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Glenoid bone loss in primary and revision shoulder arthroplasty

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Abstract

The management of glenoid bone loss is a major challenge in both complex primary and revision arthroplasty surgery. To deal with this problem, a number of techniques have been advocated, although there has been no previous systematic review of the literature. In the present review, we have attempted to identify a coherent strategy for addressing this problem, taking into account the degree of bone loss, the advantages and limits of standard implants, bone reconstruction techniques and the use of customized prostheses.

Keywords

anatomic replacement, arthroplasty, glenoid, primary, reverse replacement, revision, shoulder

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Introduction

Shoulder arthroplasty was popularized by Neer in the 1970s for the treatment of primary osteoarthritis. Subsequently, its indications have been expanded to include inflammatory arthritis, osteonecrosis, instability and trauma.[1] As a result, the number of arthropasties performed in the UK has more than doubled from 1396 in 2012 to 3032 procedures in 2014.[2] Associated with this increase, there has been a greater awareness of the problems of glenoid bone loss.

Historically, severe glenoid bone loss was a relative contraindication to performing a primary or reverse shoulder replacement. More recently, however, there has been considerable interest in compensating for this deficiency.[3–7]

In the present review, we aim to outline the patterns of glenoid bone loss encountered in both primary and revision shoulder arthroplasty and discuss the options available for assessment and reconstruction of these deficits. Namely:

- Assessing glenoid bone loss.
- The role of humeral hemiarthroplasty.
- The limits of implantation of a standard glenoid implant.
  - Anatomic shoulder replacement
  - Reverse shoulder replacement
- Bone graft reconstruction techniques.
- The role of augmented and custom implants.

Assessing Glenoid Bone Loss

Pre-operative planning is essential in assessing glenoid bone loss. Radiographs should always be performed and help identify the pattern and degree of arthritic changes.[8] Anteroposterior and axillary views also provide a useful, initial, two-dimensional assessment of glenoid bone stock. This is best appreciated on the axial radiograph but it has been shown that this view overestimates retroversion in up to 86% of cases.[8] Computed tomography (CT) provides more detailed, three-dimensional information with regards to bone loss, version and vault anatomy.[8,9] The axial CT slice

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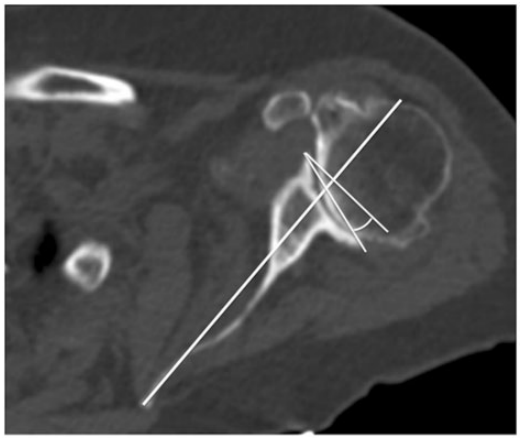

Figure 1. The method of Friedman et al.[9] for assessing glenoid retroversion. An axial computed tomography slice is taken at the level of the tip of the coracoid and a line is drawn from the medial scapula border through the middle of the glenoid. The retroversion is calculated by the angle between the glenoid joint line and the perpendicular of Friedman's line.

is the most reproducible method of quantifying version. Friedman et al.[9] described a method using an axial slice at the level of the coracoid tip. The version is equal to the angle subtended by a line drawn between the scapular axis (from the medial tip of the scapula to the midpoint of the glenoid) and the glenoid face (between the anterior and posterior margins of the glenoid face) (Fig. 1).

A number of classification systems based on radiographs and CT have been advocated to help define glenoid bone loss[10] but we will only consider those that are most commonly used. Walch et al.[11] described glenoid wear in primary osteoarthritis and developed a classification based on the glenoid version identified on the axillary lateral radiograph:

- A (59%) Central erosion (1: minor; 2: severe).
- B (32%) Posterior humeral subluxation (1: joint narrowing; 2: marked erosion and biconcave glenoid).
- C (9%) Greater than 25° retroversion (Fig. 2).

In as many as 40% of these cases, posterior glenoid erosion culminating in retroversion needs to be addressed at the time of arthroplasty.

Habermeyer et al.[12] proposed a complimentary classification that examined the inferior tilt and erosion of the glenoid to document inferosuperior bone loss. This is underappreciated if the classification of Walch et al.[11] is used in isolation. The classification relies on the relationship of a line drawn from the superior to the inferior glenoid rim in comparison to a vertical line at the level of the coracoid.

- Type 0 (13%) demonstrated parallel lines.
- Type 1 (16%) demonstrates intersection of the lines below the glenoid, type 2 (54%) at the level of the glenoid.
- Type 3 (17%) the intersection is above the coracoid (Fig. 3).

Correction of glenoid alignment is therefore important in both planes.

Rotator cuff arthropathy produces a different pattern of wear as a result of the loss of restraint to superior migration of the humeral head. Sirveaux et al.[13] described another type of wear pattern resulting from superior migration and superior glenoid erosion:

- E0 (49%) Superior migration with no erosion.
- E1 (35%) Concentric glenoid erosion.
- E2 (10%)Superior glenoid erosion.
- E3 (6%) Progression to inferior glenoid erosion.

Over 50% of patients with a cuff arthropathy will have a degree of glenoid erosion. Of note, this approach only documents the erosion in a supero-inferior plane and, commonly, there is also a degree of posterior glenoid wear that also needs to be appreciated and addressed.[2]

Assessing a three-dimensional structural deficit in two dimensions clearly has limitations. Our experience would suggest that most patients exist along a spectrum of glenoid arthrosis between a pure primary arthrosis and a pure cuff deficient arthropathy. Antuna et al.[7] described an intra-operative classification of glenoid bone loss during revision surgery. It is based on a two part classification relating to the area of bone loss (central, peripheral or combined) and the severity (mild,moderate and severe). Of note, of the 43 patients in whom the glenoid component was removed, 18 (42%) had such poor bone stock that a new component could not be implanted.

Page et al.[14]proposed a modification of this classification to aid impaction grafting at revision. They classified defects as:

- Type 1: contained (an intact glenoid rim and vault wall).
- Type 2: uncontained but can be converted to containable (an intact rim but a vault perforation).
- Type 3: uncontainable (a deficient rim and vault) (Fig. 3).

Type 1 are amenable to impaction grafting, type 2 can be converted to type 1 with either mesh or cortical graft and then receive impaction grafting and, finally, type 3 are not amenable to impaction grafting (Fig. 4). Antuna and Seebauer later proposed a modified classification system based on this for describing all glenoid

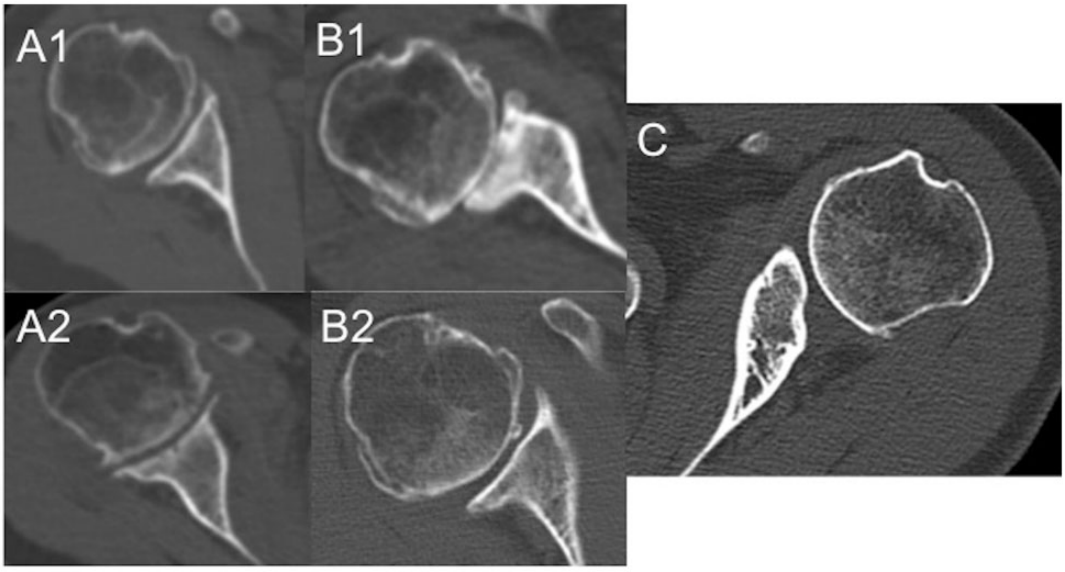

Figure 2. Examples of axial computed tomography slices to illustrate the classification of Walch et al.[11] for glenoid erosion: A1, mild concentric glenoid wear; A2, marked concentric glenoid wear; B1, eccentric posterior glenoid erosion; B2, with a biconcave glenoid; C, greater than 25° retroversion.

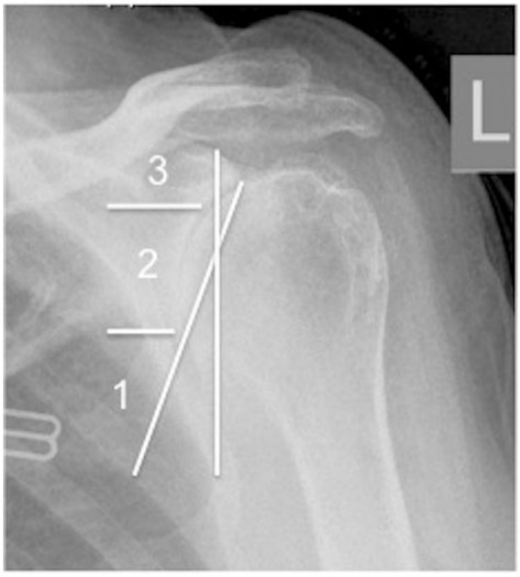

Figure 3. Classification of Habermeyer et al.[12]: a line is drawn from the superior to the inferior glenoid rim and compared with a vertical line at the level of the coracoid. Type 0, parallel lines; type 1, intersection of the lines below the glenoid; type 2, at the level of the glenoid; type 3, the intersection is above the coracoid.

wear patterns. It essentially describes defects as centric (C1–4 depending on the degree of vault destruction) and eccentric [E1–4 based on the percentage of the defect (minimal, < 30%, 30% to 60% and > 60%) and the location (anterior, posterior, etc.)].[10]

In summary, a clear understanding of the glenoid defect in both primary and revision surgery forms a key part of pre-operative planning. A CT scan is superior to radiographic assessment in appreciating the three-dimensional nature of the deficit and the challenges in restoring correct glenoid alignment and version.

The Role of Humeral Hemiarthroplasty

A shoulder hemiarthroplasty has always been a viable option in the management of shoulder arthritis.[1,15] When, however, a direct comparison is made between a total shoulder replacement and a hemiarthroplasty, the total replacement provides superior results in terms of pain relief, function and satisfaction.[16] A hemiarthroplasy procedure still retains value in certain cases. It can be suitable in the management of younger patients with minimal glenoid wear to provide simpler revision options in the future.[17] It can also act as a reserve option in patients with poor glenoid bone stock that would not tolerate a glenoid component.[3]

There is evidence to suggest that the pattern of glenoid bone loss influences the outcome of a hemiaerthroplasty. Levine at al.[18] reported 86% satisfactory outcomes in concentric glenoid erosion and only 63% satisfactory outcomes in nonconcentric glenoid erosion in 31 patients (over 2 years of follow-up). Ironically, it is often patients with severe eccentric bone loss and retroversion that are not amenable to glenoid implantation and therefore receive a hemiarthroplasty.[3,11,18] Reaming the glenoid (so called 'ream-and-run') to

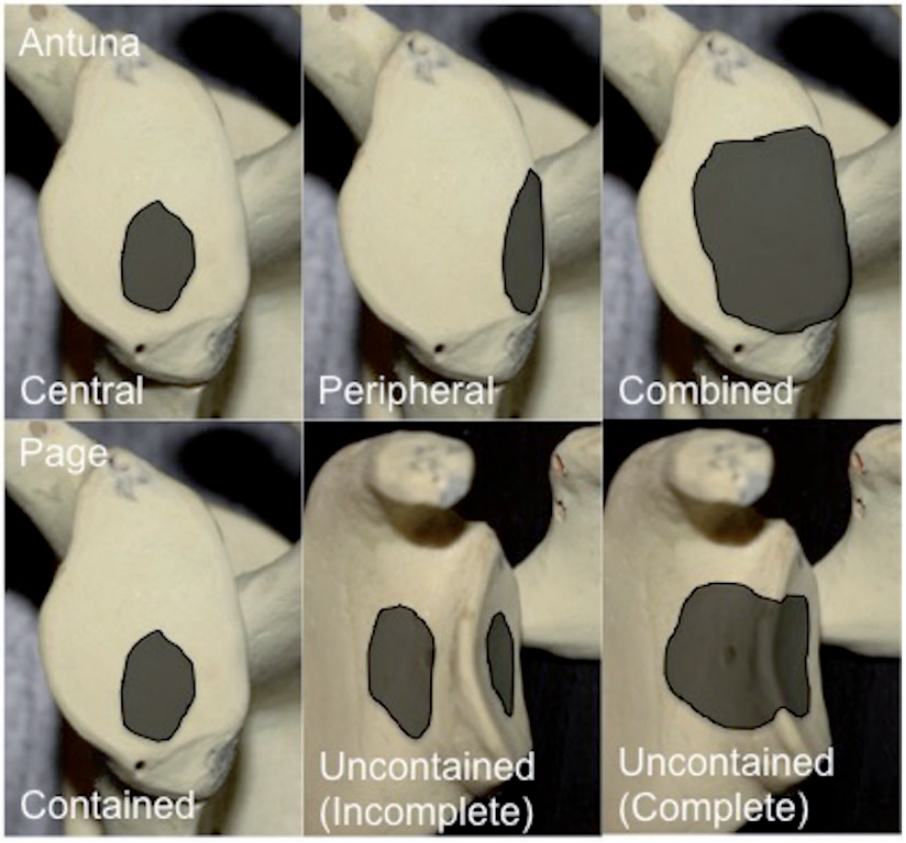

Figure 4. A comparison of the classifications of Antuna et al.[7] and Page et al.[14] for glenoid assessment in the revision. The classification of Antuna et al.[7] describes the defects as central, peripheral or combined as demonstrated (and subdivided into mild, moderate and severe). The classification of Page et al.[14] comments on the state of the vault. A contained defect can easily be impaction-grafted. An uncontained (incomplete) defect requires the defect to be converted to a contained defect prior to grafting. An uncontained defect is not re-constructable with impaction grafting.

produce a concentric defect is a recognized technique[19] but can exacerbate the loss of bone stock and limit future options. Finally, soft tissue resurfacing (with fascia lata or Achilles allograft) has been described[20] but the long-term results are unknown and it is difficult to reproduce.[21]

Prior to the popularization of reverse polarity shoulder replacements, hemiarthroplasty was also used in patients with rotator cuff arthropathy. The results, however, in terms of pain relief and function are poorer than in patients with an intact rotator cuff.[22] Indeed, approximately 25% of patients will report poor pain relief and there is a recognized problem with further bony erosion and instability.[23] The superior results of the reverse polarity design has made it the gold standard implant in the treatment of cuff tear arthropathy and fracture sequelae, and some would suggest it is also the revision implant of choice.[6,24] Despite this, hemiarthroplasty remains a viable salvage option for truly unreconstructable glenoid bone loss (in complex primary and revision situations) and intractable instability in a reverse shoulder replacement. The only other alternatives are excision arthroplasty or attempted arthrodesis.[3,7,12,22,25]

In summary, a humeral hemiarthroplasty will continue to form part of the arthroplasty armamentarium in challenging complex primary and revision situations when implantation of the glenoid component is not a viable option. It also continues to play a role in younger patients and patients with chronic instability following a reverse prosthesis.

The Limits of a Standard Glenoid Implant: Anatomic Shoulder Replacement

The viability of a standard glenoid replacement component is highly dependent on two important principles. First, the glenoid must be carefully reamed to denude the bone but preserve the subchondral plate.[26] Inadequate eburnation can lead to poor seating and fixation of the implant.[25] Over-reaming can risk perforating the subchondral plate, which makes the implant

reliant on the inferior and significantly weaker cancellous bone.[27] This is a recognized cause of early failure.[26]

Second, the glenoid retroversion must be corrected because it will affect the soft tissue balancing and therefore the joint reaction force of the joint. Cadaveric models have demonstrated that as little as 2.5° of glenoid retroversion results in posterior humeral head subluxation, shifting the joint reaction force away from the midline and resulting in eccentric loading of the glenoid component.[28] Indeed, once retroversion increases beyond 10°, fine element studies have demonstrated a significantly reduced contact area, higher contact pressures and a more than seven-fold increase in micro-motion, promoting early loosening.[29] Eccentric loading of the glenoid leads to a 'rocking horse' motion and subsequent failure.[28] In their analysis of 122 failed shoulder arthroplasties, Moskal et al.[30] found that the glenoid component was implanted in excessive retroversion in up to 46%.

As glenoid erosion progresses from grade B1 to B2 according to the classification of Walch et al.[11], we have an increasing dilemma. Do we preserve bone stock and accept a degree of retroversion? Or do we ream the high side ('high-sided reaming') to restore the version and risk compromising the bone stock and loose the subchondral plate? Certainly, B2 glenoids are associated with a degree of retroversion that is likely to lead to early failure.[28]

High-sided reaming involves reaming the anterior glenoid to the level of the posterior glenoid to recreate the glenoid version and re-centre the humeral head, creating a neutral articulation with congruent contact between the bone and the glenoid component. At least 80% of the glenoid component needs to be in contact with the glenoid to be successfully implanted without grafting.[31] Cadaveric studies have shown that high-sided reaming can correct up to 15° of retroversion without compromise.[32,33] In a study of 92 anatomic shoulder replacements, Walch et al.[34] noted that pre-operative humeral head posterior subluxation of 80% or more (of humeral head width) carried an 11% rate of postoperative posterior humeral component dislocation. In addition, when the pre-operative glenoid retroversion was 27° or more, the risk of glenoid component loosening or posterior humeral head dislocation was 44%. The biggest concern with high-sided reaming in B2 or C glenoids is the loss of glenoid vault volume resulting in perforation of the vault wall (with extravasation of cemented in non-metal backed components), violation of the subchondral plate resulting in suboptimal fixation of the implant, and medialization of the joint line resulting in suboptimal soft tissue balancing.[26,27]

Of interest, the development of patient-specific instrumentation is a useful tool in pre-operative planning and may improve the options available to the surgeon. This has been found to be particularly useful in patients with a pre-operative retroversion of 16° or greater.[35]

In summary, care must be taken to correct retroversion to restore soft tissue balance and prevent eccentric glenoid loading. If retroversion is greater than 15°, then consideration should be given to patient-specific instrumentation or consideration of a bone graft.

The Limits of a Standard Glenoid Implant: Reverse Shoulder Replacement (RTSR)

The glenoid component of a reverse shoulder replacement consists of a central peg (with a porous coating for oseointegration) to achieve late fixation via osseointegration and two to four screws to hold the component initially until it integrates.[15,24] It is a more invasive implant than the shallow peg/keel of a total shoulder arthroplasty and there are different considerations when it comes to bone stock. In essence, the two key factors are the depth of the glenoid vault and the volume of the vault. The depth of the vault varies depending of the degree of erosion, although it can be as large as 35 mm and is often at the centre-point of the inferior glenoid circle.[36] Typically, a common peg length starts from approximately 15 mm[36] but this will vary between implant designs. There is little consensus as to the minimum length of peg required, although Boileau et al.[37] reported success with a minimum of 8 mm depth of the central peg as part of their bone increased offset (BIO) technique. We would recommend a minimum depth of at least 10 mm of the coated portion of any implant's central peg.

The volume is important, in that a minimum of two screws must also be inserted to achieve initial fixation. Hopkins et al.[38] performed a finite element analysis of various screw configurations and sizes. In essence, an increase in screw length from 16 mm to 30 mm led to a 30% reduction in micromotion. Increasing the angle of the screw from that of the peg also displayed a linear reduction of micromotion. One must therefore assess the volume of the vault to determine whether it will support longer screws, particularly the superior and inferior screws because they tend to be the longest (Fig. 5). Care must be taken to avoid injury to the suprascapular nerve with the most superior screw.[37]

The advantage of a reverse replacement is that it is less dependent on anteroposterior soft tissue balance and it is therefore more tolerant to retroversion. Wall et al.[39] reported the results of 33 patients who underwent RTSR with static posterior humeral head subluxation as a result of severe retroversion. They noted statistically significant improvements in Constant scores at mean follow-up of 39.9 months. Mizuno et al.[40] reported

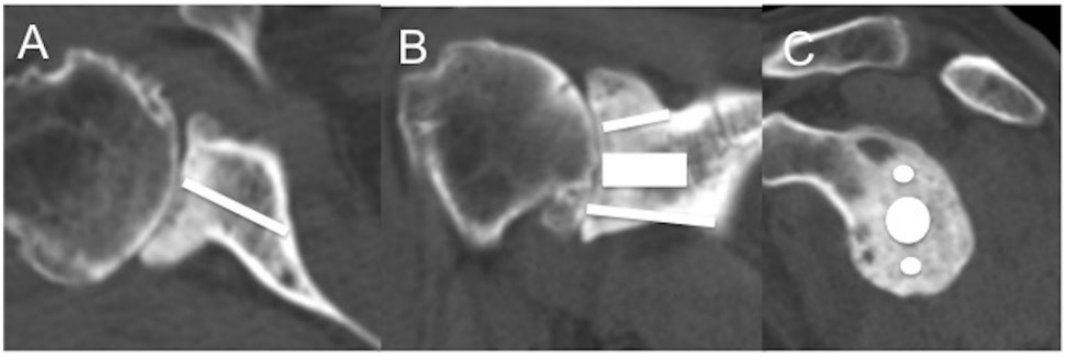

Figure 5. Pre-operative computed tomography scan for a reverse shoulder prosthesis. (A) Axial slice to assess the vault depth to demonstrate at least 10 mm of central peg accommodation. (B, C) A coronal and saggital slice, respectively, with an estimation of the volume of the vault and the room for central peg and screw placement (and screw diversion).

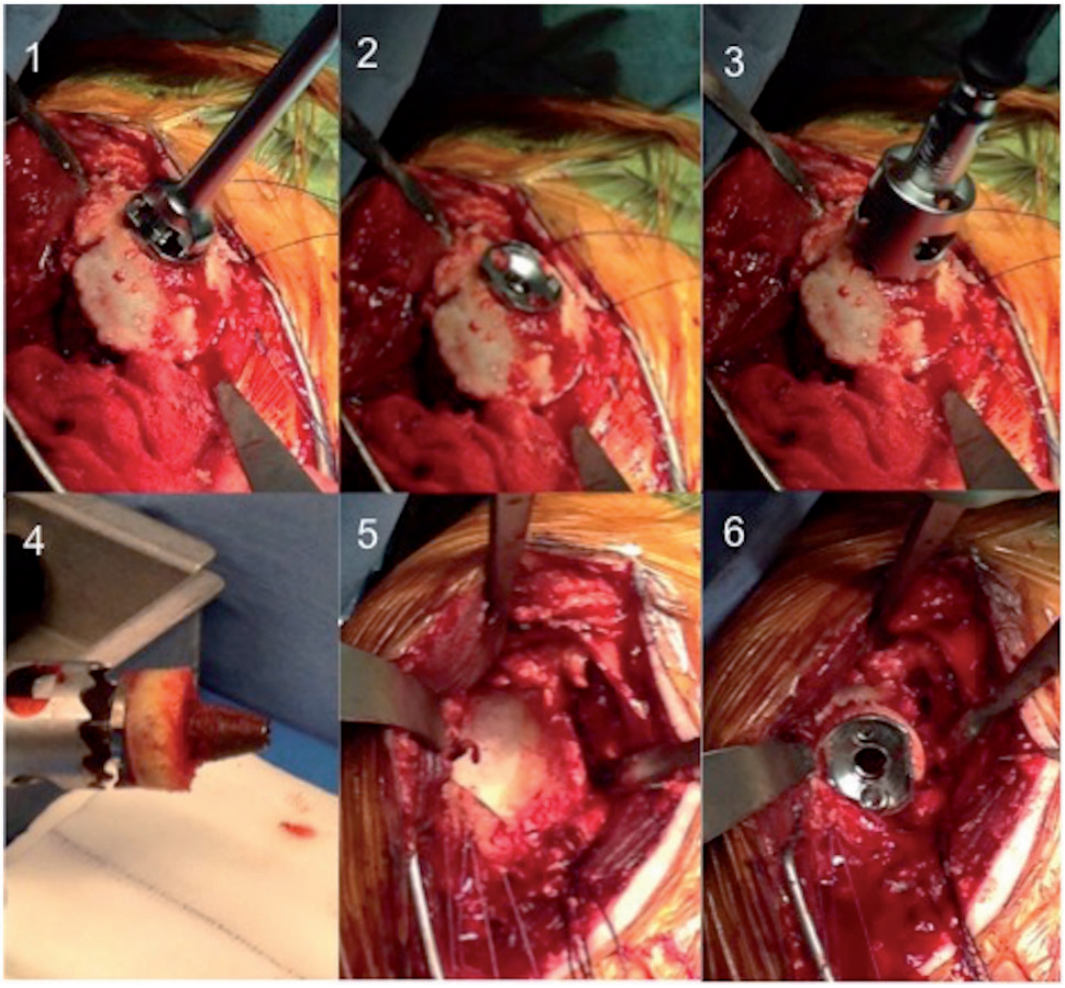

Figure 6. Clinical images demonstrating the harvesting of a autograft from the humeral head (implant: Lima™ Axioma® TT). 1 and 2: The definitive metaglene is implanted into the humeral head. 3: The graft and baseplate is harvested with a circular corer. 4: A significant thickness of graft is obtained and this can be trimmed and shaped to the required depth or even into a wedged graft. 5: The native glenoid is exposed and prepared. 6: The definitive baseplate graft–implant composite is inserted and fixed with two supplementary screws in compression.

statistically significant improvements in Constant score in 27 consecutive RTSR for type B2 glenoids with a mean follow-up of 54 months and with only one case of early glenoid loosening and no posterior instability.

In summary, during pre-operative planning on a CT scan, we recommend that there should be at least 10 mm of native vault depth. In addition, there should ideally be sufficient volume to facilitate at least a 30 mm superior and inferior screw.

Bone Graft Reconstruction Techniques

Bone grafting of a glenoid is indicated when the bone loss is sufficiently severe to prevent the implantation of a standard implant but is contraindicated if the bone loss is so severe that a stable glenoid graft–implant construct is not achievable. There are numerous techniques and approaches to glenoid bone grafting and we will address them in a logical order. The type of technique used will depend on the type of defect, as described by Antuna et al.[7]: central, peripheral or combined. The procedure can be performed as a one- or two-stage procedure and there is also a debate on the type of graft to use.

Central defects are by nature contained and therefore amenable to impaction of the graft into the cavity unless very deep. In their original series, Neer and Morrison[3] reported some success in 45 primary total shoulder arthroplasty cases where a central glenoid deficit was treated with a small, unfixed cancellous graft and implantation of a standard glenoid implant. In the revision setting, Neyton et al.[41] used an iliac crest cortico cancellous graft to pack and fill the large central defect left by a failed anatomic cemented glenoid component. In this series, however, no new glenoid component was inserted. Page et al.[14] described impaction grafting and re-insertion of a glenoid component in the revision setting in four patients with good short-term results. They classified the defect as to whether it is contained, containable (with the use of mesh or cortical graft) or uncontainable. Isolated central defects can be treated with impaction grafting techniques.[14]

Peripheral defects have proven a greater challenge to treat. The main indication has been the correction of B2 type glenoids according to the classification of Walch et al.[11] in the process of total shoulder replacement. Steinman and Cofield[42] reported a series of 17 patients with wedge grafts, separately fixed to the defect, as part of an anatomic replacement. They achieved good or excellent results in approximately 68% of cases but had complete graft lucency in 14% of patients. Hill and Norris[43] had a similar experience with 47% (eight of 17) of cases either demonstrating graft failure/resorbtion or required revision. In a series of 92 anatomics studied by Walch et al.[34], seven patients required grafting and, of those, only two healed. Although there is no direct evidence to pinpoint the reasons for such results, they may be a result of the use of cement that interposes between the glenoid and graft or even a result of chronic soft tissue imbalances causing eccentric glenoid loading and preventing graft union.

In an attempt to improve the results, grafting has been perfomed without a new glenoid implant and, in some cases, a new glenoid prosthesis has been implanted at a later date. In their series of 18 cases, Ianotti and Frangiamore[44] reported resorption in up to 10 cases (55%). Similarly, Phipatanakul and Norris[45] reported up to 50% subsidence of the graft. It is worth noting that, in both series, a humeral component was inserted and this may have affected the union rates.

A good solution to dealing with bone defects has developed from the literature on reverse replacements. Grammont[15] popularized the placement of a reverse glenosphere inferiorly in a medialized glenoid to both tension the deltoid and medialize the centre of rotation (thus reducing stress and the bone–implant interface). This approach will certainly tolerate a degree of erosion of the glenoid when considering the minimum requirements for a reverse baseplate. There are, however, concerns regarding the inferior scapula notching that can occur.[15] In an effort to reduce notching, Frankle et al.[46] examined lateralization of the implant and the centre of rotation. This lateralization of the centre of rotation, however, can increase deltoid abduction forces, raising concerns regarding the implant–bone interface, and scapula impingement[37,47–50]. Boileau et al.[37] proposed a BIO technique, which reconstructs the offset with a circular graft threaded through the peg and pinned with the metaglene screws (Fig. 6).[37] Once united, the implant–bone interface will also be lateralized (although not necessarily over-lateralization of the centre of rotation). In his series, Boileau et al.[37] reported full incorporation of the graft in 41 of 42 cases (98%). It may be the combination of compression of the graft and the added stability of a reverse-type baseplate that provides such favourable results. These results have similarly been replicated in the use of a reverse prosthesis in the revision setting[51,52] (nine patients, 2-year follow-up and no graft failures).

We reported our early experiences[52] of 56 cases with the autologous bone graft–implant composite technique (similar to the BIO technique but without necessarily lateralizing the joint line) for primary and revision cases, with a peg integration rate of 95% and a graft integration rate of 90%. We attribute part of this success to the application of compression onto the graft (by the metal baseplate) and part of it to the use of trabecular metal, which was shown to have excellent

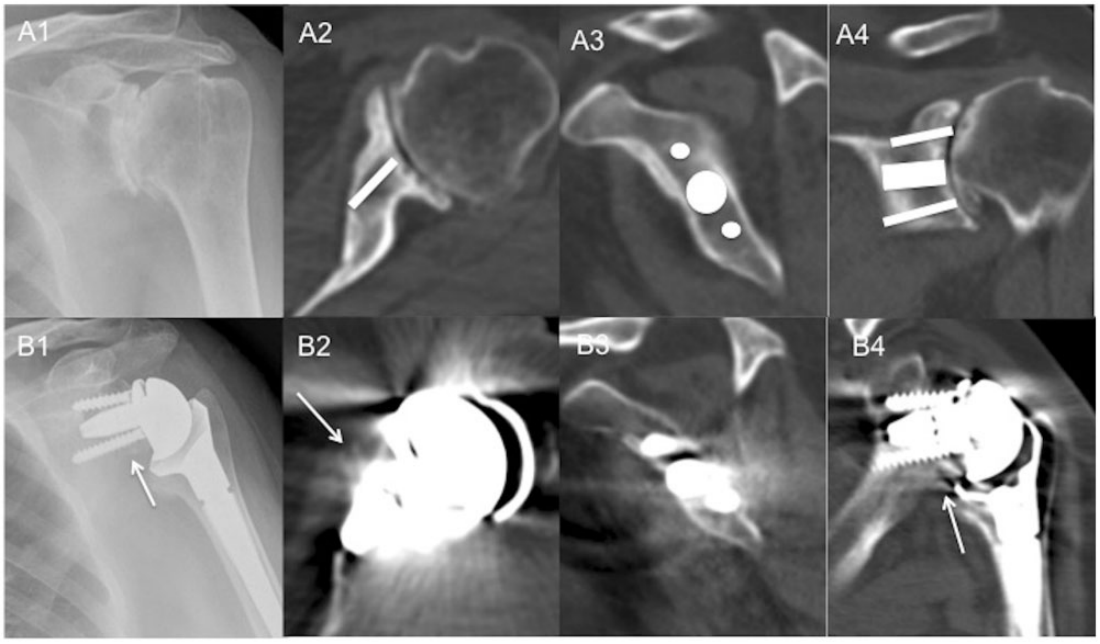

Figure 7. An example of a case treated with a graft–implant composite glenoid reverse shoulder replacement (Lima™ SMR® Axioma TT®). (A) The pre-operative films. Of particular note is the extremely narrow vault on the axial slice (A2) once the glenoid osteophytes are removed. Similarly, the saggital and coronal sclices (A3, A4) demonstrate a limited volume in which the fixation screws can be placed. (B) The 3-month postoperative films and a computed tomography scan demonstrating full integration of the graft and integration of the prosthesis into the native glenoid vault. (B1) The arrow highlights the graft glenoid interface. (B2–4) are available for comparison with the pre-operative films, with the arrow highlighting the graft–glenoid demarcation.

osseo-integrative properties[53,54] (Fig. 7). Of particular note is that, with some modular systems, it is possible to perform an anatomic replacement but to use a metal baseplate with a large peg and screw supplementation (similar to a reverse metaglene). We have used this technique in 16 anatomic shoulder replacements with good results. In our cases where stable fixation was not achieved, the procedure was converted into two stages, with final implantation occurring once the graft had united on CT scan.

The source of bone graft in many of the series discussed has either been a humeral head autograft[14,37,42,51] (in primary replacements) or Iliac crest autograft[3,14,37,41,51]. There is no evidence to support any superiority of iliac crest autograft over humeral head autograft and, given the associated complications of iliac crest graft harvest, we prefer the use of humeral head in the primary setting.[55] This is supported by the literature.[56,57]

In summary, in the case of an anatomic replacement, central defects can be impact grafted and will take a cemented component. Peripheral defects are harder to graft with a standard glenoid implant, and either a glenoid component with a reverse type metal backed baseplate with an autologous graft–implant composite technique or a reverse replacement should be considered. In the case of a reverse replacement, the autologous graft–implant composite technique is a reliable method for restoring bone stock, although good fixation is required in the native glenoid bone stock for it to succeed.

The Role of Augmented and Custom Implants

There are two main indications for the use of nonstandard implants in the presence of glenoid bone deficiency. The first involves the use of glenoids with posterior augmentation in anatomic shoulder replacements to compensate for bone loss. In B2 type glenoids according to the classification of Walch et al.[11], the posterior bone loss can be compensated by wedge augments on the glenoid componenet rather than trying to rebuild the bone. The viability is certainly supported by laboratory and finite element analysis.[58,59] Similarly, a step-cut prosthesis can also be considered to avoid shear stresses at the bone–implant interface.[60] Rice et al.[61] reported the results of 14 keeled cemented all polyethylene posteriorly augmented glenoid components with mean 5-year follow-up. However, the implant did not address posterior subluxation of the humeral head, which resulted in unsatisfactory results.

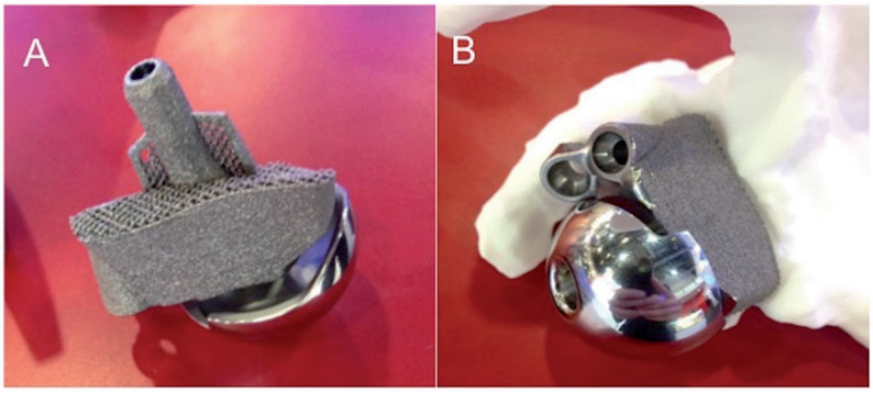

Figure 8. An example of a custom made implant (Lima™ Promade®). (A) Note the custom wedge augment with trabecular metal backing. (B) The implant on a sawbone model. Note the custom screw holes for supplementary fixation.

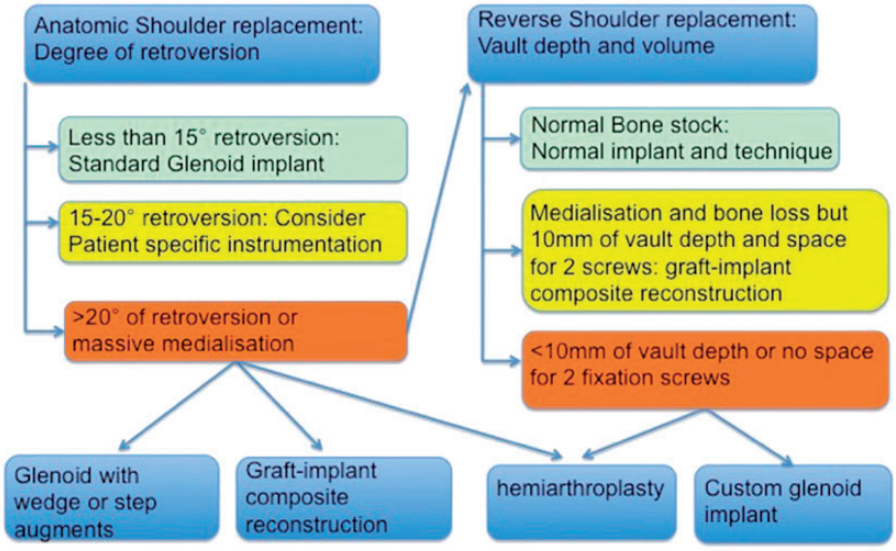

Figure 9. An approach to glenoid bone deficiency management in primary shoulder arthroplasty.

There is a small series by Gunther and Lynch[62] using custom-made glenoid implants in seven patients with severely medialized glenoids. More recently, Sandow et al.[63] reported their series of 10 patients with total shoulder replacements, who received glenoid implants with trabecular metal augments. They demonstrated a correction of up to 25° of retroversion and good integration of the implant at 2 years. There is no long-term clinical evidence regarding the survivorship of posterior augmented implants.

The second indication is the use of a custom made implant specific to that patient. This is an option in the situation where there is such destruction of the glenoid vault that secure fixation of a reverse-type prosthesis is impossible as a result of a lack of bone to accommodate the central peg and predefined screw placement. We have already reviewed the poor results for two-stage bone grafting and therefore we feel that the use of a custom implant may be an option in the future. Much of the experience within the literature relates to the use of tumour endoprosthesis[64,65] and, as such, the results are much poorer than might be expected. This may be the result of the tumour itself or the effect of chemotherapy or radiotherapy. When the hip literature is examined, there is reasonable evidence to support the role of custom acetabular components to treat massive acetabular bone loss.[66,67] There are companies[68] that will offer a custom glenoid implant (Fig. 8) to deal with large bone deficits, although there is no evidence in the literature to support its use at this time.

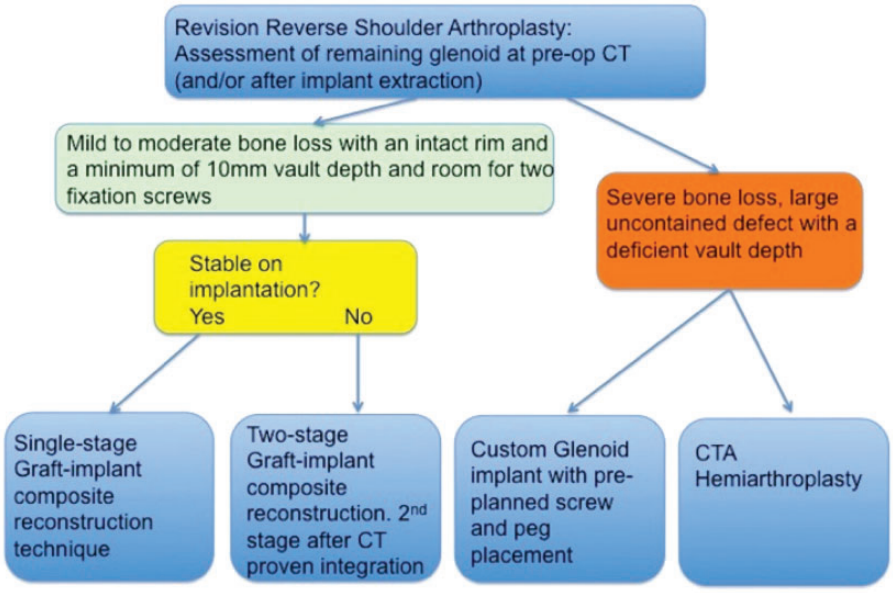

Figure 10. An approach to glenoid bone deficiency at revision surgery (revising to a reverse shoulder replacement).

Conclusions

Although glenoid bone loss represents a significant challenge in shoulder arthroplasty, there are a number of treatment options available. Pre-operative planning with adequate imaging (in the form of a CT scan) and an intimate knowledge of the limitations of each option are the fundamental perquisites for success (Figs 9 and 10).

In an anatomic shoulder replacement, correction of version and soft tissue balancing are important principles that must be corrected in Walch[11] type A and B1 glenoids, In type B2 glenoids, up to 15° of retroversion can be corrected with high-sided reaming. Although central defects can be primarily grafted, peripheral defects and significant retroversion require consideration of either bone grafting, the use of a 'reverse type' metal glenoid baseplate or converting to a reverse prosthesis.

In a reverse replacement, the BIO bone graft technique offers a reliable method of restoring bone stock as well as lateralizing the component to the original joint line. However, a minimum of 10 mm of original vault depth is required to accommodate the peg and screws. We would also recommend at least two fixation screws of 30 mm or greater. If this is not possible, then one should consider either a two-stage procedure (grafting then the definitive implant) or simply use humeral hemiarthroplasty. There is nothing in the literature, at this time, to strongly suggest the use of custom glenoid implants for reverse replacements.

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Ethical Review and Patient Consent

This is purely a review article and any clinical photographs used in the article were taken with written consent from the patients involved.

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