Management of Glenoid Bone Loss in Reverse Shoulder Arthroplasty

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Abstract

Reverse shoulder arthroplasty has greatly improved the outcome of patients who required a shoulder arthroplasty but have concomitant rotator cuff pathology. The most important aspect of reverse shoulder arthroplasty is securing a stable glenoid baseplate. This may be challenging in cases with severe glenoid bone loss and also in revision cases. This purpose of this review is to cover the diagnosis, evaluation, and treatment of glenoid bone loss in primary and revision reverse shoulder arthroplasty

Keywords: Reverse shoulder arthroplasty, glenoid bone loss, outcomes

Introduction:

Since its introduction in France in the early 1990s and its approval by the Food and Drug Administration in 2003, the indications for the reverse prosthesis have expanded exponentially [49]. Reverse shoulder arthroplasty (RSA) has become a successful treatment option for patients with advanced glenohumeral arthritis and whose rotator cuff pathology precludes the use of anatomic style prostheses. Indications for the reverse arthroplasty include rotator cuff tear arthropathy, proximal humerus fractures and their sequelae, inflammatory arthritis, revision arthroplasty, and glenoid bone loss in the primary and revision settings [10; 20; 38; 39; 44].

In the setting of glenoid bone loss, the reverse prosthesis provides the surgeon with multiple options to achieve a functional, stable shoulder. However, all of these options are dependent on establishing a stable glenoid baseplate in the correct location and version. In the setting of advanced glenoid bone loss, this can be difficult to achieve. Furthermore, the semi-constrained nature of RSA places increased stresses on glenoid fixation, which may lead to glenoid component loosening and implant failure [5; 7; 8; 37; 40]. Although this is often encountered in the primary setting, severe glenoid bone loss can be particularly challenging in the revision setting.

This purpose of this review is to cover the diagnosis, evaluation, and treatment of glenoid bone loss in primary and revision reverse shoulder arthroplasty.

Glenoid Bone Loss: Etiologies, Evaluation, and Classifications

Etiologies of Glenoid Bone Loss

Understanding the etiology for glenoid bone loss is critical to effectively managing patients, as many of the causes present and progress with specific unique patterns. An in depth understanding enables the surgeon to both counsel patients about their nonoperative and operative options, the likelihood of disease progression, and their reconstructive options. Although proximal humerus fractures and their sequealae can be associated with glenoid bone loss, it is not as commonly seen as with the other indications for reverse shoulder arthroplasty.

In the setting of rotator cuff tear arthropathy, a superior glenoid bone loss pattern is often seen. Occurring in up to 40% of cases of rotator cuff tear arthropathy [10], advanced superior glenoid wear can often be difficult to recognize and plan for preoperatively. Failure to adequately address the superior erosion can lead to excessive superior tilt of the glenoid component, increasing the risk of scapular notching and subsequent glenoid component failure[13; 30].

In the setting of primary osteoarthritis (OA), posterior glenoid wear is often seen, leading to glenoid retroversion in severe cases. In Walch's classic article, greater than 50% of patients with advanced shoulder OA had this abnormal glenoid pattern with some degree of subluxation45. In cases of severe posterior erosion and/or glenoid retroversion, failure to correct this bony defect can lead to poor outcomes related to poor function, instability, and glenoid loosening from malpositioned components with poor underlying bone stock [10; 22; 46].

In the setting of inflammatory arthritis and associated shoulder arthropathy, there is usually a central glenoid erosion pattern and subsequent medialization of the joint line. Reverse arthroplasty is often indicated in these patients, given their either torn or non-functional rotator cuffs as a result of the mechanical disadvantage from joint medialization, as well as their eventual proximal migration of the humerus over time [2]. In the setting of reverse arthroplasty, excessive medialization can lead to a biomechanical disadvantage, compromising shoulder function, stability and potentially increasing the incidence of scapular notching [4].

In the revision setting, glenoid bone loss can be of many different patterns, depending on the remaining bone stock after implant removal. When revising a hemiarthroplasty, the glenoid erosion patterns often mimic

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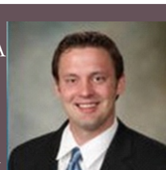
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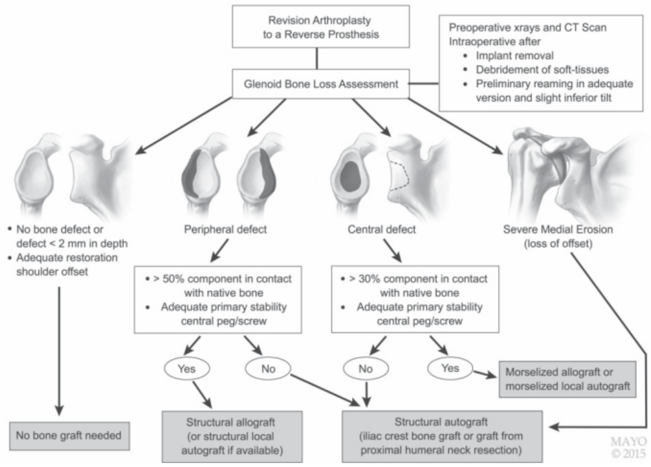

Figure 1: Glenoid Bone Grafting Treatment Algorithm. In an attempt to maximize the implant-bone contact surface, this is the treatment algorithm when deciding to utilize bone grafting in primary and revision reverse shoulder arthroplasty

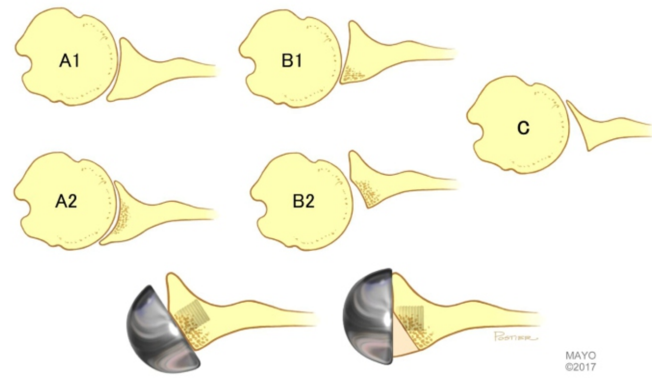

Figure 2: The Walch classification describes the patterns of posterior glenoid bone loss, as seen in OA: A1 minor central glenoid erosion, A2 marked central glenoid erosion, B1 minor posterior glenoid erosion, B2 marked posterior glenoid erosion with retroversion (often above 10o), C glenoid retroversion >25º. Glenosphere placed without graft in retroverted position, and with graft in correct version.

those seen in the primary setting, as previously described. During the revision of a total (anatomic or reverse) shoulder arthroplasty, prior baseplate loosening or removal of a well-fixed glenoid component has the potential to be associated with large glenoid bony defects. The bone loss pattern is variable, and when it is severe enough, can markedly compromise baseplate fixation and overall component stability [43].

Evaluation of Glenoid

A comprehensive preoperative evaluation is imperative prior to performing any type of arthroplasty in the setting of glenoid bone loss. Preoperative radiographic evaluation should include anteroposterior (AP) Grashey in internal rotation and external rotation, axillary, and scapular Y views. The axillary view is especially useful to assess for central, anterior, and posterior glenoid bone loss that might predispose to excessive anteversion, or retroversion. The AP view estimates the central defects that could lead to excessive medialization, or superior defects that might lead to implantation of the glenoid component with a superior tilt.

In addition to standard x-rays, a two-dimensional computed tomography (CT) scan (with slice thickness <1.5 mm) is critical to understand the glenoid bone loss pattern and morphology. The location and extent of the defect is determined using the standard centerline perpendicular to the glenoid surface, exiting on the anterior aspect of the scapular neck [3; 27]. The amount of bone available for central screw or post placement and location of the defect will allow the surgeon to plan their preferred method to reconstruct the glenoid preoperatively. It is also important to determine the effects of the arthritis on the native glenoid version, as studies have found increases in retroversion from 6-10o from arthritis alone [19]. Digital templating software may also be used to estimate not only the size of the new glenoid components, but also the need and size of augments or bone graft, in the primary setting [15; 42]. However, in revision surgery it is common for the surgeon to have to modify their strategy according to

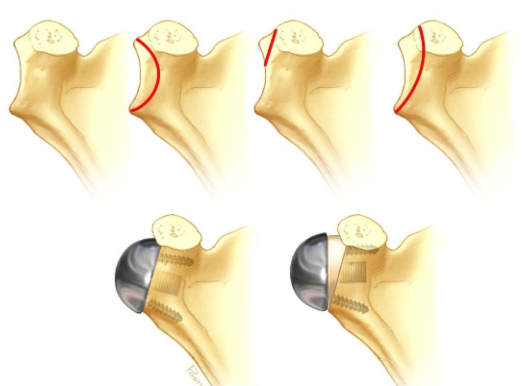

Figure 3: The Favard Classification describes the patterns of superior glenoid bone loss, as often seen in rotator cuff arthropathy: E0 superior humeral head migration without glenoid erosion, E1 concentric erosion of the glenoid, E2 superior erosion of the glenoid, E3 superior erosion of the glenoid extended inferiorly. Glenosphere placed without graft in superior tilt, compared to glenosphere placed with graft in neutral tilt.

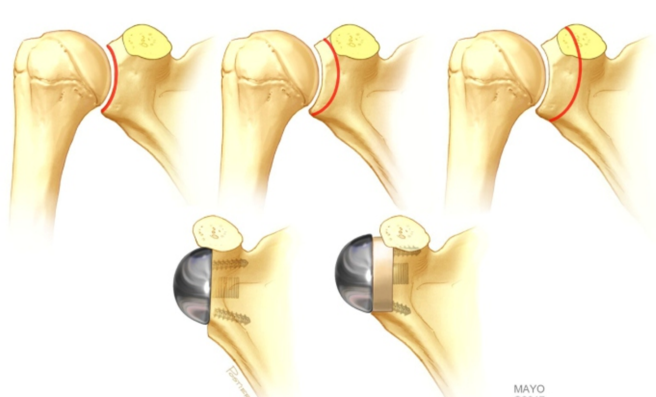

Figure 4: The Levigne classification describes the patterns of central glenoid bone loss, as seen in rheumatoid arthritis: Stage 1 minor central erosion, Stage 2 central erosion to the level of the coracoid, Stage 3 central erosion medial to the level of the coracoid. Glenosphere placed medially, then with graft in more native lateral position.

intraoperative assessment of glenoid bone loss after component removal.

Glenoid Bone Loss Classifications

There are multiple classification systems that have been established to describe the classic glenoid morphology patterns in the setting of glenoid bone loss.

The Walch classification describes the patterns of posterior glenoid bone loss, as seen in OA: A1 minor central glenoid erosion, A2 marked central glenoid erosion, B1 minor posterior glenoid erosion, B2 marked posterior glenoid erosion with retroversion (often above 10º), C glenoid retroversion >25o45. This is useful in the setting of larger glenoid defects, to help the surgeon compensate for retroversion and the potential need for baseplate augmentation posteriorly.

The Favard Classification describes the patterns of superior glenoid bone loss, as often seen in rotator cuff arthropathy: E0 superior humeral head migration without glenoid erosion, E1 concentric erosion of the glenoid, E2 superior erosion of the glenoid, E3 superior erosion of the glenoid extended inferiorly30. This is particularly useful when planning to compensate for superior wear and the need to avoid superior tilt of the baseplate.

The Levigne classification describes the patterns of central glenoid bone loss, as seen in rheumatoid arthritis: Stage 1 minor central erosion, Stage 2 central erosion to the level of the coracoid, Stage 3 central erosion medial to the level of the coracoid. This is useful in cases of marked medialization, when the surgeon desires to restore close to normal glenoid lateral offset, potentially improving shoulder function, stability, and incidence of scapular notching [4].

In the revision setting, the algorithm proposed by Wagner et al. helps to determine the need for and type of bone graft, or alternatively, component augmentation, with the goal of obtaining at least 30-50% implant-bone contact to facilitate adequate ingrowth [43]. Furthermore, as in primary arthroplasty, the graft, eccentric reaming, or component augmentations can be used to correct superior tilt, retroversion, or excessive medialization.

Glenoid Bone Loss: Primary Reverse Arthroplasty

Treatment Strategies

The strategies for addressing glenoid bone loss during reverse shoulder arthroplasty all have a goal of restoring glenoid version, offset, and tilt. Three of the strategies discussed in this article, which all have had moderate success in small short-term studies, include eccentric reaming, use of a lateralized implant, bone grafting, augmented components[14; 10; 23; 27; 33; 38; 43; 50].

Eccentric Reaming +/- Lateralized Implant

Although the algorithm was designed for the setting, its notion of attempting to obtain 50% contact between the baseplate and the glenoid is applicable to the primary setting (Figure 2). In cases of mild glenoid bone loss, eccentric reaming can be a very effective strategy to maximize the contact area of the implant-bone interface and potentially improve ingrowth [27]. A critical step when performing this technique is to determine the correct glenoid version and tilt, as estimated on preoperative imaging [19]. The center guide pin should be placed in the axis of the scapular spine, along the inferior part of the glenoid. Although it is important to maximize implant-bone contact, excessive reaming should be avoided due to the concern of removing unnecessary glenoid bone stock and over medializing the implant. In particular, there is concern with this technique regarding excessive violation of the subchondral plate thought to be important for glenoid component stability [14; 46]. This would cause the implant to be reliant on weaker cancellous bone, potentially compromising stability and ingrowth. Therefore, morselized corticocancellous allograft or autograft can be packed into any remaining small defects after the eccentric reaming has been finished [17; 43]. Another technique utilizes a lateralized prosthesis to overcome any medialization from the glenoid erosion and eccentric reaming [9]. There have been very few studies that have specifically examined the use of eccentric reaming alone or in combination with glenoid bone grafting. Correcting the underlying glenoid deficiency is critical to correct glenoid tilt and version. Furthermore, preoperative subluxation has been associated with poor outcomes after shoulder arthroplasty [22]. Klein et al. examined 56 reverse shoulder arthroplasties with glenoid bone defects treated with eccentric reaming, with 22 requiring augmentation with bulk autograft [27]. At 31 months follow up, patients had a significant improvement in pain scores and shoulder function, including ASES scores and shoulder motion. Those shoulders that required bone grafting did not have different outcomes compared to those that did not require grafting. Only 2 (4%) required revision surgery secondary to infection. In regards to preoperative subluxation, their review of 240 patients that underwent reverse shoulder arthroplasty, Wall et al. examined 33 patients who required a reverse prosthesis for osteoarthritis associated with static posterior humeral head subluxation [47]. These patients did well, with postoperative Constant score of 65, elevation of 115^{0,} and low number of complications.

Glenoid Bone Grafting

In cases of moderate to severe glenoid bone loss where achieving 50% or greater contact area between the baseplate and native bone is not possible, glenoid bone grafting can help to make up for this bone loss (Figure 2). As detailed above, minor central or peripheral cases of glenoid bone loss can be managed utilized morcellized corticocancellous bone graft. However, in cases of larger defects, structural grafts are needed to achieve glenoid component stability, while restoring near anatomic version, tilt, and offset. The source of the structural graft in the primary setting is often from the resected humeral head [4; 28; 29; 32]. Alternatively, if there is insufficient bone in the humeral head due to prior pathology, trauma, or surgery, the autologous tricortical iliac crest or allogenic structural graft can be utilized1; [25; 33].

It is critical for the surgeon to preoperatively plan the desired reconstruction in these cases of severe glenoid bone loss. In cases of superior glenoid bone loss, it is critical to avoid superior tilt and achieve at least neutral, or even slight inferior glenoid tilt with the use of a structural graft [29]. Peripheral defects require structural grafts compensate for excessive glenoid anteversion (anterior) or retroversion (posterior) [43]. Central defects require bone graft to restore glenoid offset through lateralizing the prosthesis4. Furthermore, in cases of marked medial wear, it is important to have at least 8-15 mm of bone available for the central peg and peripheral screw purchase [4; 31; 35]. In fact, a finite element analysis by Hopkins et al. suggested 16-30 mm of screw purchase in bone lead to a 30% reduction in micromotion18. In all of these cases, the structural bone graft is contoured prior to implantation, then either secured with the baseplate and screws alone, or in combination with separate screws outside the baseplate. Although the indications for glenoid bone grafting with the reverse arthroplasty are still evolving, cadaveric studies involving the anatomic arthroplasties suggest cases of 15o or more of glenoid retroversion should be corrected with structural bone graft [6; 11].

In anatomic total shoulder arthroplasty, glenoid bone grafting is associated with increased rates of complications, as glenoid deficiency leads to increased rates of glenoid retroversion, failure of graft incorporation, and glenoid component loosening leading to resultant revision surgery [16; 24; 33; 34; 41]. To date, there remain few studies examining the results of glenoid bone grafting using the reverse prosthesis. Although not in the setting of glenoid bone loss, Boileau et al. examined 42 patients who underwent structural humeral head grafting to increase the lateralization of glenoid components in in patients without marked bone loss4. At a minimum of 2 years follow-up, no graft resorption or glenoid loosening occurred, 41 of 42 had full incorporation of the graft, and only 19% rate of scapular notching.

Augmented Component

The role of augmented glenoid components is controversial, as its specific indications continue to evolve. Its use has been described in anatomic [12; 21; 26; 34; 36; 48] and reverse [23; 50] shoulder arthroplasty, mostly in the setting of a marked peripheral bone defect (E.g. Walch B2) or with severe glenoid destruction requiring a custom made, patient specific implant. In anatomic shoulder arthroplasty, Rice et al. examined 14 posteriorly augmented keeled polyethylene glenoid components [34]. At a mean 5 year follow-up, patients achieved predictable pain relief and restoration of shoulder function, but had a relatively high rate of unsatisfactory results from recurrent instability and posterior subluxation. Two other small series by Gunther et al.[12] and Sandow et al.[36] reported on custom made augmented glenoid components, demonstrating better short-term results in series of 7 and 10 patients, respectively.

There remains a paucity of long-term studies examining the use of augmented glenoid components, particularly with reverse shoulder arthroplasty. Undoubtedly, there is tremendous potential in cases of severe medial or peripheral bone loss, however, further investigation is required to better elicit its role in reverse shoulder arthroplasty.

Glenoid Bone Loss: Revision Reverse Arthroplasty

Considerations

Although there remains a need for further study regarding glenoid bone loss and the reverse prosthesis in the primary setting, there is even less information regarding its use in the revision setting of glenoid bone loss. Neyton et al. reported on the early outcomes of 9 patients who underwent revision reverse shoulder arthroplasty with glenoid bone grafting33. At 31 months follow-up, patients had a relatively low Constant Score, but had significant pain relief without signs of glenoid loosening, graft failure, or need for revision surgery. Kelly et al. examined 28 patients who underwent revision shoulder arthroplasty using the reverse prosthesis, with 12 shoulders treated with glenoid bone grafting [25]. Although their series reported a complication rate of 50% and a 23% revision rate at 34 months follow up, there was a high level of satisfaction in this complex patient population with 29 of 30 shoulders with a stable prosthesis at last follow up.

We reported on our outcomes of 41 patients who underwent glenoid bone grafting in the revision setting utilizing a reverse prosthesis [43]. At a mean 3 years of follow-up (range, 2-5), 7 (18%) required revision surgery with the majority (n=4) for glenoid loosening. Furthermore, 6 patients had signs of moderate or severe glenoid loosening at last radiographic follow-up, with factors such as increasing BMI, smoking, and a lateralized implant center of rotation increasing the risk. However, patients that did not undergo revision surgery had predictable pain relief, improvements in their shoulder motion, and high satisfaction. It should also be noted that only 5 patients were treated with structural grafts, potentially leading to the higher rates of glenoid loosening.

Bone Grafting Treatment Algorithm in Revision Reverse Arthroplasty

From our past experience, we have a proposed treatment algorithm (Figure 1) [43]. In patients that the glenoid is felt to be inadequate for stable fixation in an acceptable position, glenoid bone grafting is strongly considered. Implant-bone contact should be maximized, as well as preserving stability and shoulder motion. In cases with a small glenoid defect, a smaller baseplate can be utilized to maximize contact with the glenoid surface, while filling in the remaining defect with corticocancellous graft. However, in larger bone defects, a larger baseplate is utilized in combination with a structural graft.

As mentioned previously, structural autograft or allograft can be utilized for a variety of glenoid bone defect locations. Larger peripheral defects should be augmented by structural grafts to restore version and improve implant-bone contact. Superior defects predispose to superior tilt, and therefore, morselized (for smaller defects) or structural (for larger defects) can be used to restore neutral or inferior tilt and reduce the risk of scapular notching. And finally, large central (or global) deficiencies predispose to medialization, and thus require structural grafts to restore the natural lateral offset. We recommend if 80% of the undersurface of the glenoid baseplate is not in contact with the baseplate, morselized bone grafting is considered, while structural graft is considered in cases where less than 30%-50% of the component is in contact with the glenoid to augment the glenoid contact and fixation.

Conclusions

Glenoid bone loss represents a challenging problem in the primary and revision arthroplasty setting. It has been associated with increased rates of complications, including glenoid malposition, graft resorption, glenoid loosening and increased rates of revision. It is important to have a thorough preoperative work-up, including a high resolution CT scan to evaluate the extent of the bone loss and develop a surgical plan. In cases of mild to moderate glenoid bone loss, eccentric glenoid reaming and/or corticocancellous bone grafting is a reasonable option with the reverse arthroplasty. However, in more advanced cases of moderate or severe glenoid bone loss, structural bone grafting or, potentially, augmented baseplates should be considered. The long-term outcomes of glenoid bone loss treated with the reverse arthroplasty is largely unknown, and further study is critical to better understand the specific indications and treatment options in primary and revision reverse shoulder arthroplasty.

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Conflict of Interest: NIL

Source of Support: NIL

How to Cite this Article

Wagner E, Sperling JW. Management of Glenoid Bone Loss in Reverse Shoulder Arthroplasty. Acta of Shoulder and Elbow Surgery Jan - July 2017;2(1):28-32