REVIEW ARTICLE

Current concepts in the surgical management of primary glenohumeral arthritis with a biconcave glenoid

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Glenoid morphology has an important impact on outcomes and complication rates after shoulder arthroplasty for primary glenohumeral arthritis. The B2 glenoid, or a biconcave glenoid with posterior humeral head subluxation, in particular has been associated with a poorer outcome with shoulder arthroplasty compared with other glenoid types. A variety of techniques may be used to address the bone deficiency and instability seen with this glenoid type. Studies suggest that total shoulder arthroplasty may have a reasonable result in the short term but be associated with a high complication rate in the mid term because of recurrence of instability and early glenoid loosening when neoglenoid retroversion is greater than 27° or posterior humeral head subluxation is greater than 80%. Particularly in older patients with a substantial B2 deformity, primary reverse shoulder arthroplasty may be a more predictable means of addressing bone deficiency and restoring stability.

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Glenoid morphology is one such preoperative factor that affects shoulder arthroplasty outcomes. In their 1982 report on TSAs, Neer et al noted the existence of posterior glenoid erosion and humeral head subluxation in some cases of primary glenohumeral arthritis and advised correction of eccentric glenoid erosion during implantation of a polyethylene glenoid.26 Subsequent studies by Levine et al21 and Iannotti and Norris17 demonstrated that posterior glenoid erosion and posterior humeral head subluxation affect shoulder arthroplasty outcomes. Walch et al classified glenoid morphology in primary glenohumeral arthritis into 5 types and noted that 15% of cases had a biconcave glenoid with posterior humeral head subluxation, the so-called B2 glenoid.37 Recent reports have demonstrated that a B2 glenoid has a substantial negative influence on functional outcome and component survivorship.17,38 A variety of

In the majority of cases, primary glenohumeral arthritis refractory to nonoperative treatment can reliably be addressed with total shoulder arthroplasty (TSA). In a series of more than 2500 TSAs performed for multiple diagnoses, the revision-free survival rate was 94% at 5 years, 90% at 10 years, and 81% at 20 years.34 Young et al reported 226 TSAs performed for primary glenohumeral arthritis and similarly noted that revision-free survivorship of the glenoid was 99% at 5 years, 95% at 10 years, and 79% at 15 years.42 Whereas these overall results are encouraging, the identification of preoperative factors that affect outcome is likely to lead to improvement in patient function and component survivorship.

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techniques have been proposed to manage a B2 glenoid, but no consensus currently exists. The purpose of this review is to highlight the influence of the B2 glenoid morphology on shoulder arthroplasty outcomes and to discuss the reconstructive options for this condition.

The B2 glenoid

The B2 glenoid was first noted in 1982 by Neer et al, who described advanced cases of primary glenohumeral arthritis that were associated with posterior sloping of the glenoid and posterior humeral head subluxation that resembled “an old posterior dislocation.” In 1999, Walch et al formally classified glenoid morphology into 5 types on the basis of preoperative computed tomography (CT) scans of individuals undergoing shoulder arthroplasty (Fig. 1). Type A or concentric glenoids were most common, with minor central erosion (A1) in 43% of cases and major central erosion (A2) in 16% of cases. Type B glenoids demonstrated posterior humeral head subluxation with joint space narrowing and retroversion (B1) in 17% of cases or with a biconcave glenoid (B2) in 15% of cases. A type C glenoid was observed in 9% of cases and consisted of a dysplastic glenoid with retroversion greater than 25°.

Quantifying the B2 glenoid involves assessing both glenoid version and humeral head subluxation. Glenoid version is most commonly measured as described by Friedman et al. On axial CT images, they described use of a line between the tip of the medial border of the scapula and the center of the glenoid as a reference line for the scapula axis. In their series, they reported a mean 2° of anteversion in normal individuals compared with 11° of retroversion in individuals with glenohumeral arthritis. Rouleau et al verified the reproducibility of this method and described three different glenoid reference lines that could be used to assess version of the B2 glenoid: the neoglenoid (posterior erosion surface), the paleoglenoid (original glenoid surface), and the intermediate glenoid (line from anterior and posterior edge) (Fig. 2). Humeral head subluxation may be measured with regard to the Friedman line (scapular axis) or by use of the mediatrice method, in which a line is drawn perpendicular to the glenoid joint surface. In both cases, posterior subluxation is defined as the percentage of the humeral head that lies posterior to the given line (Fig. 3). Kidder et al demonstrated that the
The scapular axis method is more reliable, particularly in the setting of a B2 glenoid (Fig. 4).

There has been some debate about the reliability of the Walch glenoid morphology classification system. However, posterior humeral head subluxation clearly appears to be related to posterior glenoid erosion. Walch et al. described 13 patients with a mean age of 40 years who had posterior humeral head subluxation averaging 65%. Because none of these young patients had posterior glenoid erosion, the investigators suggested that posterior humeral head subluxation is the eventual cause of posterior glenoid erosion (B2 glenoid). More recently, a study of 121 preoperative CT scans found that posterior humeral head subluxation is most common with a biconcave glenoid, demonstrating that glenoid morphology is more closely related to posterior humeral head subluxation and secondary glenoid bone wear than glenoid version. This finding is important, given that posterior humeral head subluxation is associated with poorer outcomes after shoulder arthroplasty. Iannotti and Norris examined the influence of several preoperative factors, including posterior humeral head subluxation and posterior glenoid erosion, on functional outcome after shoulder arthroplasty in 128 shoulders with primary glenohumeral arthritis. In 23 (18%) shoulders, they observed posterior subluxation, which they defined as 25% or greater the width of the humeral head positioned posterior to the center of the glenoid. Compared with those without subluxation, patients with preoperative posterior subluxation had lower postoperative American Shoulder and Elbow Surgeons scores (86 vs 75; $P = .07$), higher pain (1.3 vs 2.7; $P = .07$), and less external rotation (47° vs 38°; $P = .07$). In the absence of posterior subluxation, TSA led to improved functional outcomes compared with hemiarthroplasty in terms of both pain (2.2 vs 1.1; $P = .02$) and American Shoulder and Elbow Surgeons score (88 vs 77; $P = .03$). Interestingly, however, when there was preoperative posterior subluxation, TSA did not lead to improved functional outcome compared with hemiarthroplasty. On the
other hand, in the setting of posterior erosion $\geq 5$ mm bone loss, postoperative range of motion was improved with a TSA compared with a hemiarthroplasty. These findings suggest that posterior erosion can be managed with TSA, but posterior subluxation may be difficult to overcome regardless of glenoid resurfacing.

**Treatment options**

In managing a B2 glenoid, the surgeon must address both posterior glenoid erosion and posterior humeral head subluxation. Prosthesis options include hemiarthroplasty, anatomic TSA, and reverse shoulder arthroplasty (RSA).

**Hemiarthroplasty**

Although we are not aware of any reports on hemiarthroplasty specific to the B2 glenoid, results of hemiarthroplasty are clearly influenced by glenoid morphology. In an initial report of 31 hemiarthroplasties with mean follow-up of 29 months, Levine et al reported that when the glenoid was concentric preoperatively, a satisfactory outcome was achieved in 86% of cases. However, when the glenoid had posterior erosion, satisfactory outcomes were achieved with a hemiarthroplasty in only 63% of cases. The results deteriorated with time, particularly in the setting of glenoid erosion. In a subsequent report, 28 of the 31 hemiarthroplasties were reviewed at a mean 17 years postoperatively. At long-term follow-up, they found that 42% of concentric glenoids and 13% of nonconcentric glenoids had a satisfactory result. As noted previously, Iannotti and Norris found that in the setting of posterior glenoid erosion, TSA led to better outcomes compared with hemiarthroplasty alone.

Matsen has popularized the “ream-and-run” procedure, in which the glenoid is reamed to create a concentric socket and the humeral head is resurfaced with a hemiarthroplasty; he suggested that this technique could be used to manage a B2 glenoid. Biomechanical investigation has shown that removal of glenoid cartilage and labrum leads to decreased stability and that subsequent reaming alone of the glenoid to a concentric socket helps restore stability to the glenohumeral joint. Gilmer et al recently reported the clinical outcomes of 162 ream-and-run procedures. At minimum 2-year follow-up, 124 cases had improvements in their Simple Shoulder Test (SST) scores that met minimal clinically important difference (MCID) criteria, 22 (14%) required revision, and 16 (10%) did not have MCID improvement. Notably, MCID was not achieved until a mean of 6 months postoperatively, and the SST score did not maximally improve until 2 years postoperatively. They reported that no patients had postoperative posterior instability despite glenoid morphology. However, among the biconcave glenoids (number not reported), only 23% had MCID improvement in SST scores; 38% did not have MCID improvement, 14% required revision, and 21% did not have adequate follow-up. Moreover, in an earlier report at the same center with mean 2.7-year follow-up, Lynch et al reported that 4 of 34 (12%) ream-and-runs demonstrated progressive medial erosion and 6 (18%) had recurrent posterior glenoid erosion. Given that these are short-term results and that the amount of reaming necessary to correct a B2 deformity can be substantial, we advise caution in using this technique to correct a B2 deformity.

Hemiarthroplasty with biological resurfacing has also been used, particularly in young adults, when there is concern for longevity of a polyethylene glenoid implant. A variety of techniques have been proposed, including meniscal allograft, fascia lata, and Achilles allograft. However, the results of these techniques have been mixed, and the long-term outcome of these techniques is not well quantified, particularly in the setting of a B2 glenoid.

**Total shoulder arthroplasty**

Multiple studies have demonstrated that TSA is superior to hemiarthroplasty alone in the treatment of primary glenohumeral arthritis. As such, TSA has also been the...
mainstay for treatment of a B2 glenoid for several years. The goals are to correct posterior subluxation by soft tissue balancing and to reduce eccentric loading of the polyethylene component to prevent early loosening secondary to the “rocking horse” phenomenon. Several techniques can be used to address glenoid retroversion and to implant a glenoid component, including eccentric glenoid reaming, posterior glenoid bone grafting, and augmented posterior glenoid.

The most common technique to address retroversion is eccentric reaming, in which the glenoid is reamed primarily anteriorly to re-create a concentric socket, which is then resurfaced with a polyethylene glenoid (Fig. 5). However, this technique is limited by the amount of preoperative retroversion and the fact that reaming leads to loss of bone stock because the glenoid vault narrows medially. Cadaveric and computer simulation studies have indicated that approximately 15° is the amount of retroversion that can be successfully corrected without vault penetration. However, this limit relates to the penetration of the keel or pegs through the cortex of the glenoid vault and does not necessarily correlate with the ability to correct posterior subluxation. Moreover, a study by Iannotti et al indicated that even when correction of version is possible, it is not always able to be technically accomplished, even in the hands of an experienced surgeon. In addition, there are potential downsides to progressive medial reaming. As reaming progresses medially, the glenoid vault narrows, which decreases the amount of bone stock available for glenoid implantation; significant reaming, for instance, may result in the implantation of a smaller glenoid component with substantial mismatch between the glenoid and humeral head. Severe medialization of the glenoid may also decrease tension in the rotator cuff, which may have functional consequences. Finally, excessive glenoid reaming to correct glenoid version may increase the risk of medial subsidence, as demonstrated by Walch et al. Gerber et al reported on 23 TSAs in which eccentric reaming was used to address glenoid retroversion and posterior humeral head subluxation. Five patients had a B2 glenoid, and the remainder had either a B1 or C glenoid. Glenoid retroversion was measured on CT scans by the Friedman method, which is equivalent to the intermediate glenoid retroversion. The mean retroversion was 18° preoperatively, and corrective reaming was performed up to a maximum of 15°. At 42 months after surgery, they reported that 21 of 23 patients had postoperative resolution of posterior humeral head subluxation. However, postoperative retroversion was still a mean of 9° and ranged from 0° to 25°. These values are concerning, given the risk of early failure when the glenoid is implanted in greater than 10° of retroversion. Finally, the results are difficult to interpret because only 12 of the 23 patients (52%) had primary glenohumeral arthritis, with the remaining having mixed diagnoses. Yet, the B2 glenoid was described specifically for primary glenohumeral arthritis, which is distinct in development and natural history from pathologic processes such as posttraumatic arthritis and postinstability arthritis. Similar to Gerber et al, Habermeyer et al reported that posterior humeral head subluxation could be adequately corrected with eccentric reaming and TSA. At a mean follow-up of 2 years (minimum 1 year), they reported that 20 of 24 TSAs were centered. They did not state which of these patients had a B2 glenoid, and their measurements of subluxation were based on plain axillary radiographs, which are less precise that CT scan evaluation. Both this study and the study by Gerber et al are also limited by the short-term follow-up.

Walch et al reported on 92 TSAs performed for B2 glenoids reviewed at a mean of 77 months postoperatively.
Revision surgery was required in 16%, and glenoid loosening was observed in 21% of cases. Preoperative posterior humeral head subluxation of 80% or greater carried an 11% rate of posterior dislocation with TSA. Similarly, when the neoglenoid retroversion was 27° or greater, the risk of glenoid loosening or posterior dislocation was 44% (Fig. 6). Notably, revisions for glenoid loosening were performed at a mean of 96 months after the initial surgery, and the revisions for posterior dislocation took place at a mean of 30 months after the initial surgery. These time frames suggest that the follow-up in the aforementioned studies may not have been adequate to detect the mid-term failures that occur with the use of anatomic TSA in the setting of a B2 glenoid.

In addition to eccentric glenoid reaming, it is also possible to manage posterior glenoid erosion with bone grafting or a posteriorly augmented glenoid (Fig. 7). Neer and Morrison reported excellent results in 16 of 19 (89%) TSAs at a mean of 4.4 years after autologous bone grafting of the humeral head to the glenoid.25 Similarly, Steinmann and Cofield reported that at a mean of 5 years postoperatively, 23 of 28 (82%) had satisfactory results after concomitant bone grafting and TSA.35 However, 3 (11%) of the glenoids were considered radiographically loose, and the length of follow-up was 7.7 years in the radiographically loose group compared with 5.7 years in the group without loosening, questioning the long-term viability of this approach. Hill and Norris reviewed 17 TSAs at a mean of 70 months postoperatively that had undergone concomitant bone grafting to address glenoid erosion.14 Five (29%) of the grafts failed, and the results were considered unsatisfactory in 8 (47%) cases. Moreover, only 5 cases were performed for primary osteoarthritis. In the aforementioned B2 series by Walch et al,38 7 patients underwent concomitant glenoid bone grafting (from the humeral head) and anatomic TSA when it was anticipated that anterior reaming to correct retroversion to less than 10° was not
possible. Unfortunately, this method was successful in only 2 patients.

Kirane et al performed a biomechanical analysis in which TSA with a standard glenoid implanted in neutral version was compared with a polyethylene or titanium posterior-step glenoid implanted into simulated biconcave defects (Fig. 8). They reported that the polyethylene posterior-step glenoid performed similar to a standard TSA. However, the clinical relevance of this study is not clear, and their model did not address posterior subluxation. Rice et al reported a clinical study of 14 TSAs performed with a posteriorly augmented polyethylene glenoid with an asymmetric slope (Fig. 9). They found that instability, particularly posterior subluxation, persisted despite the novel glenoid, and the device has been discontinued. Similarly, Neer et al described the use of a posteriorly augmented polyethylene component that was discontinued.

In addition to addressing the glenoid, strategies to restore glenohumeral stability in the setting of a B2 glenoid include anterior release, posterior capsulorrhaphy, and altering humeral retroversion. As in all cases of shoulder arthroplasty, a 360° release of the subscapularis tendon is important in restoring motion and achieving soft tissue balance. In the setting of posterior humeral head subluxation, the anterior structures become tight and push the humeral head posteriorly. Therefore, a thorough anterior release may help restore glenohumeral stability. In the corollary to anterior release, a posterior capsular plication can be performed at the time of TSA to tighten the posterior structures. Most studies make only casual mention of posterior capsular plication with unclear guidelines for its use. In the B2 series by Walch et al, 9 patients had a supplemental posterior capsular plication when intraoperative testing with the arm in neutral revealed posterior static subluxation of >50% of the humeral head diameter. These patients were noted to have lower postoperative forward elevation and mobility component of the Constant score. In addition, 3 patients who underwent revision for postoperative posterior dislocation had a posterior capsular plication, and all 3 were considered failures. Finally, performing the humeral osteotomy in less retroversion may theoretically be used to compensate for posterior subluxation. The utility of these techniques, however, is difficult to quantify as they are often used together and in conjunction with the aforementioned techniques described to address posterior glenoid erosion. Moreover, it appears that even when correction of the posterior glenoid erosion is possible, the long-term ability to correct posterior instability is not reliable. In other words, posterior humeral head subluxation appears to be the primum movens, or source, rather than the consequence of a B2 glenoid.

**Reverse shoulder arthroplasty**

RSA is most commonly indicated for glenohumeral arthritis with severe rotator cuff insufficiency. RSA has also
been increasingly reported in the management of revision arthroplasty because the constrained nature of the prosthesis allows correction of instability, and the ability to perform concomitant bone grafting by screw fixation of the glenosphere is useful in managing glenoid bone loss. The high failure rate of posterior bone grafting and the inability to durably correct posterior instability of the humeral head with an anatomic TSA led Mizuno et al to investigate the use of a primary RSA for a B2 glenoid. A retrospective review was performed of 27 RSAs implanted for primary glenohumeral arthritis with a B2 glenoid at a mean of 54 months postoperatively. Ten patients underwent glenoid bone grafting to address posterior glenoid erosion; 3 cases were performed as a two-stage procedure with iliac crest bone graft, 1 case was performed as a single-stage procedure with iliac crest bone graft, and 6 cases were performed with our current technique of choice as a single-stage procedure with humeral head autograft after the BIO-RSA technique described by Boileau et al (Figs. 10 and 11). The mean Constant score increased from 31 to 76, and no recurrence of posterior instability was observed. One patient, in whom glenoid bone grafting was performed with a 15-mm central post (as opposed to the 25-mm post currently used), experienced early glenoid loosening.

Although further follow-up is required to determine the long-term durability of this approach, the results suggest that RSA may provide a solution to the static posterior instability and posterior glenoid erosion that occur with a B2 glenoid, particularly in older patients.

**Conclusion**

The B2 glenoid presents a difficult reconstructive problem with high failure rates due to early glenoid loosening or recurrent posterior instability with the use of anatomic arthroplasty. Mild deformities may be corrected by eccentric reaming and TSA. However, severe deformities have a high rate of failure at mid-term follow-up. In particular when posterior humeral head subluxation is greater than 80% or neoglenoid retroversion is greater than 27°, an unacceptably high rate of complications has been observed in our experience. When posterior erosion cannot be adequately corrected with eccentric reaming, particularly in older patients, RSA may be a viable alternative to unconstrained shoulder arthroplasty.
References


