

Management of the Biconcave (B2) Glenoid in Shoulder Arthroplasty: Technical Considerations

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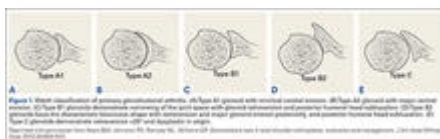
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Total shoulder arthroplasty (TSA) has demonstrated excellent long-term clinical outcomes for the treatment of advanced glenohumeral osteoarthritis (OA).¹⁻⁵ Glenohumeral OA is characterized by a broad spectrum of glenoid pathology. Both the morphology of the glenoid and humeral head subluxation are important preoperative factors to evaluate, as these have been shown to adversely impact shoulder arthroplasty outcomes.^{6,7}

Walch and colleagues⁸ have previously classified glenoid morphology in cases of advanced glenohumeral arthritis based on the preoperative computed tomography (CT) scans of individuals undergoing shoulder arthroplasty (**Figures 1A-1E**). The biconcave (B2) glenoid is characterized by asymmetric posterior bone loss and a posterior translated humeral head that is seated in a biconcave glenoid. The degree and extent of bone loss in the B2 glenoid can be highly variable, ranging from the classic interpretation, in which 50% of the native glenoid fossa is preserved, to the more extreme case with little remaining native anterior glenoid. Scalise and colleagues⁹ have reported that determining the pre-morbid native glenoid version with a 3-dimensional (3D) glenoid vault model can aid in differentiating a pathologic B2 glenoid from a nonpathologic type C glenoid.

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The B2 glenoid in particular has been associated with poor shoulder arthroplasty outcomes and component survivorship.^{6,10-12} There are many factors that are thought to contribute to this problem, such as glenoid component malposition, or undercorrection of the pathologic retroversion.^{6,13,14} Walch and colleagues¹⁰ reported that if the neoglenoid retroversion was greater than 27°, there was a 44% incidence of loosening and/or instability and 60% of the dislocations were observed when the humeral head subluxation was greater than 80%. Cases with

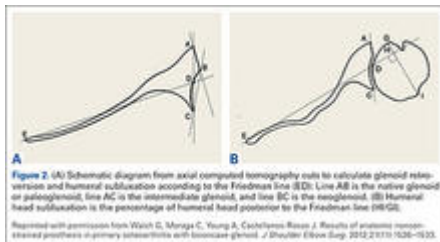
severe posterior glenoid bone deficiency present a unique challenge to the surgeon, and the ability to accurately and securely place an implant in the correct anatomic position can be compromised. Standard TSA has proven excellent outcomes in the setting of typical glenohumeral OA, but in the B2 glenoid with significant posterior bone erosion, additional attention must be given to ensure adequate correction of the bony deformity, soft tissue balancing, and implant stability.

Several strategies that have been proposed to address extreme bone loss in the B2 glenoid will be discussed in this review. These include hemiarthroplasty, TSA with asymmetric reaming of the high side, TSA with bone grafting of the posterior glenoid bone loss, TSA with an augmented glenoid component, and reverse shoulder arthroplasty (RSA). Importantly, while these techniques have been proposed for managing the B2 glenoid, currently there is no gold standard consensus for the treatment of this condition. The purpose of this review is to highlight important characteristics of the B2 glenoid morphology on clinical outcomes and discuss the current surgical management options for this condition.

Preoperative Planning

Being able to accurately determine the amount of retroversion is critical for preoperative planning. Friedman and colleagues¹⁵ initially described a method to measure glenoid retroversion; however, this is less accurate in B2 glenoids (**Figures 2A, 2B**). More recently, Rouleau and colleagues¹⁶ have validated and published methods to measure glenoid retroversion and subluxation in the B2 glenoid using 3 reference lines: the paleoglenoid (native glenoid surface), intermediate glenoid (line from anterior and posterior edge), and neoglenoid (eroded posterior surface) (Figure 2).

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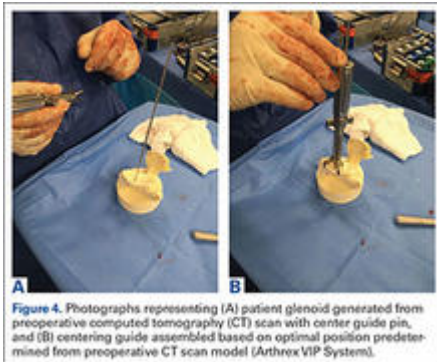
Preoperative evaluation starts with plain radiographs; however, additional imaging is needed, as the axillary view has shown to overestimate retroversion in 86% of patients (**Figures 3A-3E**).¹⁷ For a detailed evaluation of the glenoid retroversion and bone deficiency, CT scans with 3D reconstructions are useful.^{18,19} The surgical plan should be guided by the location and extent of glenoid bone loss. One tool that has been developed to help in predicting pre-morbid glenoid version, inclination, and position of the joint line is the 3D virtual glenoid vault model.^{9,20,21} This helps determine accurate pre-morbid glenoid anatomy and has been shown to assist in the selection of the optimal implant in an attempt to restore native glenoid anatomy, and avoid peg perforation.²¹ Patient-specific instrumentation (PSI) for shoulder arthroplasty is being used more frequently and has shown promise for more accurate glenoid component placement, particularly in the complex glenoid with severe bone deficiency. PSI involves creating a custom-fitted guide that is referenced to surface anatomy derived from the preoperative CT scan, which can then direct the surgeon toward optimal implant position with regard to glenoid

component location, version and inclination (**Figures 4A, 4B**). Early reports show that PSI has resulted in a significant reduction in the frequency of malpositioned glenoid implants, with the greatest benefit observed in patients with retroversion in excess of 16°. ²²

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Surgical Management

Hemiarthroplasty

Shoulder hemiarthroplasty has been traditionally described as an option for younger, more active patients in whom longevity of the glenoid component is a concern, or in patients with inadequate glenoid bone stock to tolerate a glenoid component. While there are no reports of hemiarthroplasty specifically for patients with B2 glenoids, one study has examined the effect of glenoid morphology on the outcomes of hemiarthroplasty for shoulder osteoarthritis. Levine and colleagues⁷ reported inferior clinical outcomes after shoulder hemiarthroplasty in patients with eccentric posterior glenoid wear. Several authors have advocated a “ream-and-run” technique to

create a concentric glenoid and re-center the humeral head while still maintaining the native glenoid.^{23,24} However, in a recent series of 162 ream-and-run procedures, Gilmer and colleagues²⁵ reported that only 23% of patients with B2 glenoid geometry achieved a minimal clinically important change in patient-reported outcome scores and 14% required revision. Furthermore, Lynch and colleagues²⁶ found that progressive medial erosion and recurrent posterior glenoid erosion occur in a significant percentage of patients at early follow-up. Given these recent findings, the use of hemiarthroplasty alone or a ream-and-run procedure for patients with B2 glenoid morphology should be approached with caution.

Total Shoulder Arthroplasty

As with any TSA, the primary goals in treating patients with B2 glenoid defects are to provide the patient with a pain-free, stable, and functional shoulder (**Figures 5A-5D**). There are, however, a few challenges that are unique to TSA in the setting of B2 glenoid defects. Because the humeral head is often subluxated posteriorly into the defect, the anterior capsule and rotator cuff can tighten while the posterior aspect of the joint becomes lax. These soft tissues must be balanced during TSA in order to stabilize the shoulder and restore the appropriate length-tension relationship of the rotator cuff. The other primary concern is restoration of appropriate glenoid version and lateralization. To accomplish this, the most common techniques utilized are asymmetric reaming, bone graft augmentation, and glenoid component augmentation.^{27,28}

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Asymmetric Reaming. One of the more readily utilized techniques for addressing the B2 glenoid during TSA is eccentric or asymmetric reaming. During this process, the anterior glenoid is preferentially reamed while little to no bone is removed posteriorly. This technique is generally felt to be sufficient to treat posterior defects up to 5 mm to 8 mm or retroversion up to 15°. ²⁸ These upper limits have been confirmed in a number of cadaveric and simulated models.²⁹⁻³¹

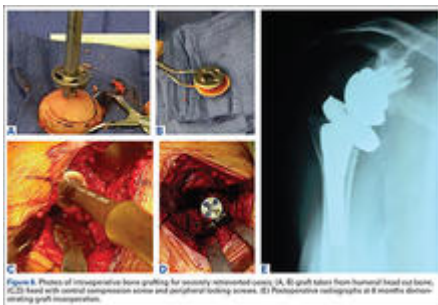
The success of this technique hinges on excellent glenoid exposure. With appropriate retractors in place, the anterior capsulolabral complex, including the biceps insertion, is resected to improve visualization. The inferior capsule must be resected carefully to ensure exposure and better motion postoperatively. On the other hand, it is imperative to protect the posterior capsulolabral attachments because of the increased risk of posterior instability in patients with B2 glenoids.

Detailed imaging such as CT scans with 3D reconstructions have improved our understanding of the degree of the deformities in all directions, which can better guide the reaming. PSI and planning software developed to improve the surgeon's ability to place the glenoid component centrally in the best possible position after version correction can be even more helpful. We find that using a burr to provisionally lower the high side (anterior) provides a more en face view, which subsequently makes the eccentric reaming easier. As a guide, we will not ream more than 1 cm of anterior bone or attempt to correct more than ~20° of retroversion. The goal should be to create a glenoid surface that is more neutral and congruent to the posterior surface of the glenoid component while not overmedializing the component.

Although eccentric reaming may be one of the more straightforward methods for addressing posterior glenoid erosion, it is not without a number of potential downsides. When attempting to correct defects >10 mm or retroversion beyond 15°, excessive medialization of the implant can occur. Although increasing the thickness of the glenoid component can compensate for small amounts of medialization, excessive medialization can lead to a number of issues.^{27,28,32} As reaming progresses medially, the risk of keel penetration increases as the glenoid vault narrows.^{30,32} Further medialization decreases posterior cortical support for the implant, which increases the risk of component loosening and subsidence.³³⁻³⁵ The more medial the implant is placed, the smaller the surface of available bone for implant fixation. This often requires utilization of a smaller sized glenoid component that may result in component mismatch with the humeral implant. Finally, excessive medialization has the potential to under tension the rotator cuff, leading to decreased shoulder stability, strength, and function.

Bone Graft Augmentation. When posterior erosion becomes too excessive to address with eccentric reaming alone, defect augmentation is another option to consider (**Figures 6A-6E**). While technically more demanding, bone graft also provides the advantage of better re-creating the natural joint line and center of rotation of the glenohumeral joint.

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For most defects, the resected humeral head provides the ideal source of graft. After initial reaming of the anterior glenoid, the defect must be sized and measured. We then recommend using a guided, cannulated system to place a central pin, lying perpendicular to the glenoid axis in neutral position. The anterior glenoid is then reamed enough to create a flat surface on which to attach the bone graft. The posterior surface is then gently burred to create a bleeding surface to enhance graft incorporation. The graft is then contoured to the defect and placed flush with the anterior glenoid. Cannulated screws are placed over guidewires to fix the graft. Using an arthroscopic cannula inserted posteriorly allows for easier placement of the guidewires and easier implantation of the screws. Although a reamer or burr can be used to contour the graft once it is fixed in place, this should be minimized to prevent loss of fixation. When the graft is fixed, we then cement the glenoid component into place.

Although good clinical results have been obtained with this technique, there is concern of incomplete graft healing and component loosening in the long term. Even in clinically asymptomatic and well functioning patients, some degree of radiographic lucency may be present in over 50% of cases.^{31,36,37} Glenoid Component Augmentation. To address the issues related to lucency and nonunion of bone graft augmentation, several augmented glenoid components have been developed. Augmented glenoid components have the benefit of filling posterior defects and stabilizing the shoulder without requiring excessive medialization (as often occurs with eccentric reaming) or union of a bone-to-bone interface (as is required in bone graft augmentation).³⁸ Although many of the metal back designs experienced undesirably high failure rates and have since been recalled,³⁹ more modern all-polyethylene components hold promise. The 2 most commonly utilized designs are the posterior step augment (DePuy) and the posterior wedge (Exactech). Although biomechanical analyses of both designs have demonstrated increased stability during loading in cadaveric and simulation models, the step augment (DePuy) has demonstrated increased stability and resistance to loosening.^{40,41} Although midterm results are not yet available for this newest generation of augmented components, short-term results with 2 to 3 years of follow-up have demonstrated excellent clinical outcomes.²⁸

Reverse Total Shoulder Arthroplasty

While most commonly indicated for patients with rotator cuff tear arthropathy, RSA has recently been advocated for older patients with osteoarthritis and B2 glenoids in the setting of an intact rotator cuff. The semi-constrained design of the RSA is a potential solution to the static posterior humeral head subluxation seen in patients with B2 glenoid geometry (Figure 6E).

Technically, RSA is often an easier solution than a TSA with bone grafting because there is usually enough glenoid bone stock for fixation. That said, we always get a CT scan with 3D reconstructions to better appreciate the anatomy. Note that in B2 glenoids, the bone loss is typically posterior and inferior. RSA in the setting of a B2 glenoid is one of the ideal indications to use PSI to ensure ideal placement of the central pin, which is the key to glenoid baseplate positioning. Even when using a RSA, eccentric reaming and/or bone grafting allow for more ideal component placement. Using the same eccentric reaming techniques described above, one should try to ream to place the baseplate at 10° of retroversion. In cases where retroversion cannot be corrected to 10°, graft can be taken from the humeral head, iliac crest, or allograft. A benefit to using bone graft with RSA as opposed to TSA is that the graft can be fashioned to the baseplate, impacted/compressed into the B2 glenoid, and then secured with a central compression screw and peripheral locking screws.

Mizuno and colleagues⁴¹ reported a retrospective series of 27 RSAs performed for primary glenohumeral osteoarthritis and biconcave glenoid. At a mean follow-up of nearly 5 years, the authors noted significant improvement in Constant scores and shoulder motion with minimal complications. There was no recurrence of posterior instability observed by the time of final follow-up.⁴¹

RSA is a promising treatment for primary glenohumeral arthritis with posterior glenoid bone loss and static posterior subluxation in elderly or less active patients, but the longevity of these implants has yet to be established for younger, more active patients and requires further study.

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Technique	Indications	Comments
Humeral head	Inferior glenoid bone stock, loose/loose bone graft/revision	Early revision Consider "bone onlay" if revision with humeral head
TSA with eccentric reaming	To treat posterior defects of the glenoid (up to 10°)	Be careful of overreaming with increasing glenoid reaming Postoperative planning and reconstruction not to rely solely
TSA with augmentation Bone graft or augmented glenoid	When eccentric reaming alone cannot correct defect and patient is not a candidate for RSA	Can use humeral head to bone graft Site of particle through anterior shoulder joint Must be prepared glenoid, not site of revision of bone graft but correct version
RSA	Older, lower demand patients with osteoporosis and bone loss glenoid	Bone grafting even with RSA (see TSA, Goal is to correct retroversion to 10°) Good clinical results for patients about longevity in younger, more active patients (longer)

Conclusion

Reconstruction of the B2 glenoid presents a challenging clinical problem that has been associated with poor clinical outcomes and implant survivorship. The high failure rate from glenoid component loosening and subsequent premature implant failure can be substantially decreased with accurate glenoid component positioning and appropriate correction of the pathologic glenoid retroversion. Careful preoperative planning is essential for accurate preparation and execution of the optimal surgical plan. There are many surgical strategies to address the B2 glenoid, but no consensus on the optimal method exists, as the technique should be uniquely customized to the individual’s pathology and surgeon preference (**Table**). Cases with mild deformity may be corrected with eccentric reaming and TSA, while the more severe deformities may require posterior glenoid bone grafting and/or augmented implants to restore native version. Finally, the RSA is a reliable option to restore stability and address bone deficiency for the severe B2 glenoid in an older, lower demand patient.

Key Info

Figures/Tables

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