Revision of the Loose Glenoid Component in Anatomic Total Shoulder Arthroplasty

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Abstract

Loosening of the glenoid component is a frequent cause of failure of total shoulder arthroplasty (TSA). The etiology of glenoid component loosening is multifactorial and includes aseptic osteolysis, rotator cuff insufficiency, soft tissue instability, and infection. A loose glenoid component is frequently associated with a substantial loss of glenoid bone, which necessitates additional procedures to implant a new component. Several studies have shown that patients with a new glenoid component have better clinical outcomes, which makes successful glenoid reimplantation a priority.

The reconstructive options when facing a loose glenoid component in anatomic total shoulder arthroplasty include the established techniques of reaming the high side or bone grafting the deficient glenoid combined with a one or two stage revision. Augmented glenoid components may allow surgeons to limit eccentric reaming or the extent of bone grafting necessary in a bone deficient glenoid. The reverse total shoulder arthroplasty (rTSA) is emerging as a useful reconstructive option capable of addressing bony and soft tissue problems encountered in revision TSA. The ream-and-run procedure remains the least desirable option in the face of significant glenoid bone deficiency. The increasing use of augmented glenoids and rTSA in revision TSA may provide opportunities for new areas of clinical outcomes research in this challenging reconstructive problem.

Loosening of the glenoid component is a frequent cause of failure of total shoulder arthroplasty (TSA).\(^1\) \(^2\) The etiology of glenoid loosening is multifactorial, including aseptic osteolysis, rotator cuff insufficiency and the so-called rocking horse phenomenon,\(^3\) soft tissue instability (leading to increased edge-loading), and infection. A loose glenoid component is frequently associated with substantial loss of glenoid bone stock, necessitating additional procedures in order to implant a new component. Several studies have shown that patients with a new glenoid component have better clinical outcomes, which makes successful glenoid reimplantation a priority.\(^4\) \(^6\)

The goal of this review is to discuss the reconstructive options when treating a loose glenoid component in anatomic total shoulder arthroplasty (aTSA). These include the established techniques of reaming the high side or bone grafting the deficient glenoid, along with a one or two stage revision. Recently, new approaches to revision have been investigated, including the use of reverse total shoulder arthroplasty and augmented glenoid components. Finally, the ream-and-run procedure remains the last resort option in the face of significant glenoid bone defects. Infection is frequently associated with glenoid component loosening. Although some of the concepts discussed here apply to an infected TSA, its management is beyond the scope of this article and will not be specifically addressed.

Diagnosis of a Loose Glenoid Component

The diagnosis of a loose glenoid component relies on identifying significant or progressive lucency surrounding a glenoid component in the context of ongoing pain. Lucent lines associated with the glenoid component following total shoulder arthroplasty are commonly reported, especially...
with the progression of time, and range between 30% and 84%.\textsuperscript{7-13} However, no definite causal relationship between their presence and clinical loosening has been established.\textsuperscript{14} The true rate of clinical failure and revision TSA due to a loose glenoid is lower than the rate of postoperative radiographic lucent lines and is reported between 3% and 10%.\textsuperscript{1,7,12,15-17}

Glenoid lucent lines are classified according to Deutsch’s modification of Souter’s classification system into 6 grades: Grade 0, for no radiolucent line; grade 1, radiolucent line less than 1 mm wide and incomplete; grade 2, radiolucent line 1 mm wide and complete; grade 3, radiolucent line 1.5 mm wide and incomplete; grade 4, radiolucent line 1.5 mm wide and complete; and grade 5, radiolucent line 2 mm wide and complete. A radiographically loose glenoid component is characterized by: 1. a circumferential radiolucent line of at least 2 mm around the glenoid component; 2. progression of radiolucent lines on serial radiographs; 3. presence of cement fragmentation; and 4. gross component migration.\textsuperscript{5}

\textbf{Operative Management of the Failed Glenoid}

The preoperative workup of a patient with suspected glenoid component loosening begins with a careful history and physical examination. The presence, duration, and character of pain is elicited, as well as any previous incisions and signs of rotator cuff and deltoid atrophy. Active and passive range of motion and a complete neurovascular exam are performed. Standard radiographs consisting of a true AP view of the scapula in neutral, internal and external rotation, along with scapular profile and axillary view help evaluate for presence of periglenoid lucencies, glenoid component shift, superior migration of the proximal humerus, and bone defects. CT scan is often helpful in providing greater detail about glenoid bone stock and version to assist with preoperative planning. Infection has to be considered in every case of a suspected loose glenoid component. Complete blood count with differential, erythrocyte sedimentation rate, and C-reactive protein levels should be obtained. Aspiration of the joint can be helpful if the clinical picture is suspicious for infection. Intraoperatively, frozen section specimens can be analyzed for signs of acute inflammation.\textsuperscript{18}

Operative management typically utilizes the deltopectoral interval. In revisions, extensive soft tissue scarring is expected, and the anatomical landmarks are less evident. It is important to release adhesions in the subdeltoid and subacromial spaces. The coracoid process is identified, and the remainder of the clavipectoral fascia is incised along the lateral aspect of the conjoint tendon. The subscapularis is tenotomized or released with its bony insertion, followed by its careful mobilization. CA circumferential glenoid capsular release is performed while protecting the rotator cuff. If present, tenotomy or tenodesis of the long head of the biceps is performed. The axillary nerve at the inferior aspect of subscapularis must be protected during dissection in this area.

Much of the surgical planning and treatment in revision TSA involves managing glenoid bone deficiencies, which are frequently present. These are a result of osteolysis or glenoid component loosening and removal.\textsuperscript{19} Antuna and coworkers\textsuperscript{4} classified glenoid bone defects based on location and severity (Fig. 1). In terms of location, the defects were subdivided as central, peripheral (anterior or posterior), or combined (central and peripheral). Based on severity, the defects were classified as mild, if involving less than one third of glenoid surface or rim; moderate if they involved one to two thirds; or severe if they involved more than two thirds of the glenoid rim or surface.\textsuperscript{4} Ultimately, the treating surgeon’s intraoperative judgment determines how large of a bone defect precludes implanting a new glenoid component. The clinical results of revision TSA in terms of pain relief and motion are historically superior in patients in whom a new glenoid is implanted.\textsuperscript{4,6} Deutsch and associates\textsuperscript{4} demonstrated this in their review of 32 patients who were revised to TSA (15 patients) or hemiarthroplasty (17 patients). Although both procedures, in the absence of preoperative glenohumeral instability, resulted in improved function (patient satisfaction and level of pain), the TSA group fared better in terms of pain relief and external rotation. This finding was confirmed by Elhassan and colleagues\textsuperscript{6} who reported on 21 patients undergoing revision with glenoid bone grafting. Although the improvements in the Constant-Murley score and external rotation were similar between the TSA and hemiarthroplasty group, the TSA proved superior in regaining forward flexion. Therefore, in revision procedures, glenoid component implantation should be performed whenever possible.

\begin{figure}[h]
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\includegraphics[width=\textwidth]{Figure1.png}
\caption{The Antuna Classification of glenoid bone loss.}
\end{figure}
The different options for managing glenoid bone defects include use of a cancellous or corticocancellous/structural bone graft, whether to implant a new glenoid as part of a one stage or two stage revision, and whether rotator cuff insufficiency will require the use of a reverse prosthesis. The advantage of a one stage procedure is avoiding the surgical morbidity of a second surgery. The downside to this approach is a potential for loosening of a glenoid component that is supported by unincorporated bone graft due to graft resorption. The choice of cancellous versus structural bone graft largely depends on surgeon preference and the type of glenoid defect. In multiple clinical studies, it has been demonstrated that graft subsidence is frequent, approaching 100% in some series.\(^{20,21}\) The degree of subsidence has been reported as up to 14 mm or more.\(^{21}\) Rotator cuff insufficiency is a frequent cause of glenoid loosening that leads to TSA revision.\(^3\) Therefore, the treating surgeon has to be prepared to perform soft tissue reconstruction or a reverse total shoulder arthroplasty, in addition to glenoid reconstruction. The reconstructive ladder, in order of increasing complexity, includes simple glenoid reimplantation, eccentric reaming along with standard glenoid implantation, augmented glenoid with or without eccentric reaming, bone graft reconstruction with either one or two-stage glenoid reimplantation, and reverse total shoulder arthroplasty (rTSA). In a situation of catastrophic glenoid bone loss a hemiarthroplasty may be the best (and only) option. Patient’s age and activity level must also be considered and integrated into the surgical decision-making process.

**TSA without Bone Graft**

**Simple Glenoid Reimplantation**

Occasionally, it is possible to revise the glenoid component without significant reconstructive measures, such as bone grafting or high side reaming. Patients with an acute infection or a traumatic event causing glenoid loosening are included in this category, which in turn represents the best-case scenario. After the removal of the loose component, attention must be paid to removal of all bone cement, if present, with as little damage as possible to the surrounding bone. This is followed by superficial reaming of the glenoid surface, sufficient to remove any fibrous tissue and to expose healthy subchondral bone. A new glenoid component is usually cemented using third generation cementing technique.\(^{22}\) Both pegged and keeled components can be used in this situation. Typically, a removed pegged component can be revised to a pegged or keeled implant, depending on the condition of the previous peg holes. A failed keeled component is typically revised to another keeled component.

**Eccentric Reaming with Standard Glenoid Implantation**

Eccentric reaming consists of lowering the glenoid surface opposite the site of peripheral erosion in order to re-establish natural glenoid version (Fig. 2). It is reserved for peripheral and some combined glenoid defects, as classified by Antuna and coworkers.\(^4\) It is imperative to preserve as much glenoid bone stock as possible, and therefore the utility of this technique is limited to small defects. Generally speaking, no more than 10° to 18° of retro- or anteversion can be corrected with this technique without narrowing the glenoid vault excessively and risking peg or screw penetration.\(^{23,24}\) Excessive reaming of the unworn glenoid surface also results in joint line medialization, placing the rotator cuff and deltoid muscles at a mechanical disadvantage, and resulting in weakness. In a clinical series, Iannotti and associates\(^{24}\) demonstrated that no more than 19° of glenoid retroversion could be corrected by high side reaming without glenoid vault perforation by the center peg. Similar findings were reported by Gillespie and colleagues,\(^{23}\) who studied the effects of high side reaming on ability to implant a glenoid component in a cadaver model. After correcting 15° of retroversion by high side reaming, 50% of glenoids were not able to be implanted due to either insufficient bone support, peg penetration, or both. They concluded that 10° of retroversion is likely the limit that can be corrected with preferential anterior reaming.\(^{23}\)

**Augmented Glenoid Implantation**

The use of an augmented glenoid component is another means of compensating for glenoid bone loss and restoring normal anatomic glenoid version. Its use can be facilitated by
simultaneous eccentric reaming or by off-axis reaming (Fig. 2). The different designs of augmented glenoids include implants with asymmetric thickness (increased toward the side of bone loss) and actual step-shaped glenoids (Fig. 3). Such implants enable the surgeon to avoid reaming the high side excessively in order to restore neutral glenoid version and thereby minimize the amount of bone removal. One of the first clinical reports of using this technique was by Rice and coworkers. The investigators implanted an augmented glenoid component in 13 patients with eccentric posterior glenoid erosion to restore neutral version. The component used was an all-polyethylene cemented keeled glenoid with asymmetric thickness in an anterior-posterior direction. The component was capable of correcting the slope of glenoid by approximately 4°. In a mean 5-year follow-up, the investigators reported 14% unsatisfactory results and concluded that although overall pain relief and improvement in function was satisfactory, instability was not always corrected. They concluded that the component did not offer any advantage over standard implants. Recently, Iannotti and colleagues revisited the topic of an augmented glenoid in a biomechanical study. They evaluated the resistance to loosening of four cemented augmented or step-glenoid designs when subjected to repetitive humeral head compression and translation. The investigators found the stepped design to have superior fixation and less implant liftoff in response to eccentric loading, when compared to the asymmetric designs, such as the one used in Rice’s study. However, asymmetric designs have been demonstrated to conserve more bone than stepped glenoid designs.

In a cadaver study, Kirane and coworkers tested two prototypes of posterior augmented glenoid implants (all polyethylene and metal-backed) in a simulated posterior-deficient glenoid (type B2). The investigators measured periglenoid bone strains for each implant under simulated physiologic loading conditions. No significant difference was found between the all polyethylene step-glenoid and a conventional implant in the absence of a defect, prompting the investigators to recommend further mechanical testing of the implant. The metal-backed component induced significantly increased periglenoid strains, potentially implying increased risk of bone resorption and loosening. Youderian and associates reported on early clinical outcomes of 24 patients treated with a new step-glenoid design in primary TSA. Eighteen patients had a minimum follow-up of 6 months, and eight patients underwent a postoperative CT scan. The clinical outcome scores showed significant improvement in 17 of 18 (94%) cases. In the eight shoulders evaluated with the postoperative CT scan, the average glenoid version correction was 16.7°, which was significantly more than the 11.3° achieved by using a standard glenoid with asymmetric reaming in the comparison group. Joint line medialization was also avoided with the augmented design. The mid- and long-term survivorship of these implants remains to be determined.

TSA with Bone Graft

One-Stage Reimplantation

One-stage bone grafting and implantation of a new glenoid component is frequently performed for contained or central glenoid defects amenable to cancellous packing. Small peripheral or combined defects that can be successfully reconstructed with high side reaming or a structural corticocancellous graft can also be managed in a one-stage revision. Immediate new glenoid implantation can be performed if sufficient glenoid rim and surface remains to support the glenoid trial and adequate cancellous bone remains to cement a new component. Generally speaking, no more than 40% to 50% of a new glenoid should be supported by bone graft although biomechanical and clinical data on this subject are lacking. Central glenoid defects are frequently managed with cancellous bone graft while the peripheral and combined defects are addressed with a combination of cancellous and structural bone graft.

There is paucity of studies aimed specifically at evaluating one-stage reconstruction. Most reports include a mixed population of patients, some of which undergo one-stage glenoid

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*Figure 3 Examples of augmented glenoid components. A, 8° Equinoxe posterior augment all-polyethylene pegged glenoid; B, 8° Equinoxe augmented baseplate for rTSA for use with anterior or posterior bone deficiency; C, Equinoxe standard and extended cage peg rTSA baseplates to facilitate bone grafting in the native glenoid; D, 10° Equinoxe superior augment rTSA baseplate for use with superior bone deficiency (Exactech, Gainesville, FL).*
revision with bone grafting. Elhassan and coworkers reported on 3 out of 21 patients undergoing revision for a loose glenoid component who received a TSA. They reported good short-term outcome and the benefit of implanting a glenoid component over biologic resurfacing or bone graft only. Cheung and associates performed revision in 68 shoulders secondary to glenoid loosening. In 33 patients, new glenoid implantation was possible at the time of the revision procedure. The remaining 35 patients were revised to a hemiarthroplasty with glenoid bone grafting. The primary statistically significant benefit of glenoid reimplantation was the increase in forward elevation. There was also a trend toward greater patient satisfaction in the group with an implanted glenoid. The rate of revision-free survival at 5 years was not significantly different between the two groups. Ten years after revision, the revision-free survival rate was marginally higher in the new glenoid group compared to hemiarthroplasty. Overall, the results suggested that a new glenoid component should be implanted if structurally feasible. On the other hand, Bonneville and associates found a significant rate of radiographic loosening of a newly implanted glenoid. In their case series of 42 TSAs revised with or without bone grafting and a cemented PE glenoid, 28 out of 42 (67%) of the new bone grafted glenoids were radiographically loose at 74 months, with seven (17%) requiring second revision due to recurrent loosening. All 10 grafts placed during the original revision were partially or completely resorbed. The investigators postulated that placing the graft between the cortical bone of the glenoid vault and the cement mantle may not be the optimal biological environment to facilitate its healing. The investigators also cautioned about the high rate of soft tissue complications in the form of subscapularis insufficiency and rotator cuff tears in the revision scenario that may contribute to the high rate of failure. Due to the potential problems associated with cementing a new glenoid into a bone-grafted bed, some investigators have preferred a metal-back ingrowth glenoid component. Valenti and colleagues reported clinical outcomes of 10 shoulders revised for glenoid loosening in anatomic TSA at a minimal follow-up of 2 years. The investigators used a new metal-backed implant with a long central peg, superior and inferior screws, and an anterior plate for additional fixation of the bone graft. They reported overall improvement in clinical outcome scores and good integration of the bone graft without radiolucency or glenoid component loosening. There was one case of PE liner dissociation. The investigators concluded that revision to a non-cemented glenoid component combined with bone graft can solve the problem of loosening as long as the rotator cuff is functional although the study population was small and the follow-up short.

Two-Stage Reimplantation

Frequently, the surgeon is faced with bone loss of the glenoid surface or vault significant enough to preclude immediate glenoid reimplantation. In this situation, the loose glenoid component is removed, and all bony defects carefully debrided and bone grafted. Central contained defects are packed with cancellous bone while peripheral or combined defects are reconstructed with a combination of cancellous and structural graft. Currently, there does not appear to be a clear advantage to using either cancellous or cortico-cancellous bone graft in terms of graft incorporation and either serves to restore glenoid bone stock to enable future glenoid revision. Clinical studies have demonstrated that many patients experience adequate pain relief following revision to hemiarthroplasty with glenoid bone grafting and do not require a delayed glenoid reinsetion. Cheung and coworkers reported on seven previously bone grafted patients undergoing glenoid reinsertion for persistent pain with an average follow-up of 79 months. The newly implanted glenoids were a mixture of bone-ingrowth, metal-backed with cement augmentation, and all-polyethylene cemented components. The investigators concluded that good pain relief can be achieved with delayed glenoid implantation, although range of motion cannot always be improved.

Phipatanakul and Norris reported on 24 patients undergoing revision TSA with removal of the glenoid component and bone grafting of the glenoid vault. Eighteen patients had adequate pain relief after the initial procedure, and four patients achieved good pain relief after a second stage glenoid implantation for persistent pain. Graft subsidence was reported in 10 out of 20 cases (50%) although it did not preclude placement of a new glenoid component during the second stage revision. Overall, the investigators found bone grafting of the glenoid beneficial in terms of pain relief (92% of patients) as well as enabling delayed glenoid implantation. However, range of motion did not improve significantly and graft subsidence rate was concerning.

Antuna and associates reported on three patients treated with glenoid implantation at a second stage. These patients previously underwent removal of a loose glenoid and bone grafting with cancellous allograft and experienced continued pain. At the time of re-revision, the investigators found the glenoid depth to be approximately 1 cm, which was limited but sufficient to implant a new metal backed component. One patient had an excellent result at 5 years postoperatively, one satisfactory result at 8 years, and one unsatisfactory result at 2 years with further need for glenoid revision.

Reverse Total Shoulder Arthroplasty (rTSA)

The reverse total shoulder arthroplasty was designed to address the problem of cuff tear arthropathy and clinically has performed well for this indication. In addition to bony glenoid deficiency, soft tissue complications, such as rotator cuff tears, subscapularis insufficiency, and implant instability, are frequently identified during revision TSA. Revision to anatomic TSA with a deficient rotator cuff predictably leads to the so-called rocking horse phenomenon and glenoid component loosening. Similarly, use of a hemiarthroplasty in this scenario is at risk for developing anterosuperior subluxation in patients with previous acromioplasty and
incompetent coracoacromial arch. The unique mechanical design of the rTSA allows it to potentially address all of the anatomical deficiencies in one setting. Recently, the rTSA has been used to address the problem of glenoid loosening in TSA, particularly if associated with rotator cuff tears and uncontained large glenoid bone deficiency. Melis and coworkers reported on 37 anatomic TSAs revised to reverse prosthesis for aseptic glenoid loosening with a mean follow up of 47 months. Thirty-four out of 37 revisions were performed in one stage. Eighty-six percent of patients were either satisfied or very satisfied, and 76% (22/29) of the glenoid bone grafts healed. Functional gains were made mostly in terms of improving active elevation and reducing pain. External and internal rotation did not change. Eight patients (21%) required further surgery due to complications, three of whom had recurrent glenoid loosening. The investigators concluded that rTSA is a reliable revision option and provides stable fixation of the underlying bone graft with the glenoid baseplate and screws. To achieve this, they prefer use of a long peg baseplate to reach native glenoid bone. However, the technique is demanding and associated with a significant rate of complications.

Norris and colleagues describe a novel technique of utilizing an rTSA baseplate fixed to the iliac crest before subsequently removing it with the portion of the ilium, which is then press fit into the glenoid defect. The entire construct is fixed into the scapular body and columns beyond the defect using an extra-long post and screws in the glenoid base plate. The common principle of the above techniques is fixation of the baseplate to the native glenoid while providing stable fixation of the bone graft to allow its incorporation. The bone graft serves to enhance baseplate fixation by being press fit into the glenoid defect. It also prevents excessive joint line medialized. The latter can also be accomplished by using an extended offset/expanded glenosphere.

Patel and colleagues recently reported on their series of 28 patients who underwent revision of a failed shoulder arthroplasty to a reverse prosthesis at an average 41 months follow-up. Amongst the cohort, there were eight failed TSAs, with the rest being failed hemiarthroplasty and rTSA. The etiology of failure of the original implants was heterogeneous with implant loosening being reported in only three patients. The glenoid was bone grafted in four patients. The investigators reported overall significant improvement in all of the outcome measures (ASES, UCLA, SST, VAS scores), as well as forward elevation which increased 64° on average. Twenty-three patients (82%) rated their outcome as good, excellent, or satisfactory, and 5 patients (18%) rated their outcome as unsatisfactory. Three of the 28 patients (10.7%) had complications. Overall, the investigators concluded that the rTSA can provide increased shoulder motion, decreased pain, and improved functional outcomes in patients with all types of failed shoulder arthroplasty.

As in anatomic TSA, the rTSA comes with an option to implant an augmented glenoid component to compensate for asymmetric glenoid wear. In a recent biomechanical study, Roche and coworkers simulated a superior glenoid defect treated either with eccentric reaming/standard baseplate or off-axis reaming/superior augmented baseplate (Fig. 2). Both constructs were cyclically loaded and compared to a control implant with no glenoid defect. Each glenoid implant remained well fixed after cyclic loading with no statistically significant difference in displacement. Since patients with a failed anatomic TSA can present with a variety of glenoid deficiency, development of augmented glenoid baseplates in rTSA may prove valuable in the future. The reverse shoulder arthroplasty should be used with caution in the revision scenario as long-term survivorship is not well known in a homogenous patient population. It should be reserved for patients 65 years and older. Long-term follow-up is needed to analyze the incidence of some of the documented complications, such as scapular notching and instability.

Hemiarthroplasty

With Glenoid Bone Graft

Revision to hemiarthroplasty (HA) is considered when faced with glenoid bone defect substantial enough to preclude immediate glenoid reimplantation. It can provide a definitive solution, particularly in an older, low demand patient wishing to avoid further surgery. For other patients, it represents the first stage of a two-stage TSA revision with the eventual goal being anatomic or rTSA. The status of the rotator cuff and patient’s age will help determine if a TSA or rTSA will be the final implant of choice. Grafting the glenoid bone deficiency restores the bone stock needed for future glenoid implantation. It also prevents excessive joint line medialized and results in significantly improved outcomes with respect to pain, mobility, and shoulder function when compared to revision without bone grafting the glenoid deficiency. Finally, multiple clinical studies of primary hemiarthroplasty performed for osteoarthritis indicate superior results in terms of function and level of comfort when performed without eccentric glenoid wear. Therefore, it would stand to reason that correcting any eccentric glenoid wear by a combination of reaming and bone grafting would result in improved clinical results in a revision situation.

Neyton and coworkers reported on nine patients undergoing TSA revision for a loose glenoid component with bone loss significant enough to prevent new glenoid implantation. The glenoid defects were reconstructed using iliac crest bone grafting with modification of positioning the bicortical graft such that the cortical surface faced laterally. In a mean follow-up of 30 months, the clinical outcome was considered satisfactory in five and unsatisfactory in four patients. The mean graft subsidence was 4.1 mm. Two cases that were observed to have 10 mm and 11 mm medialized were also found to have anterior-superior migration of the humeral head suggestive of a massive rotator cuff tear. Only one patient decided to undergo additional surgery. He was revised to a reverse total shoulder due to a massive cuff...
tear. Intraoperatively, solid graft incorporation was found, enabling stable fixation of the glenosphere. The investigators concluded that adequate pain relief and glenoid bone stock restoration could be achieved with removal of the loose glenoid combined with bone graft. This procedure also prevented excessive joint line medialization provided the rotator cuff was intact. However, functional outcomes in terms of motion did not improve. Scalise and Iannotti21 revised 11 failed TSAs to a hemiarthroplasty combined with bone grafting of glenoid defects. They used cancellous allograft to fill the void of central/contained defects, and structural graft to reconstruct peripheral or combined defects. At a minimum 2-year follow-up the investigators noted overall improvement in clinical outcome scores. All the grafts showed some degree of resorption, with 8 of the 11 patients experiencing graft subsidence greater than 5 mm. Greater subsidence was seen in structural grafts (mean 14 mm) than in cancellous graft (mean 7 mm). The investigators concluded this difference in subsidence was likely due to lack of a supporting cortical rim in defects treated with structural graft, rather than the type of graft used. The presence of graft subsidence, although concerning, did not influence the clinical outcome scores.21

**HA without Glenoid Bone Graft (Ream-and-Run Procedure)**
The ream-and-run procedure has been used with clinical and radiographic success in shoulder reconstruction. It addresses...

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**Figure 4** Treatment algorithm for the management of the loose glenoid component.
significant glenoid bone loss with reaming the glenoid to a slightly larger radius of curvature than a newly implanted humeral head. Matsen and associates\textsuperscript{48} describe this procedure and consider it a reconstructive option in patients wishing to avoid the risk of glenoid loosening.\textsuperscript{48} There is paucity of literature on the use of this technique in revision TSA. The outcome data reported is primarily associated with primary arthroplasty. Lynch and colleagues\textsuperscript{49} found significant improvement in self-assessed pain and function at a 2-year follow-up using this technique in 37 patients. The final functional outcome of patients with preoperative glenoid wear was equal to the patients without preoperative glenoid wear. Better outcomes were observed in patients who developed a lucency between the humeral component and the reamed glenoid surface on their final follow-up radiograph, suggesting some degree of joint surface regeneration.\textsuperscript{49}

Gilmer and colleagues\textsuperscript{50} analyzed the factors prognostic for clinical improvement following the ream-and-run procedure in 176 patients. They concluded the patients with the most favorable outcome were men over 60 years old with no previous surgery, primary shoulder osteoarthritis, a preoperative SST score greater than or equal to 5, and those who underwent surgery after 2004.\textsuperscript{50} In a revision situation, the ream-and-run procedure can serve as a last resort option for a surgeon facing a severely deficient glenoid without the possibility of bony reconstruction.

Conclusion

Revision of a loose glenoid component in TSA poses a surgical challenge. The literature available on this subject indicates an advantage to implanting a new glenoid component. However, the correct timing of new glenoid implantation is not clear. It may be preferable to bone graft any existing glenoid bony deficiencies and reserve glenoid reimplantation for a later stage if continuing symptoms indicated the need for further revision. Bone grafting also restores the natural joint line and kinematics. The augmented glenoid components may allow surgeons to limit eccentric reaming and the extent of bone grafting necessary in a glenoid with bone deficiency. The reverse total shoulder arthroplasty is emerging as a useful reconstructive tool capable of addressing bony and soft tissue problems encountered in revision TSA. The increasing use of augmented glenoids and rTSA in revision TSA provides opportunities for more clinical outcomes research on this important subject (Fig. 4).

Disclosure Statement

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