Review Article

Open treatment of posterior glenoid bone loss and bipolar bone loss

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Contributions: (I) Conception and design: BD Owens, EJ Testa; (II) Administrative support: R Byrne; (III) Provision of study materials or patients: BD Owens; (IV) Collection and assembly of data: EJ Testa, L Petit, R Byrne; (V) Data analysis and interpretation: EJ Testa, L Petit, R Byrne; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Abstract: Posterior glenohumeral instability is an increasingly common and challenging orthopaedic problem. While an arthroscopic soft tissue stabilization procedure (i.e., reverse Bankart repair) is effective in treating most cases of posterior instability, this procedure may be inadequate in shoulders with critical posterior glenoid bone loss (GBL), or in cases of an engaging reverse Hill-Sachs lesion. Thus, the purpose of the present manuscript was to report contemporary surgical approaches, techniques, and outcomes for the open treatment of glenoid or humeral head bone loss in posterior instability to help guide clinical decision making. Open osteoarticular augmentation procedures have emerged as a popular option to treat posterior bone loss, with bony auto- and allografts utilized from a variety of donor sites including iliac crest, scapular spine, acromion, distal clavicle, and distal tibia. The combination of glenoid retroversion and bone loss can be addressed with a posterior glenoid opening wedge osteotomy. Bipolar bone loss may be treated with a combination of the aforementioned techniques, in addition to a reverse remplissage, a modified McLaughlin procedure, or various arthroplasty-related options. Although short and mid-term outcomes are dependable, studies reporting long-term outcomes are sparse. Moreover, there is no current consensus regarding the most effective treatment of posterior shoulder instability in the setting of bone loss, and open surgical techniques continue to evolve. Further research is necessary to determine long-term effectiveness of these surgical options.

Keywords: Posterior shoulder instability; glenoid bone loss (GBL); bipolar bone loss; posterior shoulder dislocation

Received: 09 March 2023; Accepted: 21 June 2023; Published online: 10 July 2023.
doi: 10.21037/aoj-23-25
View this article at: https://dx.doi.org/10.21037/aoj-23-25

Introduction

Posterior glenohumeral instability is an increasingly common problem encountered by orthopaedic surgeons, and the management of this pathology can be challenging (1-6). Patient presentation is variable, ranging widely from vague posterior shoulder pain to acute traumatic posterior glenohumeral dislocation (7,8). The treatment of posterior glenohumeral instability can become complicated by bony abnormalities on either the glenoid [i.e., dysplasia, retroversion, acute or attritional posterior glenoid bone loss (GBL)] or humeral head [i.e., reverse Hill-Sachs lesion (RHSL)], and up to 25% of shoulders with posterior instability involve some degree of acquired bony defects (4,8-10). Bipolar bone loss involves concomitant bone loss on both articulating surfaces, a combination that is at high

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risk of humeral head re-engagement in the glenoid defect causing recurrent instability during internal rotation (11).

Recurrence of posterior glenohumeral instability is common without definitive treatment. Possible treatment modalities include nonoperative management, arthroscopic, and open surgical techniques (4,8). Unfortunately, literature regarding treatment for posterior bone loss is relatively sparse in comparison to that dedicated to bony defects in anterior instability. Although arthroscopic techniques have advanced in recent decades, open surgical stabilization is indicated in select patients. Several cadaveric and clinical studies have demonstrated that arthroscopic soft-tissue stabilization (i.e., reverse Bankart repair) may be inadequate for the prevention of recurrent instability in shoulders with critical posterior GBL, over 13.5–20% (12,13). In certain cases, such as revision surgery, cases of excessive GBL, or glenoid dysplasia, open reconstructive techniques may be the preferred surgical option. These techniques include osteoarticular glenoid augmentation with intra-articular bone grafting, glenoid osteotomy, and in severe cases with associated humeral head defects, arthroplasty.

The purpose of the current review is to provide an overview of open surgical options for patients with posterior glenohumeral instability in the setting of posterior glenoid and bipolar bone loss, including a comprehensive description of common surgical approaches, techniques, and postoperative outcomes. Given the challenging and complex nature of posterior glenohumeral instability management, and the current lack of consensus regarding the most effective surgical interventions, our goal is to offer contemporary, evidence-based techniques to consider in order to best inform case-specific clinical decision-making.

Surgical approach to the posterior glenoid for instability procedures

There are several described approaches to the posterior glenoid which may be used in the setting of glenohumeral instability cases. The patient may be placed in the lateral decubitus position on the side opposite that of the affected extremity, or in the beach chair position per surgeon preference. The arm can be draped free for manipulation, or a hydraulic arm holder may be utilized.

It is the author's preference to utilize a posterior incision along the posterior axillary crease, made vertically from the posterior acromial edge aiming toward the medial and inferior aspect of the scapular spine, which should fall over the posterior glenohumeral joint. Upon dividing the deltoid along its fibers bluntly and retracting these in line with the fibers, further blunt dissection between the teres minor and infraspinatus is performed. Neither of these muscles should be detached from their origins on the scapula. It is essential to be mindful of the surrounding neurovascular anatomy during this stage of the approach, protecting the axillary and suprascapular nerve. This then produces excellent visualization of the posterior scapular neck. The surgeon can then confirm the location of the glenohumeral joint by rotating the extremity. When in adequate position, a vertical capsulotomy can be performed. Various retractors or tagging sutures to pull tension on the capsule can be used to enhance the exposure. At this point, an elevator can be used to lift the posterior capsule off of the posterior scapular neck and reveal the bony glenoid defect (14).

Other approaches to the posterior glenoid may also be considered. For example, an angular incision from the medial 2/3rd of the scapular spine curving 1–2 cm from medial edge of the acromion distally for 8–10 cm has been utilized (15). The plane between the deltoid and posterior rotator cuff musculature is made by blunt dissection. Utilizing abduction of the arm raises the posterior inferior deltoid to assist in retraction. A limited release of the posterior deltoid may be performed, releasing the muscle subperiosteally from the scapular spine. At this point, the approach proceeds in the same fashion to the first described approach, creating the interval between the infraspinatus and teres minor, followed by a vertical capsulotomy of the glenohumeral joint.

Open posterior glenoid augmentation for instability

Osteoarticular augmentation procedures

Although arthroscopic capsulolabral repair is the mainstay of posterior stabilization after a failed trial of conservative measures, open procedures such as posterior glenoid bone block augmentation may be more appropriate for select patients. Indications include revision procedures, posterior capsular incompetency, or significant bony abnormalities (8). First described by Rocher in 1931, numerous posterior bone block techniques have emerged with a variety of graft sources; however, there remains a paucity of reported clinical outcomes (16,17). A recent systematic review from Cognetti *et al.* described the frequency of common augmentation procedures; iliac crest was most commonly used, followed by scapular spine, acromion, and distal tibia allograft (18).

To perform a posterior bone block using an iliac crest autograft, as described by Levigne *et al.*, the patient is placed in a lateral decubitus position on the uninvolved side, with a U-shaped support anterior to the patient to support the involved shoulder in either anterior elevation or neutral rotation (19). The incision may be oriented vertically or horizontally based upon surgeon preference; regardless, it is recommended to split the infraspinatus horizontally in line with its fibers at the lower third/middle third junction (generally marked by a layer of fat), instead of using blunt dissection to move between the infraspinatus and teres minor as described above. Internal rotation of the humerus will tense the infraspinatus and allow for a smooth incision. The posterior capsule and glenoid cortex are then exposed with the placement of angled retractors, with careful avoidance of the suprascapular nerve in the superomedial corner of the field. A T-shaped arthrotomy is made with the horizontal aspect at the level of the glenoid equator extending laterally and the vertical line following the edge of the posterior labrum; the T-shape is preferred due to the ease of adding a capsulorrhaphy if necessary. Once the capsular flaps are secured with sutures, an intra-articular retractor is placed on the anterior glenoid rim to retract the humeral head laterally and allow for joint exploration and repair of labral lesions if present. The posterior glenoid cortex is then abraded with an osteotome or burr, with care to preserve the lateral posterior labrum, to prepare a smooth and bleeding surface for the graft. An iliac crest graft is harvested from the ipsilateral hip at the level of the gluteus medius tubercle. The graft should be bicortical, and should measure 2–3 cm long, and at least 10 mm thick and wide (20). The graft is then prepared and adapted to the posterior aspect of the glenoid, with the cancellous side facing anteriorly, the upper edge of the iliac crest will rest posteriorly, and the inner table will face towards the joint. The graft should extend approximately 5–10 mm over the posterior glenoid rim. The graft can be pinned to the posterior glenoid in position, and then a burr is used to trim the graft to create a posterior increase in the glenoid cavity, rather than a buttress effect (20). Once the bone block is shaped—maximizing the posterior articulating surface while maintaining the smooth continuity of the joint surface to avoid impingement of the humeral head—the pin and bone block can be removed to allow for a pilot hole to be drilled in the glenoid pin hole, maintaining the same orientation. As described by Fronek *et al.*, in the setting of hyperlaxity, capsulorrhaphy may be performed at this stage; the inferior flap of the capsule is shifted superior medially and secured to the posterior glenoid labrum with No. 2 nonabsorbable sutures, followed by the superior flap being shifted inferior medially and secured in the same way (21). Fixation of the bone block is achieved with 3.5 to 4.5 mm cortical screws as per surgeon preference aiming towards and obtaining purchase into the anterior cortex. The first screw should be inserted into the predrilled inferior hole while the second is placed 1cm higher. Screws should be tightened in alternating fashion to avoid unequal distribution of force and subsequent fracture of the graft.

Following iliac crest posterior bone block, clinical outcomes are variable. The literature is comprised of numerous, relatively small (minimum n=5, maximum n=66), low level of evidence, case series (16,22-29). Follow up time periods range from 10 to 282 months, and clinical outcome measures reported are heterogenous although favorable with low complication rates in the short- to mid-term. However, long-term outcomes are more questionable, with almost all series report high rates of recurrent dislocation, ranging from 76–100% of postoperative shoulders (23,24,26-29). A high risk of secondary osteoarthritis has also been reported by some studies (26,28) In his series of 31 shoulders, Levigne *et al.* also described 39% of patients with persistent pain, and 23% with graft lysis (19).

Use of the scapular spine for a posterior bone block has also been described, but clinical outcomes are even more scarce (21,29). The surgical approach is similar, although harvest of the graft can be achieved through a single posterior skin incision. The tricortical bone graft, measuring 2–3 cm long and 1cm wide, is then positioned similarly and fixed with two 3.5 mm cannulated screws (3.2 mm drill) positioned in the center, half a centimeter below the glenoid level. Fronek *et al.* conducted a prospective case-control study in which patients were treated nonoperatively versus operatively (n=5), with high level disability and insufficient posterior capsule as indications for scapular spine bone block (21). At a minimum of 24-month follow up, there was improvement in subjective instability and pain, and all patients were "satisfied". More recently, Struck *et al.* retrospectively reviewed single-center outcomes following posterior bone block procedure with scapular spine (n=11) or iliac crest (n=4) (29). In their series, the procedure returned joint stability without decreasing range of motion or increasing risk of arthritis in a majority of cases; differences in postoperative pain and function were non-significant between surgical technique groups.

Another option is to harvest the bone block from the

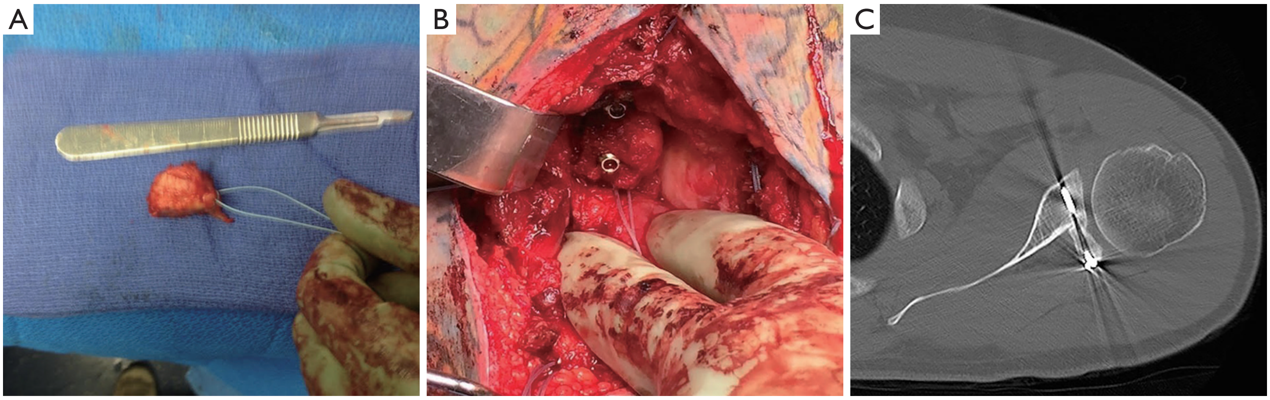

Figure 1 Clinical images of a distal clavicle autograft for posterior instability. (A) Demonstrates a clinical photo at the time of surgery following distal clavicle autograft harvest. (B) Shows an intraoperative image following fixation of the graft to the glenoid. (C) Shows an axial CT slice postoperatively, demonstrating a concentric glenohumeral joint. Images courtesy of SAGE publications. Antosh IJ, Tokish JM, Owens BD. Posterior Shoulder Instability. Sports Health. 2016 Nov/Dec;8(6):520-526. doi: 10.1177/1941738116672446. Epub 2016 Oct 4. PMID: 27697889; PMCID: PMC5089362 (7). CT, computed tomography.

acromion, as described originally by Kouvalchouk *et al.* (30). In this technique, the acromial graft is harvested from the posterior acromion with a deltoid flap; this allows for a complex posterior restraint from the combination of both active and mechanic stabilizers. Clavert *et al.* reported clinical outcomes from 9 patients in their retrospective, multicenter case series, who received acromion bone block (as well as 57 with iliac crest) (16). Although the researchers noted that the study was not large enough to determine which graft was most appropriate, they reported overall significant improvement in Constant, pain, and function scores.

Distal clavicle autograft has also been utilized as an autogenous osteoarticular bone graft option for posterior GBL (7,31). Tokish *et al.* reported a technique of open distal clavicle harvest, followed by arthroscopic fixation, but for those who feel more comfortable with open bony stabilization procedures, any of the aforementioned posterior approaches to the glenoid can be performed to achieve fixation (31). Graft harvest can be performed using an additional 3-cm incision horizontally over the acromioclavicular joint at the mid-axis of the clavicle. Skin and subcutaneous tissues are sharply divided. A periosteal flap is elevated superiorly and inferiorly to expose the distal 8 mm of clavicle, which is harvested using a small sagittal saw. This graft is then prepared by evaluating the patient's glenoid anatomy to find the graft's best fit, cutting the graft perpendicularly at a width that matches the appropriate amount of required bony restoration. Typically, 7–8 mm of additional osteoarticular surface is sufficient to reconstruct roughly 30% bone loss (31). The graft can be drilled with 2 drill holes as planned for 3.5 mm cortical screw fixation and subsequently secured at the inferior 1/3rd and superior 2/3rd of the graft, 3–4 mm away from the articular surface. *Figure 1* demonstrates a harvested graft fixed in this fashion, with a postoperative radiograph of the final construct.

Finally, Gupta *et al.* presented a "mini-open" technique using distal tibial allograft (DTA) for posterior glenoid augmentation (32). Unlike the aforementioned open procedures that are the primary focus of this review, this technique is primarily arthroscopic. Following arthroscopic approach, a 3 cm incision is made 2 cm distal and 2 cm lateral to the posterior portal incision. Blunt dissection is performed down to the infraspinatus. A horizontal 2 cm opening is created in the infraspinatus muscle belly following the fiber orientation, with care to protect the lateral branch of the suprascapular nerve. Gentle retraction will expose the capsule without injury to the axillary nerve. The posterior capsule can then be incised vertically, in line with the joint superiorly from 7 to 10 o'clock positions. Using blunt dissection, the capsulotomy can be widened from the 3 cm initial incision. While maintaining arthroscopic visualization through the anterior portal, the graft with 2 k-wires is introduced into posterior position; one k-wire is advanced unicortically to hold the graft in place while the remaining k-wire is retracted to fine tune graft placement. It is then advanced at a 15-degree angle to the face of the glenoid in bicortical fashion and overdrilled using the lag technique.

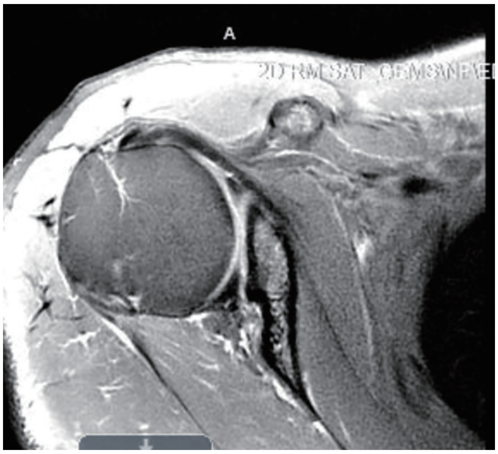

Figure 2 An axial MRI slice of a patient who presented with posterior glenohumeral instability. Note the hypertrophied posterior labrum and dysplastic posterior glenoid, which is characteristic of posterior glenohumeral instability. MRI, magnetic resonance imaging.

A depth gauge can then be advanced over the pin, and a 3.5 mm screw is placed. The second k-wire is retracted and advanced through the second cortex parallel to the first, to stabilize the graft. It is then overdrilled and a screw and washer are placed. The graft itself is the lateral third of the distal tibial plafond, from a donor cadaver; it is prepared by making a 10-degree cut on the part of the graft to be placed on the glenoid footprint. Typical dimensions are 7–8 mm wide and 25 mm long, with rounded superior and inferior edges. Outcomes have been reported by Gilat *et al.* in their retrospective series of ten patients with at least of year of follow up; pre-operative range of motion was regained, however there was no statistically significant differences between pre- and post-operative physical and mental component SF-12 scores (33). Although noted to be a challenging technique, good outcomes and reasonable complication rates were reported by the authors. *Figure 2* demonstrates an axial magnetic resonance imaging (MRI) image of a patient with a severely dysplastic glenoid and posterior instability, which ultimately was treated with DTA augmentation. *Figure 3* demonstrates an example of preoperative and postoperative images following DTA fixation for posterior glenoid insufficiency (*Figures 2,3*).

Posterior glenoid opening wedge osteotomy

As first described by Scott in 1967, the posterior glenoid opening wedge osteotomy (34) is another option for glenoid augmentation and theoretically helps simultaneously address posterior GBL and pathologic retroversion (14,35,36). Various studies have demonstrated that pathologic retroversion and/or posterior GBL are risk factors for posterior glenohumeral instability and poor humeral head centricity (37-39). Biomechanically, Marcaccio *et al.* found that, in a model simulating critical (i.e., 20%) posterior GBL, posterior glenoid opening wedge osteotomy was superior than capsulolabral repair alone in resisting posterior glenohumeral translation (35). Similarly, Ernstbrunner *et al.* used a J-shaped iliac crest bone graft into a posterior opening-wedge osteotomy to demonstrate that reconstructing the glenoid to 0 degrees of retroversion significantly increased posterior glenohumeral stability and normalized contact patterns to that of an intact shoulder in a posterior deficiency model (14).

To perform a posterior glenoid opening wedge osteotomy, any of the aforementioned approaches to the posterior glenohumeral joint can be taken. The patient can be placed in the lateral decubitus or beach chair position per surgeon preference. Firstly, formal evaluation of the glenohumeral joint under anesthesia with or without diagnostic arthroscopy can be performed to assess the capsulolabral complex and the extent of GBL. The technique presented is generally as per the technique initially described by Scott and modified by Waltenspül *et al.* (34,40). An approximately 10–12 cm incision is made posteriorly, starting at the posterior acromial edge and aiming towards to the inferior border of the scapula. The posterior deltoid is exposed and sharply incised vertically at the level of the posterior glenohumeral joint, and then reflected away from the scapular spine, exposing the underlying infraspinatus and teres minor. The interval between these muscles should be made bluntly without detaching either from the scapula. The posterior glenohumeral arthrotomy is made in a vertical fashion. A retractor may then be placed intraarticularly to visualize the glenoid orientation. Then, the posterior scapular neck should be exposed in an extra-articular fashion. A wide osteotome is then used to create the osteotomy, placed parallel to the glenoid base and aiming towards the coracoid process. Preoperative planning utilizing computed tomography can be utilized to plan the desired osteotomy and correction; generally, the authors find that placing the osteotomy 15 mm medial to the glenoid rim avoids intraarticular fracture and neurovascular structures, and permits sufficient correction. Care must be taken to avoid the suprascapular nerve as well as any

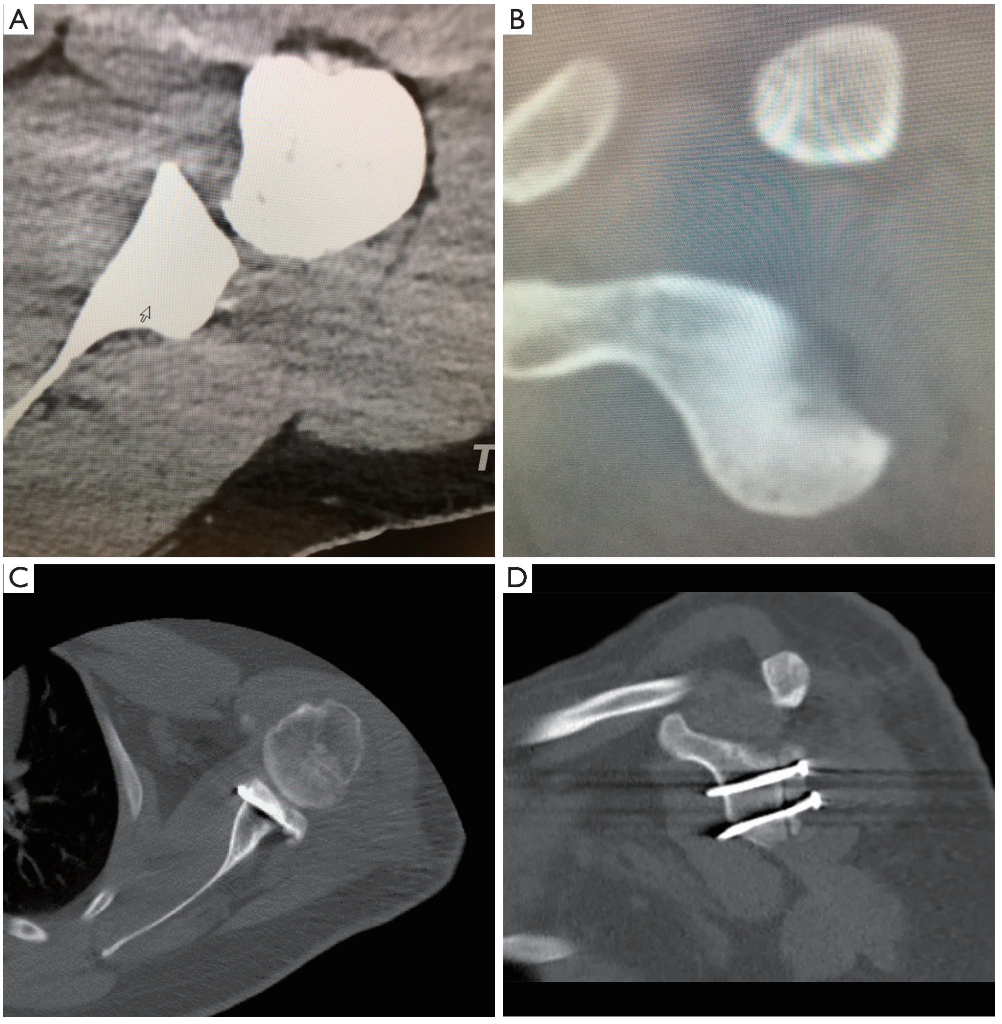

Figure 3 Pre- and post-operative images of distal tibial allograft for posterior glenoid bone loss. (A,B) Preoperative axial and sagittal CT images of a patient with posterior glenoid bone loss with a history of posterior glenoid instability. (C,D) Postoperative axial and sagittal CT images following distal tibial allograft fixation for posterior glenohumeral instability in the case of posterior glenoid bony insufficiency. CT, computed tomography.

intraarticular penetration. An image intensifier can be used if necessary. The anterior cortex should be left intact as a hinge. A ruler can then be used to determine the graft size and the graft can be harvested per surgeon preference. Bicortical scapular spine autograft in a wedge shape, is the author's preferred graft for this technique. The graft is then carefully impacted, typically with the widest portion of the graft located inferiorly given the posteroinferior nature of the pathology (*Figure 4*).

Clinically, the results of posterior glenoid opening wedge osteotomy are mixed. Lacheta *et al.* evaluated the outcomes of 12 shoulders treated with this technique (41). They found that, at a mean follow up of almost 2 years, there were no postoperative re-dislocations or need for revision surgeries; however, they also noted 4 cases of glenoid neck fractures which were asymptomatic and one case of symptomatic recurrent instability. These researchers highlighted that patient selection and surgeon technical competency are imperative to reduce the risk of complications, but the clinical results are reliable in reducing the risk of re-dislocation. Hawkins found that the average correction of retroversion with this technique was 10.8 degrees, but noted local complications in the form of intraarticular fracture, lack of correction caused by failure

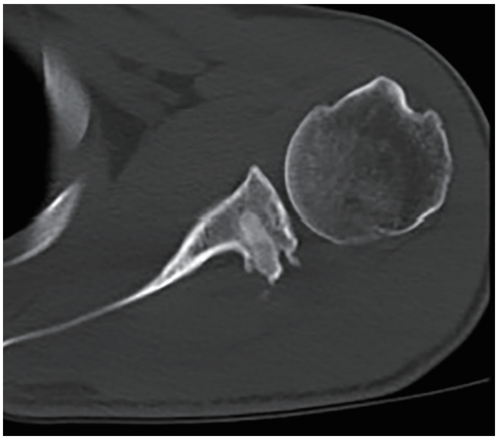

Figure 4 An axial CT postoperative image following posterior glenoid opening wedge osteotomy for excessive glenoid retroversion. Image courtesy of Elselvier Open Access publication (40). CT, computed tomography.

of the anterior hinge, and graft extrusion again leading to lack of correction (36). Plating is a technical option to avoid the latter complication, but ultimately, extreme care must be taking in performing this surgery as technical errors can lead to significant complications (35,36). A 2022, long-term report of 7 shoulders following posterior opening wedge osteotomy for symptomatic posterior shoulder instability with excessive glenoid retroversion, with mean follow-up of 15 years showed that 6/7 shoulders demonstrated symptomatic recurrent posterior instability, and all shoulders demonstrated progressive glenoid arthritic changes (40). These researchers implore authors to consider alternative surgical techniques, as they doubt the reliability of long-term restoration of shoulder stability or the prevention of degenerative changes. Finally, a systematic review of 9 studies from 2021 reported a significant complication profile at 18.3%, with the most common complications being glenohumeral degenerative changes in 7.3% of cases and iatrogenic fracture in 5.5% of cases (42). This study also found a 22% overall recurrence rate, which may not be considered acceptable to many surgeons and patients. Ultimately, this surgical option should be performed by surgeons comfortable with the technical aspects of the procedure, and only after a frank discussion with the patient about the guarded long-term outcomes.

Posterior addition acromioplasty

While prior bony augmentation procedures have addressed deficiencies about the glenoid, in 2006 Scapinelli posed a unique bony augmentation procedure for recurrent posterior instability (43). He described a technique of posterior addition acromioplasty, harvesting scapular spine autograft and subsequently fixing this to the posterolateral aspect of the acromion. The purpose of this grafting technique is two-fold, providing a physical buttress to posterior dislocation, but also providing slight pressure to the posterior rotator cuff which the author proposed may provide an activation effect of the infraspinatus that could potentially stabilize the glenohumeral joint. Scapinelli explains that his group has used this technique since 1970 in patients with atraumatic posterior shoulder instability, and describes the results of 8 consecutive patients who underwent his procedure with good results (43). They reported no complications and full satisfaction at a mean follow-up of 9.5 years. However, they did report a mild reduction in internal rotation with their initial technique, subsequently ensuring that they fixated their graft with the arm in extension and internal rotation and successfully prevented this in subsequent cases.

The posterior addition acromioplasty is performed in the prone position utilizing general anesthesia. A 10 cm incision is made about the inferior border of the scapular spine extending past the glenohumeral joint. The posterior deltoid and trapezius insertions are detached from the bone and the supraspinatus and infraspinatus muscle bellies are dissected in a subperiosteal fashion at the central 1/3rd of the scapular spine. A 2 to 3 cm wide graft is taken using a sagittal saw from the central aspect of the scapular spine, ensuring to stay medial to the spinoglenoid notch at the lateral aspect of the graft harvest to avoid the suprascapular neurovascular bundle. The graft is taken with a rectangle piece of cortical bone from either the supraspinatus or infraspinatus fossa. This segment of bone is flipped and fixated to the posterolateral aspect of the acromion, overlying the posterior humeral head, utilizing two cortical screws from posterior to anterior through the graft and acromion. The authors note that the graft should place slight pressure over the infraspinatus muscle, and can be trimmed to a smooth and founded finish on the upper aspect to prevent irritation. While this option appears to be promising, the 2006 article by Scapinelli appears to be the only clinical series available and it remains to be seen whether his group's outcomes are reproducible. Moreover, this option was not described for use in cases of posterior GBL or bipolar bone loss, and further research would be useful to elucidate its potential use in these clinical settings.

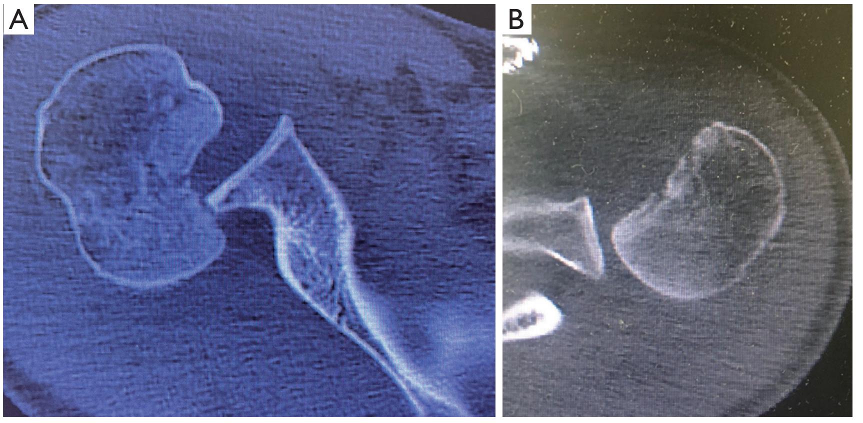

Figure 5 Reverse Hill Sachs Lesions. (A) Shows an axial CT cut of a locked posterior glenohumeral dislocation requiring surgical management with a sizable RHSL. In this case, arthroscopic treatment with reverse remplissage was sufficient to restore stability. However, (B) demonstrates a larger RHSL requiring open surgical management. CT, computed tomography; RHSL, reverse Hill-Sachs lesion.

Bipolar bone loss and posterior glenohumeral instability

As is known from anterior shoulder instability research, the presence of bipolar bone defects in both the humeral head and glenoid increases the risk of re-engagement in subcritical Hill-Sachs lesions depending on the glenoid defect size (44). Bipolar bone loss is relatively common in the presence of RHSL and posterior glenoid defects may be encountered in approximately 20–30% of cases (*Figure 5*) (11,45,46). The gamma angle was introduced and utilized to identify RHSL which would be prone to re-engagement with a critical angle being determined at approximately 90 degrees. This study, however, only evaluated isolated RHSL and did not consider posterior glenoid rim defects. Moroder recently expanded this gamma angle concept to account for posterior glenoid rim defects and found that the degrees of achievable internal rotation without the risk of engagement (delta angle) are reduced by a mean of 2.3 degrees per millimeter bone loss at the posterior glenoid rim (11). While there are several well-established concepts with respect to anterior bone loss to determine whether soft tissue versus bony augmentation will sufficiently provide stability, the degree of critical bone loss to lead to posterior instability has not yet been well established. One study showed that the critical amount of posterior GBL was >13.5% and a biomechanical model suggested that bony augmentation would be necessary with >20% of posterior GBL (12,47). Glenoid morphology has also been shown to play a role with retroverted glenoids displaying increased bone loss following posterior instability events (48).

Bipolar posterior bone loss remains a challenging clinical scenario to treat. While surgical options exist to treat posterior humeral bone loss as well as posterior GBL individually there is little evidence to support surgical strategy in the bipolar setting. Regarding treatment of the humeral defect, the current treatment of choice for an engaging humeral lesion with a gamma angle >90° is a reverse remplissage using the subscapularis tendon, which is a derivative of the original McLaughlin procedure in which the subscapularis tendon was transferred into the anterior humeral head (49). Outcomes following these procedures are favorable, but limited. In a retrospective study of 12 patients who underwent the McLaughlin procedure for RHSL, Romano *et al.* reported improvements in mean Western Ontario Shoulder Index (WOSI) and Constant-Murley (CM) scores. They also reported statistically significant range of motion improvement at final 2-year follow-up (50). Cohen *et al.* similarly reported significant improvements in range of motion as well as CM, visual analog scale score, and University of California, Los Angeles scores following a mean 59 month follow-up in 10 patients with chronic locked posterior shoulder dislocation after McLaughlin procedures (51). The modified McLaughlin procedure has also been recommended in the case of 20% to 45% anterior humeral head loss in posterior instability (52). In this procedure, the lesser tuberosity is transferred and fixated into the humeral head defect. This procedure has been successfully used in posterior glenohumeral fracture dislocations, although large case series are not available (52).

The concept of allograft reconstruction for humeral head defects was initially described in 1996 by Gerber and has had success in some studies (53). Thirteen patients who underwent femoral head allograft reconstruction of the humeral head for chronic posterior shoulder dislocation were studied and 9 of the patients had no pain or restriction of activities of daily living. Their mean CM shoulder score was 86.8 and no patient had symptoms of instability of the shoulder (54). Other studies have had good results addressing humeral head defects by elevating the depressed cartilage defect and backfilling with spongiotic allograft and autograft (55). Another option for severe humeral head bone defects is the HemiCAP (Arthrosurface) which was first implanted in 2004. While indicated for use in resurfacing for cases of avascular necrosis and focal post traumatic osteoarthritis, the implant has also been used in case reports for humeral bone loss in cases of anterior instability (56,57). This has also been used in a case of posterior instability following a fixed posterior shoulder dislocation, however further research is needed to determine outcomes following resurfacing for posterior instability (58).

As a last resort, shoulder arthroplasty, either hemiarthroplasty (HA) or total shoulder arthroplasty (TSA), is usually used to treat chronic dislocations over 6 months, associated with large defects over 45% or deformities of the humeral head, in which all other options are estimated to fail. The decision to proceed with arthroplasty should not be taken lightly, however, as the outcomes for arthroplasty to treat unsalvageable instability are generally poor (59). Wooten *et al.* treated 18 patients with a HA and 13 with a TSA for chronic posterior shoulder fracture-dislocation with a minimum follow-up of 2 years. In their study 13 patients reported unsatisfactory outcomes according to a Neer-modified rating system (60). Despite the many available treatment options to address bone loss, more research is needed to determine the optimal treatment algorithm and degree of critical bone loss in both the humeral head and glenoid to guide surgical management.

Conclusions

The open treatment of posterior GBL and bipolar bone loss in the setting of posterior glenohumeral instability is an emerging area of interest and can be approached in several potential ways. Open, intra-articular bone block procedures have emerged as a popular option to treat posterior bone loss, while glenoid retroversion and bone loss can also be addressed with posterior glenoid opening wedge osteotomy. The results of these treatments are fairly reliable in the short and mid-term to reduce posterior instability events; however, long-term outcome studies are sparse and must be pursued to evaluate for the progression of degenerative changes, particularly after intra-articular procedures. Bipolar bone loss in posterior glenohumeral instability is an uncommon and challenging problem and can be addressed with a combination of the aforementioned techniques with reverse remplissage, a modified McLaughlin procedure, or various arthroplasty-related options.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Jonathan D. Hughes and Albert Lin) for the series “Bone Loss in Shoulder Instability and Shoulder Arthroplasty” published in *Annals of Joint*. The article has undergone external peer review.

Peer Review File: Available at https://aoj.amegroups.org/article/view/10.21037/aoj-23-25/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://aoj.amegroups.org/article/view/10.21037/aoj-23-25/coif). The series “Bone Loss in Shoulder Instability and Shoulder Arthroplasty” was commissioned by the editorial office without any funding or sponsorship. BDO reports receiving royalties from Conmed and Linvatec, consulting fees from Conmed, Mitek, Vericel Corp, Miach, Linvatec, DePuy Synthes Products, Musculoskeletal Transplant Foundation, and Medical Device Business Services, honoraria from Vericel and stock options in Vivorte. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Krøner K, Lind T, Jensen J. The epidemiology of shoulder dislocations. Arch Orthop Trauma Surg 1989;108:288-90.
2. Lanzi JT Jr, Chandler PJ, Cameron KL, et al. Epidemiology of Posterior Glenohumeral Instability in a Young Athletic Population. Am J Sports Med 2017;45:3315-21.
3. Owens BD, Duffey ML, Nelson BJ, et al. The incidence and characteristics of shoulder instability at the United States Military Academy. Am J Sports Med 2007;35:1168-73.
4. Provencher MT, LeClere LE, King S, et al. Posterior instability of the shoulder: diagnosis and management. Am J Sports Med 2011;39:874-86.
5. Song DJ, Cook JB, Krul KP, et al. High frequency of posterior and combined shoulder instability in young active patients. J Shoulder Elbow Surg 2015;24:186-90.
6. Yow BG, Wade SM, Bedrin MD, et al. The Incidence of Posterior and Combined AP Shoulder Instability Treatment with Surgical Stabilization Is Higher in an Active Military Population than in the General Population: Findings from the US Naval Academy. Clin Orthop Relat Res 2021;479:704-8.
7. Antosh IJ, Tokish JM, Owens BD. Posterior Shoulder Instability. Sports Health 2016;8:520-6.
8. Dickens JF, Owens BD. Shoulder Instability in the Athlete: management and surgical techniques for optimized return to play. Vol. 1 SLACK Incorporated; 2021.
9. Weishaupt D, Zanetti M, Nyffeler RW, et al. Posterior glenoid rim deficiency in recurrent (atraumatic) posterior shoulder instability. Skeletal Radiol 2000;29:204-10.
10. Longo UG, Ciuffreda M, Locher J, et al. Posterior shoulder instability: a systematic review. Br Med Bull 2020;134:34-53.
11. Moroder P, Plachel F, Tauber M, et al. Risk of Engagement of Bipolar Bone Defects in Posterior Shoulder Instability. Am J Sports Med 2017;45:2835-9.
12. Nacca C, Gil JA, Badida R, et al. Critical Glenoid Bone Loss in Posterior Shoulder Instability. Am J Sports Med 2018;46:1058-63.
13. Hines A, Cook JB, Shaha JS, et al. Glenoid Bone Loss in Posterior Shoulder Instability: Prevalence and Outcomes in Arthroscopic Treatment. Am J Sports Med 2018;46:1053-7.
14. Ernstbrunner L, Häller T, Waltenspül M, et al. Posterior Open-wedge Osteotomy and Glenoid Concavity Reconstruction Using an Implant-free, J-shaped Iliac Crest Bone Graft in Atraumatic Posterior Instability with Pathologic Glenoid Retroversion and Dysplasia: A Preliminary Report. Clin Orthop Relat Res 2021;479:1995-2005.
15. van Noort A, van Loon CJ, Rijnberg WJ. Limited posterior approach for internal fixation of a glenoid fracture. Arch Orthop Trauma Surg 2004;124:140-4.
16. Clavert P, Furioli E, Andieu K, et al. Clinical outcomes of posterior bone block procedures for posterior shoulder instability: Multicenter retrospective study of 66 cases. Orthop Traumatol Surg Res 2017;103:S193-7.
17. Rocher H. Posterior glenoid bone block by costal (rib) graft in a repetitive subluxation of the shoulder due to obstetrical palsy. Paris Chir 1931:33-43.
18. Cognetti DJ, Hughes JD, Kay J, et al. Bone Block Augmentation of the Posterior Glenoid for Recurrent Posterior Shoulder Instability Is Associated With High Rates of Clinical Failure: A Systematic Review. Arthroscopy 2022;38:551-563.e5.
19. Levigne C, Garret J, Walch G. Posterior bone block for posterior instability. Tech Should Elb Surg 2005;6:26-35.
20. Barbier O, Ollat D, Marchaland JP, et al. Iliac bone-block autograft for posterior shoulder instability. Orthop Traumatol Surg Res 2009;95:100-7.
21. Fronek J, Warren RF, Bowen M. Posterior subluxation of the glenohumeral joint. J Bone Joint Surg Am 1989;71:205-16.
22. Ahlgren SA, Hedlund T, Nistor L. Idiopathic Posterior Instability of the Shoulder Joint: Results of Operation with Posterior Bone Graft. Acta Orthopaedica Scandinavica 1978;49:600-3.
23. Aksekili MA, Uğurlu M, Işık Ç, et al. Posterior bone block of chronic locked posterior shoulder dislocations with glenoid augmentation: a retrospective evaluation of ten shoulders. Int Orthop 2016;40:813-20.
24. Barbier O, Skalli W, Mainard L, et al. The reliability of the anterior pelvic plane for computer navigated acetabular component placement during total hip arthroplasty: prospective study with the EOS imaging system. Orthop Traumatol Surg Res 2014;100:S287-91.
25. Bessems JHJM, Vegter J. Gynoplasty for recurrent posterior shoulder instability: Good results in 13 cases followed for 1-16 years. Acta Orthopaedica Scandinavica 1995;66:535-7.

26. Meuffels DE, Schuit H, van Biezen FC, et al. The posterior bone block procedure in posterior shoulder instability: a long-term follow-up study. J Bone Joint Surg Br 2010;92:651-5.
27. Mowery CA, Garfin SR, Booth RE, et al. Recurrent posterior dislocation of the shoulder: treatment using a bone block. J Bone Joint Surg Am 1985;67:777-81.
28. Servien E, Walch G, Cortes ZE, et al. Posterior bone block procedure for posterior shoulder instability. Knee Surg Sports Traumatol Arthrosc 2007;15:1130-6.
29. Struck M, Wellmann M, Becher C, et al. Results of an open posterior bone block procedure for recurrent posterior shoulder instability after a short- and long-time follow-up. Knee Surg Sports Traumatol Arthrosc 2016;24:618-24.
30. Kouvalchouk JF, Coudert X, Watin Augouard L, et al. Treatment of posterior instability of the shoulder joint using an acromial stop with a pediculated deltoid flap. Rev Chir Orthop Reparatrice Appar Mot 1993;79:661-5.
31. Tokish JM, Fitzpatrick K, Cook JB, et al. Arthroscopic distal clavicular autograft for treating shoulder instability with glenoid bone loss. Arthrosc Tech 2014;3:e475-81.
32. Gupta AK, Chalmers PN, Klosterman E, et al. Arthroscopic distal tibial allograft augmentation for posterior shoulder instability with glenoid bone loss. Arthrosc Tech 2013;2:e405-11.
33. Gilat R, Haunschild ED, Tauro T, et al. Distal Tibial Allograft Augmentation for Posterior Shoulder Instability Associated With Glenoid Bony Deficiency: A Case Series. Arthrosc Sports Med Rehabil 2020;2:e743-52.
34. Scott DJ Jr. Treatment of recurrent posterior dislocations of the shoulder by glenoplasty. Report of three cases. J Bone Joint Surg Am 1967;49:471-6.
35. Marcaccio SE, O'Donnel RM, Schilkowsky R, et al. Posterior Glenoid Osteotomy With Capsulolabral Repair Improves Resistance Forces in a Critical Glenoid Bone Loss Model. Orthop J Sports Med 2022;10:23259671221083579.
36. Hawkins RH. Glenoid osteotomy for recurrent posterior subluxation of the shoulder: assessment by computed axial tomography. J Shoulder Elbow Surg 1996;5:393-400.
37. Brewer BJ, Wubben RC, Carrera GF. Excessive retroversion of the glenoid cavity. A cause of non-traumatic posterior instability of the shoulder. J Bone Joint Surg Am 1986;68:724-31.
38. Imhoff FB, Camenzind RS, Obopilwe E, et al. Glenoid retroversion is an important factor for humeral head centration and the biomechanics of posterior shoulder stability. Knee Surg Sports Traumatol Arthrosc 2019;27:3952-61.
39. Gottschalk MB, Ghasem A, Todd D, et al. Posterior shoulder instability: does glenoid retroversion predict recurrence and contralateral instability? Arthroscopy 2015;31:488-93.
40. Waltenspül M, Häller T, Ernstbrunner L, et al. Long-term results after posterior open glenoid wedge osteotomy for posterior shoulder instability associated with excessive glenoid retroversion. J Shoulder Elbow Surg 2022;31:81-9.
41. Lacheta L, Singh TSP, Hovsepian JM, et al. Posterior open wedge glenoid osteotomy provides reliable results in young patients with increased glenoid retroversion and posterior shoulder instability. Knee Surg Sports Traumatol Arthrosc 2019;27:299-304.
42. Malik SS, Jordan RW, Tahir M, et al. Does the posterior glenoid osteotomy reduce the rate of recurrence in patients with posterior shoulder instability - A systematic review. Orthop Traumatol Surg Res 2021;107:102760.
43. Scapinelli R. Posterior addition acromioplasty in the treatment of recurrent posterior instability of the shoulder. J Shoulder Elbow Surg 2006;15:424-31.
44. Di Giacomo G, Itoi E, Burkhart SS. Evolving concept of bipolar bone loss and the Hill-Sachs lesion: from "engaging/non-engaging" lesion to "on-track/off-track" lesion. Arthroscopy 2014;30:90-8.
45. Moroder P, Tauber M, Scheibel M, et al. Defect Characteristics of Reverse Hill-Sachs Lesions. Am J Sports Med 2016;44:708-14.
46. Saupe N, White LM, Bleakney R, et al. Acute traumatic posterior shoulder dislocation: MR findings. Radiology 2008;248:185-93.
47. Wolfe JA, Elsenbeck M, Nappo K, et al. Effect of Posterior Glenoid Bone Loss and Retroversion on Arthroscopic Posterior Glenohumeral Stabilization. Am J Sports Med 2020;48:2621-7.
48. Bedrin MD, Owens BD, Slaven SE, et al. Prospective Evaluation of Posterior Glenoid Bone Loss After First-time and Recurrent Posterior Glenohumeral Instability Events. Am J Sports Med 2022;50:3028-35.
49. Besnard M, Audebert S, Godenèche A. Arthroscopic McLaughlin Procedure for Treatment of Posterior Instability of the Shoulder With an Engaging Reverse Hill-Sachs Lesion. Arthrosc Tech 2019;8:e1491-4.
50. Romano AM, Edwards TB, Nastrucci G, et al. Arthroscopic reduction and subscapularis remplissage (ARR) of chronic posterior locked shoulder dislocation

leads to optimized outcomes and low rate of complications. Knee Surg Sports Traumatol Arthrosc 2021;29:2348-55.
51. Cohen M, Fonseca R, Galvão Amaral MV, et al. Treatment of chronic locked posterior dislocation of the shoulder with the modified McLaughlin procedure. J Shoulder Elbow Surg 2022;31:100-6.
52. Konda SR, Fisher N, Gage M, et al. Posterior Fracture Dislocation of the Shoulder: A Modified McLaughlin Procedure. J Orthop Trauma 2017;31 Suppl 3:S36-7.
53. Gerber C, Lambert SM. Allograft reconstruction of segmental defects of the humeral head for the treatment of chronic locked posterior dislocation of the shoulder. J Bone Joint Surg Am 1996;78:376-82.
54. Diklic ID, Ganic ZD, Blagojevic ZD, et al. Treatment of locked chronic posterior dislocation of the shoulder by reconstruction of the defect in the humeral head with an allograft. J Bone Joint Surg Br 2010;92:71-6.
55. Bock P, Kluger R, Hintermann B. Anatomical reconstruction for Reverse Hill-Sachs lesions after posterior locked shoulder dislocation fracture: a case series of six patients. Arch Orthop Trauma Surg 2007;127:543-8.
56. Moros C, Ahmad CS. Partial humeral head resurfacing and Latarjet coracoid transfer for treatment of recurrent anterior glenohumeral instability. Orthopedics 2009. doi: 10.3928/01477447-20090624-21.
57. Bessette MC, Frisch NC, Kodali P, et al. Partial Resurfacing for Humeral Head Defects Associated With Recurrent Shoulder Instability. Orthopedics 2017;40:e996-e1003.
58. Lenarz CJ, Shishani Y, Gobezie R. Surface Replacement: The Hemicap Solution. Semin Arthroplasty 2011;22:10-3.
59. Kokkalis ZT, Iliopoulos ID, Antoniou G, et al. Posterior shoulder fracture-dislocation: an update with treatment algorithm. Eur J Orthop Surg Traumatol 2017;27:285-94.
60. Wooten C, Klika B, Schleck CD, et al. Anatomic shoulder arthroplasty as treatment for locked posterior dislocation of the shoulder. J Bone Joint Surg Am 2014;96:e19.

doi: 10.21037/aoj-23-25
Cite this article as: Testa EJ, Byrne R, Petit L, Owens BD. Open treatment of posterior glenoid bone loss and bipolar bone loss. Ann Joint 2023;8:29.