, variable biomechanical results and donor

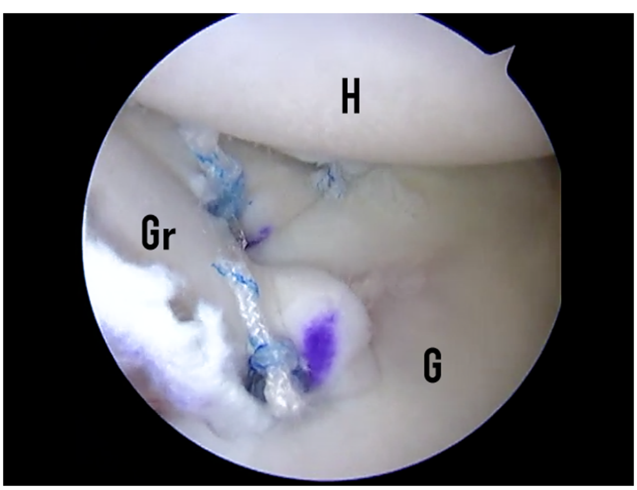

Fig. 7 Arthroscopic view of humeral head well balanced over glenoid with a well-tensioned anterior capsular graft

Fig. 8 A 3D model of the shoulder being used for measurements for a posterior capsular reconstruction procedure

site morbidity including increased risk to neurovascular structures [51, 52]. Acellular human dermal matrix allograft (AHDMA) has been used in open ACR procedures with good results but is associated with longer recovery periods associated with the open technique [53]. Compared to tendon transfers, these grafts are more anatomic, biomechanically stronger, have faster recovery times and eliminate the donor-site morbidity associated with autograft harvests [53].

Whelan et al. [52] recently described an arthroscopic technique of performing an ACR which has the added benefits of further decreased recovery time and post-operative pain (Fig. 7). The arthroscopic technique also has the advantage of direct visualization of the glenohumeral joint following graft fixation to ensure accurate humeral head positioning. Increased operative time in cases of graft suture entanglement, difficult technique and increased costs are the disadvantages of the arthroscopic ACR procedure [52]. Careful suture management and use of 3D models in pre-operative planning for graft sizes can decrease the chances of these complications [52, 54].

Three-dimensional printing is increasingly being utilised in the pre-operative planning for the treatment of shoulder instability. Sheth et al. [55] reported the use of 3D model in planning the stages of Bankart repair, determining depth of Hill–Sachs lesion (HSL) and the abduction-external rotation (ABER) position at which the HSL engaged. It can also be used to assess the glenoid bone loss and for measurements of allograft in capsular reconstruction for anterior and posterior instability. [54] In our institute, we routinely use 3D models in the pre-operative planning for AAGR and ACR procedures (Fig. 8) [54]. We believe that a 3D model is a useful aid in pre-operative and intraoperative planning to help improve accuracy and decrease operative time.

Conclusions

Newer techniques have emerged in the last decade which offer the opportunity to anatomically reconstruct and repair the glenoid bone loss and capsular deficits and may allow better, safer outcomes without increasing risk of revision surgery. Long-term clinical outcome studies and large randomised trials in the future comparing the new techniques to the established techniques will determine if these innovative procedures stand the test of time and lead to the establishment of new evidence-based treatment algorithms.

Compliance with Ethical Standards

Conflict of Interest Ivan Wong reports grants from Depuy, outside the submitted work.

Rakesh John declares that he has no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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