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Review

What to expect after revision shoulder arthroplasty? A comprehensive review of the literature

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Abstract. The number of shoulder arthroplasties has increased tremendously over the last twenty years, creating a proportional increase in complications rates and revision. Shoulder arthroplasty surgeon should have a clear understanding of the reasons for failure based on the specific index procedure that was performed. The main challenge includes the need for component removal and managing glenoid and humeral bone defects. This manuscript aims to outline the most common indications for revision surgery and treatment options based on a careful and detailed review of the available literature. This paper should help the surgeon in patient evaluation and selection of the optimal procedure for an individual patient. (www.actabiomedica.it)

Key words: shoulder arthroplasty, anatomical, reverse, glenoid and humeral bone loss, revision

Introduction

As the rate of primary shoulder arthroplasty continues to increase significantly worldwide so does the need for revision shoulder arthroplasty. While hip and knee replacement are growing at 2 to 3% per year, shoulder arthroplasty growth exceeds 13% (1). Shoulder surgeons must have a clear understanding of the reasons for failure based on the specific index procedure that was performed (2-5). Additionally, the development of a standardized testing regimen is essential to evaluate the most common causes for failure and to plan the revision procedure.

Revision shoulder arthroplasty presents additional challenges including the need for component removal and the more frequent need for managing glenoid and humeral bone defects. Understanding techniques to remove humeral and glenoid components with minimal bone loss is key to avoid significant bone destruction and facilitate reconstruction. Thankfully, there has been an evolution in technology available to manage bone deficiencies. Previously, bone graft was the only option. Similar with hip and knee arthroplasty surgery, there has been a significant trend to the use of metal to manage these deficiencies. This eliminates concern over graft availability, which can be difficult in the revision setting, as well as challenges with bone graft resorption.

This manuscript aims to outline the most common indications for revision surgery and treatment options based on a careful and detailed review of the available literature. This paper should help the surgeon

in patient evaluation and selection of the optimal procedure for an individual patient.

Pathomechanic and cause of failure of anatomical shoulder arthroplasty

Anatomical implants are available in variable design and size with the intent to recreate the proximal humeral individual anatomy (6-7). Research studies demonstrated that increasing the humeral head thickness by 5 mm reduces glenohumeral joint motion by 20° to 30° and results in obligate translations earlier in the range of motion (8); conversely, decreasing the thickness of 5 mm reduces shoulder motion of a similar amount because there is less surface arc available between humeral head and glenoid (9). An undersized humeral head increases capsular laxity and would possibly results, at the extremes of rotation, abutment of the tuberosities against the glenoid rim (10-11). The release of contracted soft tissues is another mandatory step to recover joint motion and restore the appropriate tension of the rotator cuff (RC) and deltoid muscles (10-16). Varus malposition or a high humeral head osteotomy produce overstuffing of the joint, with increased tension on the deltoid and the cuff; prominence of the greater tuberosity due to inferior placement of the humeral component can potentially induce cuff impingement (17). Proper size and position of the prosthetic components and balancing of soft tissue contribute to the joint stability too (18). The stability of a shoulder prosthesis in the transverse plane is related to the force coupling of the posterior and anterior RC muscles. Subscapularis failure is a source of pain and of a variable grade of anterior shoulder dislocation, while a deficient posterior-superior RC induces superior escape of the humeral head (19) (Fig. 1). Most of the issues after anatomical shoulder arthroplasty are present on the glenoid side. Normal glenoid version has been reported close to 0°, rarely with slight anteversion but more often with a retroversion, less than 10° (20). The erosion found in arthritic glenoids was described as central or posterior, with a variable retroversion (21). In presence of abnormal glenoid version, before performing a replacement, the glenoid should be reamed to restore the physiologic version and to preserve the stability of the final glenoid component. Nevertheless, the extensive reaming can lead to an unacceptable loss of cancellous bone, thus increasing the risk of glenoid loosening. The use of modern posteriorly augmented and inlay glenoid components, reducing the need of extensive reaming in posteriorly eroded glenoids, represent a viable replacement option, compared with standard poly-glenoids or to posterior glenoid bone grafting (22-24) (Fig. 2 A-C). Some authors have proposed hemiarthroplasty (HA), as alternative to total shoulder arthroplasty (TSA) in patients with posteriorly worn glenoid. However, the literature showed that HA were associated with residual posterior subluxation and progressive glenoid erosion, sources of continuing symptoms (25) (Fig. 3). TSA are not exempt from complications and the cause of failure have to be analyzed in relation to the type of implant. Metal-backed glenoid (MBG) components have a higher rate of failure and fail by different modes

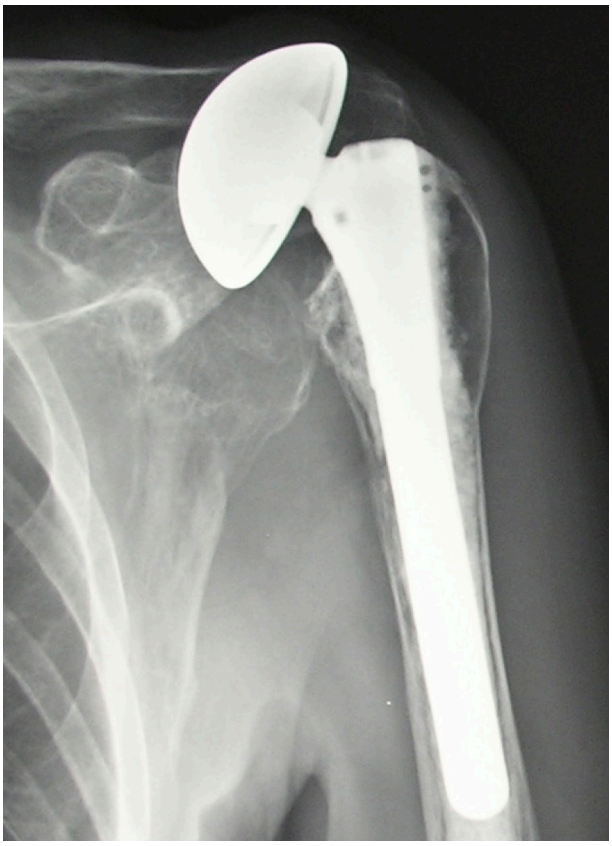

Figure 1: Bipolar Neer II hemiarthroplasty. Anterior-superior escape of the head prosthesis for deficient posterior-superior rotator cuff and subscapularis failure.

Figure 2: A, Standard pegged poly-glenoid component with a flutted central peg (Cortiloc TM, Wright Medical, Tennessee, USA); B, Stemless head prosthesis with inlay poly-glenoid component (Arthrosurface, MA, USA); C, Posteriorly augmented hybrid glenoid component (Zimmer Biomet, Indiana, USA).

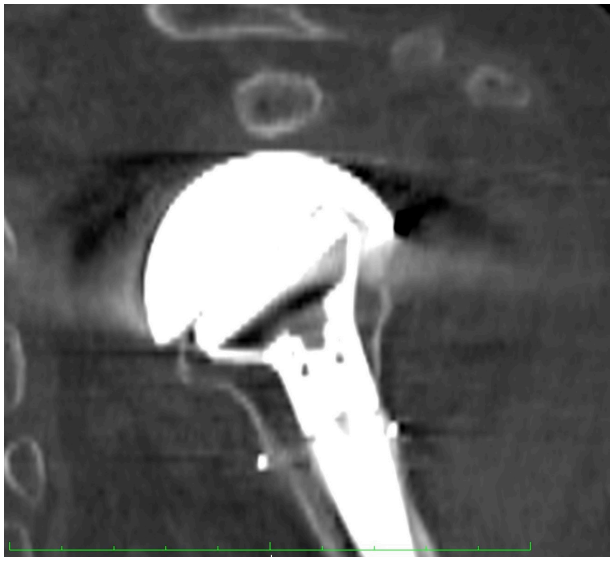

Figure 3: Computed tomography of painful shoulder hemiarthroplasty showing severe glenoid erosion and overstuffing of the head prosthesis.

in comparison with all-polyethylene glenoid components (APGC) (26). The two types of components showed a similar increase in failure at more than seven years of follow-up, but the reasons for revision were loosening for APGC, while MBG failed for reasons other than loosening, such as polyethylene wear, instability, and component dissociation (26). In summary, the failure of APGC in TSA are related to the i) failure of the component itself, ii) failure of seating and fixation, iii) failure of the glenoid bone and management of eccentric loading (2). Distortion of the prosthetic surface and fracture or delamination of the component have been documented (2). Failure of seating and fixation have been related to inadequate preparation of the bone surface, incomplete seating of the prosthesis on the prepared bone, loss of cement between the component and the glenoid bone surface, bone deficiencies, resorption or fracture, and suboptimal cement technique. Loss of glenoid bone quality and quantity leads to failure of glenoid loosening. Increase thickness and extent of radiolucent lines between cement and bone may induce bone resorption and undermine glenoid component fixation. Such bone resorption can result from micromotion, infection or from bone death due to the heat produced by the drilling holes or the curing of cement (27-31). The metal-polyethylene composite of MBG tends to be thicker than an APGC with the effect of lateralizing the articular surface and potentially increase the risk of subscapularis and rotator cuff failure. Increased component thickness may also increase the moment of force associated to the risk of loosening during eccentric loading. The mismatch in stiffness between metal and bone on the deep surface of the component increase the stress shielding on the underlying bone; stiffness between metal and polyethylene on the superficial surface increases the risk of polyethylene wear by increasing contact stresses and the risk of failure of the prosthesis at the metal-polyethylene interface (26) (Fig. 4).

In order to address those deficiencies, hybrid fixation glenoid components with porous ingrowth metal central posts combined with peripherally cemented polyethylene pegs were developed (Fig. 2 C). The advantages of this construct include the potential for long term fixation with growth of bone into the metal post combined with a thickness of the polyethylene that is the same as an all polyethylene glenoid component. Marigi et al. noted that among 1550 hybrid glenoid components implanted between 2021-2019 the survival rate free of component loosening was 99.7% (32). Loosening of the humeral component after TSA is a less common complication (3). The humeral stem should be centered in the humeral shaft to avoid lateral or medial translation that results in altered load distribution and cortical bone resorption (33) (Fig. 5). In order to reduce the risk of stress shielding and facilitate the revision of failed humeral component, novel shorter and modular stems, as well as stemless component have been designed (3) (Fig. 2 B). Adding a surface textured and hydroxyapatite coating around the stem ensures stable fixation, reduces the risk of mechanical failure, and the disadvantages of removal of a cemented stem. Stem subsidence may be suspected in humeral loosening and can be associated with shoulder stiffness and RC dysfunction (33). Size, location and progression of radiolucent lines about the humeral component > 0.5 mm may represent aseptic loosening or small-particle disease related to polyethylene or methyl methacrylate cement; radiolucency associated with periostitis and swelling of the soft-tissue should raise suspicion of deep infection (34). Two recent studies exploring peri-implant lucencies about standard humeral component in TSA reported a rate of 13.2% and 14.6% radiolucent lines at 7 and 8-years follow-up, respectively (4,35). Radiolucency about anatomic uncemented short-stem humeral components range from 0% to 39% (36-37). A recent systematic review of radiographic outcomes following uncemented humeral stems in TSA showed a rate of lucent lines of 0% for long coated stems and 8%-25% for long uncoated stems (3).

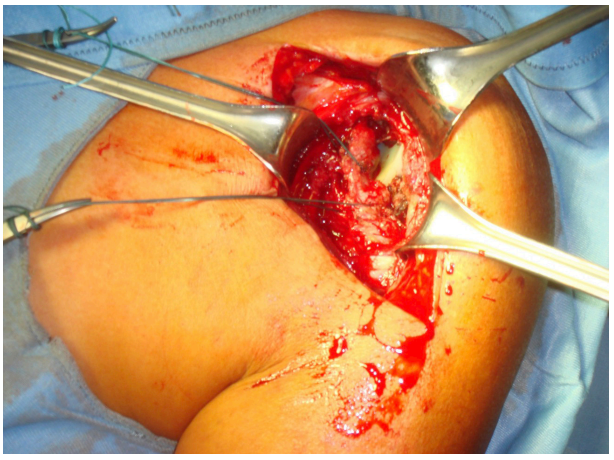

Figure 4: Intraoperative finding at the time of revision total shoulder arthroplasty demonstrating liner loosening of metal backed glenoid component.

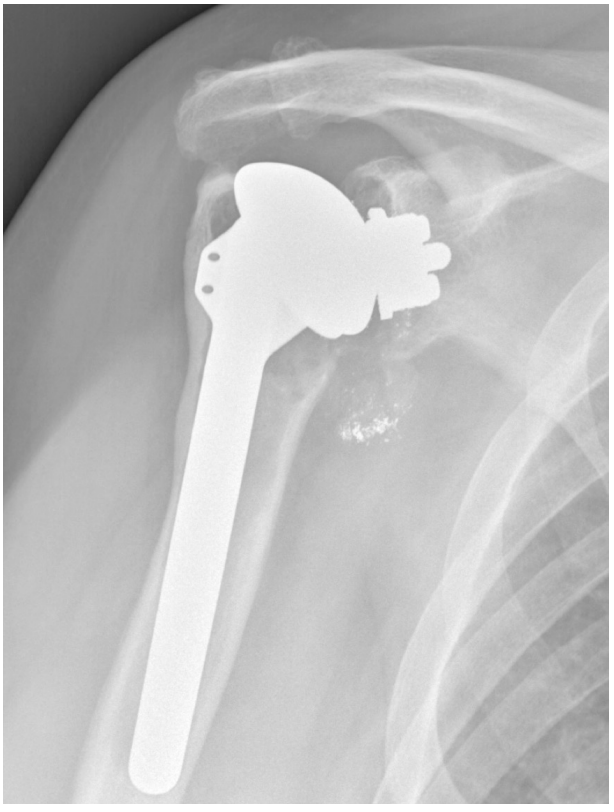

Figure 5: Stem subsidence and tilt in loosed humeral component of total shoulder arthroplasty. Tantalum debris of the TM glenoid component can be also notice.

Evolution of the design and complication of reverse total shoulder arthroplasty

The Grammont reverse shoulder prosthesis is a semi-constrained implant design where the positioning and geometry of the glenoid component results in a joint center of rotation located medial to the glenoid-bone-prosthesis interface (38). The neck-shaft angle at 155° allow the humeral cup to cover less than half of the glenosphere which results in lowering of the humerus and increased tensioning of the deltoid (39). Medialization of the center of rotation of the glenohumeral joint recruits more fibers of the deltoid during elevation, improving force production and reduces torque and shear force generated at the glenosphere-bone interface (5). However, over tensioning of the deltoid may increase the risk of acromion and scapular fracture and is also thought to be the cause of mid- to long-term decline in deltoid function (40-42). Failure to achieve the appropriate tension of the deltoid may place the reverse implant at risk of instability, which represents the most common cause of revision of reverse total shoulder arthroplasty (RTSA) (Fig. 6).

Risk factors for instability include i) shortening of the humerus for proximal bone loss, ii) excessive glenoid medialization due to the glenoid bone loss and iii) soft tissue deficiency (anterior deltoid atrophy and subascapularis deficiency) (43-47). Shortening of the humerus length, compared with preoperatively and compared with the contralateral humeral length, is significantly associated with dislocation (47). Implant malpositioning can also contribute to the dislocation (45,48) as well as to a reduced range of motion (49). However, in some cases it is extremely difficult to identify the specific causes and the mechanism at the basis of the instability.

RTSA has greater stress on the humeral side which can increase the risk of humeral complications and loosening; a lack of the greater tuberosity can induce humeral loosening and/or implant disassembling because the humeral component undergoes extreme rotational stress (50). The long-term radiographic outcome of Grammont reverse implants in cuff tear arthropathy has noted scapular notching in 73% of shoulders (51).

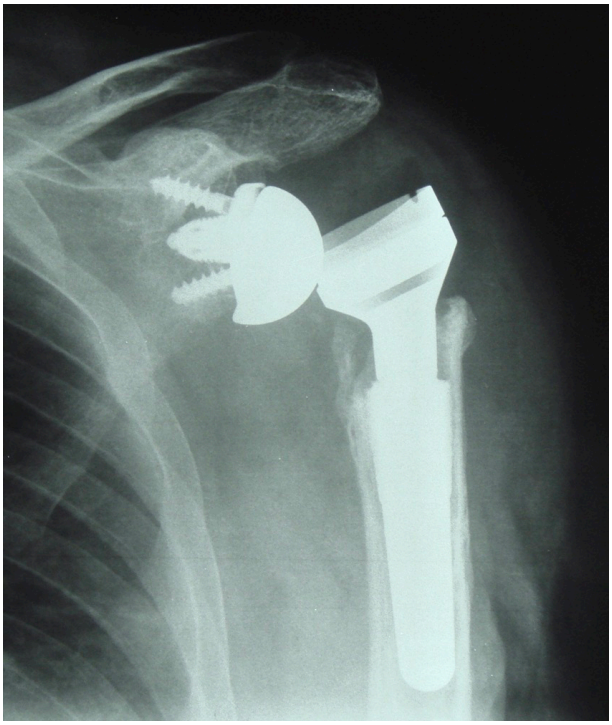

Figure 6: Unstable reverse total shoulder arthroplasty with proximal humeral bone loss. The glenosphere is medialized (Grammont design) and eccentrically placed.

Long-term deterioration of RTSA outcomes were related not only to patient aging, but also to the bone erosion, and deltoid impairment (51). Furthermore, patients with severe posterior cuff deficiency had limited external rotation, particularly with the arm abducted (52). The modifications directed at reducing scapular notching included: i) lateralization of the center of rotation (COR) at the level of the baseplate with bone or metallic increased offset implants (BIO-RSA and MIO-RSA) (Fig. 7 A-B) or at the level of the glenosphere changing its design, ii) inferiorization of the glenosphere with a low baseplate or with eccentric glenosphere (53) (Fig. 6). Lateralization of the COR away from the glenosphere/glenoid interface has the disadvantages of generating torsional forces at the fixation interface, thus increasing the risk of mechanical loosening (54). A recent biomechanical study showed that the inferiorization of the glenosphere of 2.5 mm has significantly lower deltoid force than RTSA with glenoid lateralization at higher abduction angles (55).

Stem geometry and reverse tray position were also changed to preserve the bone stock of the tuberosities,

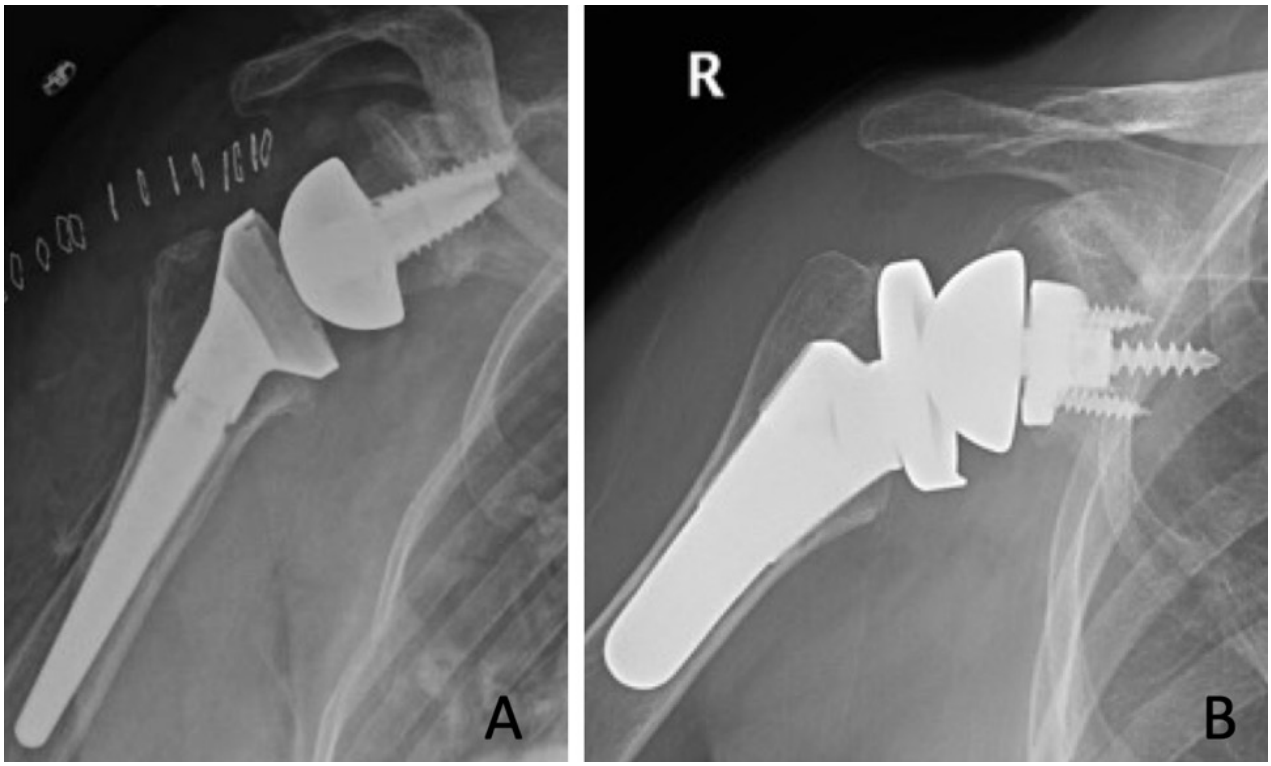

Figure 7: A, Glenoid lateralization in reverse total shoulder arthroplasty with bone (BIO-RSA); B, Glenoid lateralization with metal using a superior augmented baseplate (MIO-RSA).

and the insertion of the RC (if present), offering an easy conversion from TSA to RTSA in case of failure (56). Onlay system increased humerus offset, with beneficial effects on external rotation recovery (57), but decreased the acromion-humeral distance, with risk of acromial impingement during abduction (56). In addition, the use of lateralized humeral component (>15 mm) increases the risk of acromial and scapular stress fractures. However, a large study of Routman of over 4000 onlay reverse showed a rate of acromial/scapular fracture of less than 2% (58). Disassembly of humeral or glenoid component are less commonly found and have been associated to humeral/glenoid bone loss, and to technical problems (59).

Revision shoulder arthroplasty: strategic approach

The causes of failure of a shoulder arthroplasty are complex and include component failure, instability, soft tissue dysfunction, peri-prosthetic fractures, infection, and a variety of miscellaneous issues (2, 5, 40, 45, 46, 48, 60). Treatment should be planned not only on the primary cause of failure, but also considering any additional complications or underlying issues. The best result is achieved through understanding of the patient's needs and choosing the appropriate tailored treatment. Here we describe the current approach to failed shoulder arthroplasties based on the literature evidence and surgeon's experience in this field.

Revision of hemiarthroplasty

The most common causes of HA failure are related to prosthesis instability, glenoid erosion, and rotator cuff dysfunction (61). Long-term radiographic results of HA in gleno-humeral osteoarthritis showed high rate of glenoid erosion (49%) and subluxation (44%), and an estimated survival of 92% at five years, 83% at ten years, and 73% at fifteen years (62). About 19% of HA were revised at > 5 years follow-up and most of the revision procedures were performed because of painful glenoid arthritis. The risk of revision

was significantly higher for the shoulders that had had previous operations and in those cases that had a HA as sequela of proximal humeral fractures (62). Other authors emphasized that the severity of glenoid erosion was associated with humeral head decentering and valgus positioning of the humeral component. They reported that decentering resulted from uncorrected posterior glenoid erosion, inadequate soft tissue balancing and humeral head malposition (63).

A recent 10-years prospective study reported a low rate of revision with adjustable stemmed HA and only 5% were revised for glenoid erosion (64). Primary osteoarthritis was the most frequent indication, followed by shoulder instability arthropathy, rheumatoid arthritis and fracture sequelae. It is noteworthy that the best clinical outcomes were found in patients with shoulder instability arthropathy compared with patients with fracture sequelae and primary osteoarthritis (64). The good preoperative status of the RC and the centering of the humeral head in the glenoid, commonly found in shoulder osteoarthritis secondary to recurrent instability, contributed to those results. Performing a HA in a young subject, aged fifty years or younger, is controversial. The estimated survival rate of HA in this subset was 82% at 10 years and 75% at 20 years; unsatisfactory outcomes ratings in this subset were most commonly a result of motion restriction from soft-tissue abnormalities (65).

Biologic resurfacing of the glenoid in combination with humeral head HA, in young and active patients, has been described with poor mid-term clinical outcomes (66). Meniscal allograft and human acellular dermal tissue matrices showed a clinical failure rate > 50% and, therefore, have an undefined role in the treatment of glenoid arthritis in the young compared with standard methods of HA or TSA (66).

How to address a failed HA is a matter of concern. Revision of a failed HA to anatomical TSA can achieve successful mid-term outcomes and implant survival rates (67). This revision procedure is recommended in patients with glenoid arthrosis and an intact and functional RC. However, the rates of intraoperative (fractures, iatrogenic RC tears) and postoperative complications (components loosening, subscapularis failure, infections, lesser tuberosity non-union, posterior-superior RC tears) are substantial and up to 46%. Overall, indications to revise HA to an anatomical TSA are supported by those authors who believe that the longevity of RTSA is poorly understood (67).

In recent years, the revision of failed HA to a RTSA has increased. RTSA is often preferred for its semi-constrained nature in the setting of deficient soft tissue stabilizers (Fig. 8) Merolla et al. investigated the results of the largest series of failed HA revised to a reverse, achieving satisfactory pain relief and improvements in shoulder motion (61). Revisions were performed for humeral component instability in association with massive RC tears in 80% and for glenoid wear in 20%; instability and glenoid wear were associated in 24%. The need of humeral osteotomy and extensive soft tissues exposure in cemented HA negatively influenced clinical outcomes. Interestingly, they found a relatively low rate (7%) of repeat revision surgeries and reasonable 5-year implant survivorship (93%), with instability and glenoid loosening being the most common causes (61).

Those reflect one particular concern in the revision setting concerning the higher stress on the glenoid fixation placed by the increased constraint of the reverse design. Additional research findings confirmed good to satisfactory results of RTSA with specific glenosphere design in the revision of failed HA (68). Sheth et al reported outcomes of 110 patients underwent revision to RTSA after failed anatomical arthroplasty including 64% HA (69). The implant survival rate for patients with prior HA was 95% at 2 years and 94% at 5 years (69). The main limitation of this study was the lack of objective clinical data and an exhaustive radiographic evaluation of the revision implants. Additional deficiencies of the study included i) lack of a subgroup analysis that discern the effective rate of complication in HA patients and ii) the heterogeneous and not exhaustive descriptions of the modes and reasons of the failure in HA and TSA groups, iii) lack of data on modular components implanted at the index operations that may address humeral side complications that arise in the revision surgery. One technique that can be extremely helpful in the revision of the failed cemented hemiarthroplasty to reverse arthroplasty is the cement-within-cement technique (70). The surgeon may remove a regular length stem that is cemented and then use a shorter thinner stem that can be cemented

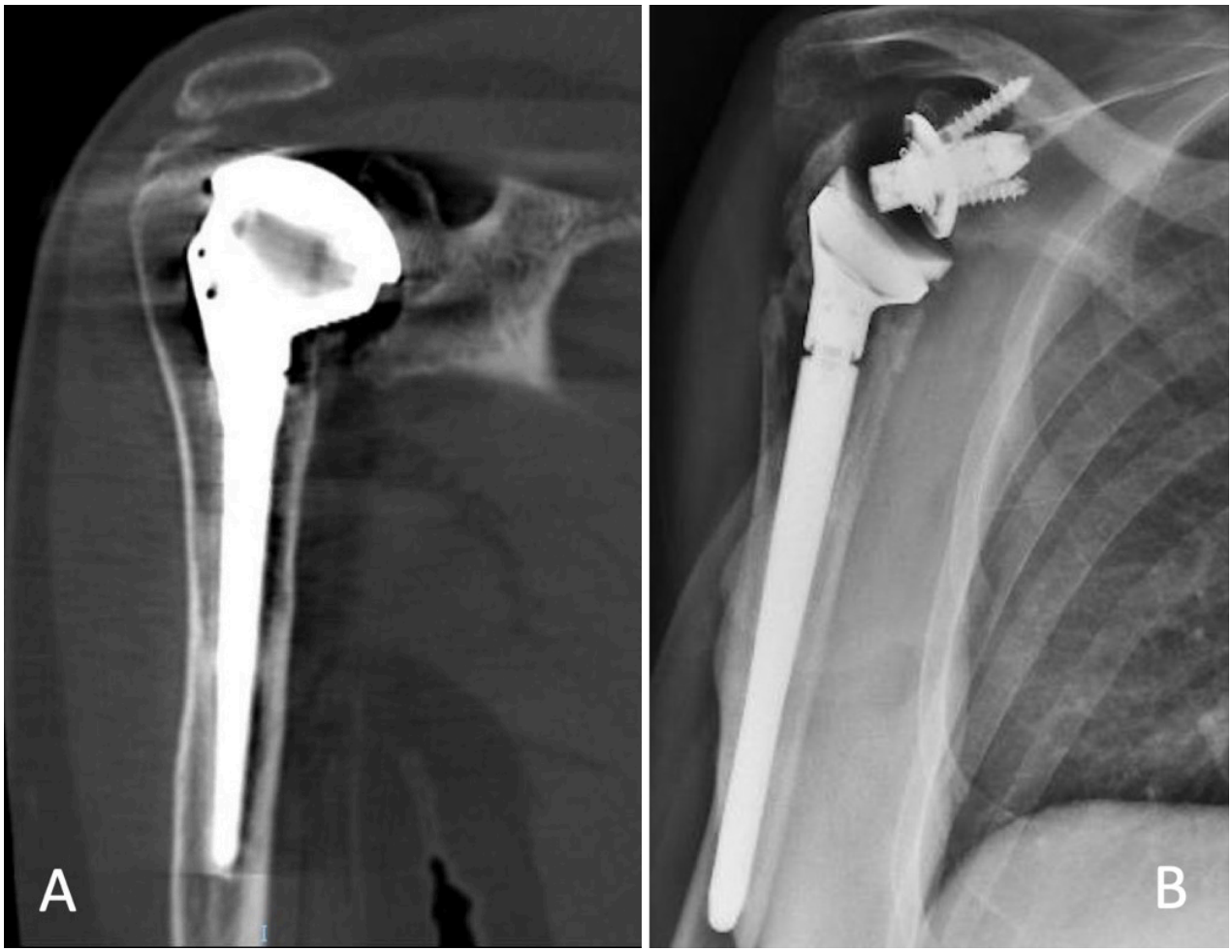

Figure 8: A, Failed shoulder hemiarthroplasty for rotator cuff deficiency and superior glenoid erosion; B, Revision in reverse total shoulder arthroplasty with uncemented stem and polyethylene glenosphere.

in the previous cement mantle. This can be very helpful due to the fact that the humerus typically is superiorly subluxed in these cases. When revised to a reverse, the surgeon typically needs to place the humerus lower and resect more proximal humeral bone. The use of a shorter and thinner stem obviates the need for removing the cement plug distally. Moreover, it eliminates the use of a heated device that is used to remove cement, and related risk of radial nerve injury.

Total shoulder arthroplasty survival and revision

TSA ensures satisfactory medium and long-term clinical outcomes if the RC is intact, and the glenoid component is well fixed after restoring the physiologic glenoid version. Glenoid component loosening has been identified as the major cause of failure of TSA (62,65,71) (Fig. 9). Pegged glenoid fixation results in a decreased risk of revision TSAs, but no significant differences in patient-reported outcomes have been identified (72). TSA in patients younger than 65 years is a viable option with a predictable improvement of mid-term and long-term shoulder function (71). However, patient-reported outcomes in this young population appear to be inferior of the overall TSA population. The reported revision rate was 17.4% at an average of 9.4 years from surgery (71). The revision rate of TSA implant for aseptic loosening of humeral and glenoid components was 12%, with 9% of failures attributed to aseptic glenoid loosening only. Keeled implants showed an overall revision rate of 23% at an average 8.7 years follow-up (71). The reoperation-free

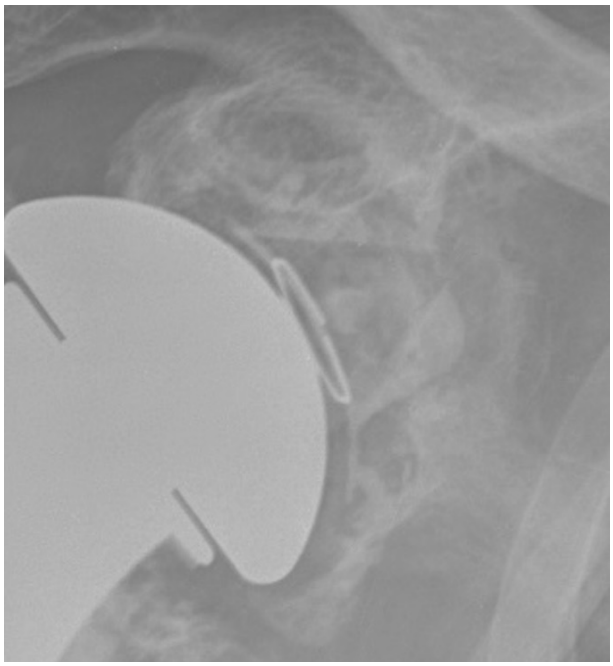

Figure 9: Radiographic loosening of a keeled glenoid component with medial migration and gross radiolucency.

implant survival of TSA in patients < 65 years ranged from 98% to 100% at 5 years, from 62% to 92% at 1 years and from 83 to 89% at 20 years, excluding cases of septic failures. Denard et al showed a decreased survivorship of the glenoid component with over-sized humeral heads and in case of glenoid curettage technique as opposed to more extensive reaming (73). The same authors reported an 88% of 10-year survival rate in concentric glenoids as opposed to 50% for non-concentric ones (B1 and B2) preoperatively. A recent systematic review confirmed worse outcomes and higher complication rates in TSA with B2 preoperative glenoid (74); glenoid retroversion and bone loss were corrected with asymmetric reaming, posterior bone-grafting or with an augmented glenoid component. The reported rate of glenoid loosening was 42%, although not all of these patients were symptomatic (74). Symptomatic glenoid loosening has been reported at 1.2% per year, and surgical revision at 0.8% per year (26).

Ma et al reported no significant relationship between postoperative glenoid retroversion or humeral head subluxation and clinical outcomes in patients following TSA. In patients with preoperative glenoid retroversion >15°, change of retroversion during TSA had no impact on their clinical outcomes at short-term follow-up (75). A multicenter study of over 1200 individual patients underwent TSA using a basic all-polyethylene glenoid component (APGC), showed early and mid-term outcomes of shoulders with retroverted or type B glenoids similar to those with neutral version or type A glenoids (1). Those results confirm that the risk of APGC loosening arise in the long-term. Furthermore, an APGC that is visibly loose on radiographs can be tolerated clinically in some patients rather than always requiring revision. There is no clear agreement on the treatment of aseptic loosening of an APGC. Some authors recommend revision with a new when the RC is intact and glenoid bone stock allows. When glenoid bone loss is significant and precludes a reimplantation, glenoid removal with limited reaming and bone grafting can be a reasonable option (76). There is substantial agreement to perform revision in RTSA in case of shoulder instability (76,78). Several studies confirm the high rate of restoration of shoulder stability with RSA components used for treatment of prosthetic instability (77-80); conversely, a very high rate of instability (58%) was reported in patients treated with non-RTSA solutions that focused on improving component position and soft tissue tension (81). Revision of modular stemmed hemiarthroplasty or total to RTSA without stem exchange had less intraoperative blood loss and operative time, fewer intraoperative complications, and fewer revisions compared with patients requiring revision with a full stem exchange (61,82,83).

Failure of MBG is another matter of concern for the risk of severe glenoid bone loss that may preclude a new glenoid reimplantation or conversion to RTSA. Failed MBG are also associated with polyethylene thinning, attrition of the joint surface and metallosis, thus contributing to severe shoulder dysfunction (84). Failed MBG are extremely painful compared with APGC. As for modular stem, the use of modular design of MBG are encouraged by some because theoretically reduces the risk of glenoid bone loss and foster the revision in reverse prosthesis (85) (Fig. 10). The rate of radiolucency and radiographic loosening has been reported to be higher for APGC than for MBG; however, the rate of revision is three time higher for MBG than for APGC (26). A recent review article demonstrated that modern MBG designs (second generation of SMR MBG and TM glenoid) seem to have no difference in failure, at least in the < 36-month and 36–72-month subgroups compared to the cemented APGC (86).

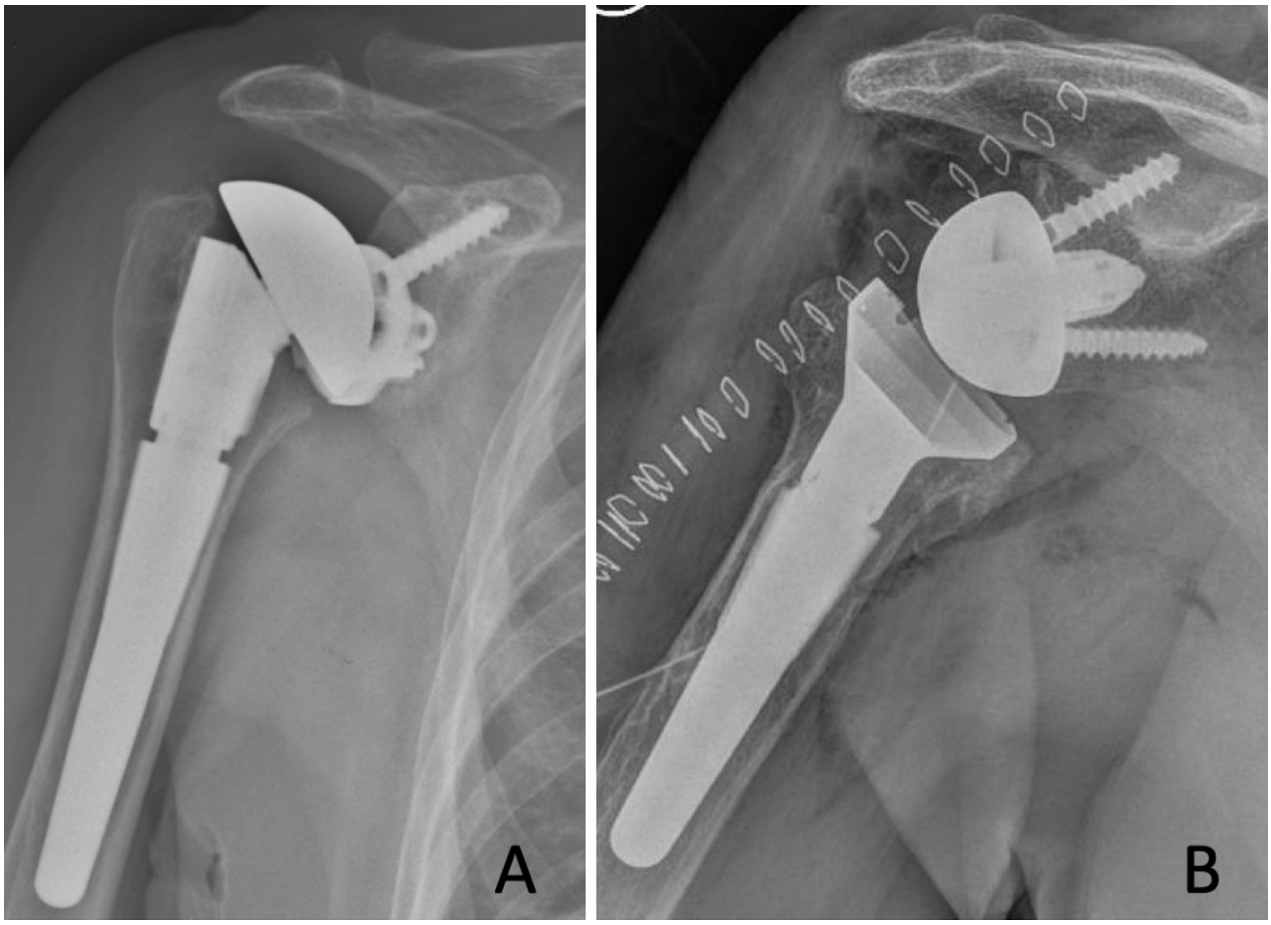

Figure 10: A, Failed total shoulder arthroplasty due to polyethylene liner dissociation; B, Conversion in reverse total shoulder arthroplasty with stem and baseplate retention.

Removal of a well fixed MBG can be extremely challenging if it is well fixed leaving a severe glenoid bone defect that precludes a new glenoid replacement and requires the conversion in HA or revision with a custom implant (87).

Soft tissue management in revision shoulder arthroplasty

Stiff arthroplasty

A stiff arthroplasty can be related to inadequate release of contracted tissues, particularly the subscapularis and anterior capsule at the time of primary arthroplasty; non-anatomic soft-tissue reconstruction can also contribute to contracture and stiffness (1). Scar tissue may adhere to the subscapularis, and the RC adheres to the undersurface of the acromion. Adhesions can be also seen between the deltoid and the underlying peripheral RC and proximal humerus. All these conditions could be managed with arthroscopic circumferential soft-tissue releases and excision of scar tissue (2). In some cases of anterior soft tissue contracture, the posterior capsule is stretched and the head prosthesis becomes posteriorly subluxated. This kind of prosthesis instability can be addressed by releasing the subscapularis tendon, anterior capsule and the upper portion of the pectoralis major.

Rotator cuff deficiency

Currently, there is no consensus about the decision to perform a RC repair in the revision of a TSA.

When the RC is not intact and functional, a revision with a new anatomical implant is at high risk of failure. Attempt to restore anterior stability in a TSA focusing on soft tissue tension, tendon transfer or use of tendon allograft failed and was gradually abandoned (81). The use of posterior capsular plication to correct posterior instability during revision of TSA showed an unacceptably high failure rate. As for anterior instability, even in posterior instability of an anatomical shoulder arthroplasty conversion to a RTSA remains the most reasonable option (88).

Infected shoulder arthroplasty: one or two stages surgical revision?

Periprosthetic shoulder infection (PSI) has a relatively low incidence ranging from 1% to 4% after primary and up to 4%-15% after revision arthroplasty (89,90). The most frequently isolated bacteria are propionibacterium acnes (38.9%), *Staphylococcus aureus* (14.8%), *Staphylococcus epidermidis* (14.5%) and coagulase negative Staphylococcus (14%) (91).

An accurate diagnosis of PSI is critical because infection requires appropriate medical and surgical management. Besides standard clinical-radiographic investigations and bone scintigraphy (92), specimen cultures from periprosthetic tissue is recommended for a microbiological diagnosis (60,93-95). Benefits of implant sonication fluid culture over standard intraoperative cultures in revision shoulder arthroplasty are debatable (96).

PSI is the most common cause of revision within 2 years after an arthroplasty (97). The scoring system proposed by the 2018 International Consensus Meeting seem to be highly sensitive to rule out a PSI (98). Two positive cultures or the presence of a sinus tract are considered as major criteria; minor criteria include: i)elevated serum CRP (>1mg/dL), ii)D-dimer (>860 ng/mL), and erythrocyte sedimentation rate (>30 mm/h), iii)elevated synovial fluid white blood cell count (>3000 cells/mL), iv)alpha- defensin (signal-to-cutoff ratio >1), v)leukocyte esterase (++), vi)polymorphonuclear percentage (>80%), and vii)synovial CRP (>6.9 mg/L) (9). However, the rate of false negative cultures has been reported as high as 20% (99).

Standard radiographs are the first line investigation in suspicion of PSIs. CT can demonstrate a fluid collection with increased density surrounding infected bone-implant interface, while the role of MRI is controversial. Nuclear medicine techniques including bone scintigraphy, radio-labelled white blood cell (WBC) scintigraphy, anti-granulocyte antibody scintigraphy, and fluorodeoxyglucose positron emission tomography (FDG-PET) show a high sensitivity and specificity.

One- and two-stage procedures have been proposed for the management of PSI (100,101). Single-stage revision has been reported to be more effective than 2-stage, but these findings may be confounded by a treatment bias given the higher propensity of virulent and drug-resistant bacteria treated with 2-stage (100). One-stage exchange showed to give better results than 2-stage exchange, with 3-fold less reinfection (7% versus 21.3%), and almost 2-fold fewer complications (17% versus 32/8%). Functional benefit, however, remains undetermined, and further studies are needed (100,101). Antibiotic spacer, proposed as a definitive management of an infected shoulder arthroplasty, has marginal functional outcomes (102,103).

Re-revision shoulder arthroplasty: problems and solution

One of the biggest challenges in re-revision surgery is glenoid bone deficiency. Over the past few years, there has been increasing emphasis on how glenoid bone can be preserved in the primary and the revision setting. In 2019 was described the Reverse Shoulder Arthroplasty (RSA) angle, defined as the mean superior tilt from the bottom part of the glenoid, where the glenoid baseplate is placed, and it amounted to 21° (104). It is well known that superior tilt must be avoided in reverse arthroplasty. There are 3 options to correct the RSA angle: 1) eccentric ream the inferior and central glenoid, 2) use of bone graft and 3) use of an augmented base plate.

Eccentric glenoid reaming is associated with removal of a large amount of central and inferior glenoid bone. Moreover, the bone that is removed is the best quality cortical bone. This medialization results in shorter screw fixation, placing the baseplate on softer cancellous bone,

and decreases associated soft tissue tension. The second option is the use of bone graft to correct the RSA angle. Several studies demonstrated a high rate of graft resorption. The Rothman Institute reported a 25% failure rate with bone grafting in primary reverse arthroplasty (105). Edwards et al. reported a 33% rate of partial or complete graft resorption in primary reverse arthroplasty at 2 years at AAOS, while Bartels et al. reported a 25% failure rate of bone grafting at the time of revision reverse arthroplasty (106). The third option to correct the RSA angle is the use of an augmented baseplate. Duquin et al. demonstrated a 54% decrease in glenoid bone removal of augmented baseplate compared to eccentric reaming (107). Additionally, there was 4 mm more of glenoid lateralization compared to eccentric reaming. The ability to perform an augmented baseplate in the same rotation without concerns of graft availability or resorption has resulted in a large number of surgeons to use augments on all of their primary revision cases to preserve glenoid bone (Fig. 7B). Moreover, in the revision and re-revision setting, an augmented baseplate maximizes contact of the implant with native bone.

In cases of massive bone deficiency, a custom glenoid component may be considered. These are frequently done as a staged procedure with component removal, debridement, and placement of an antibiotic spacer. The removal of the metal component and placement of the spacer improves the quality of the CT scan by eliminating metal artifact. The custom glenoid component typically takes 10 to 12 weeks to manufacture for that specific patient. Screw trajectories are specifically planned to optimize fixation (Fig. 11). These have demonstrated a very good track record of success. Rangarajan et al. reported on 18 custom glenoid components for massive glenoid bone deficiency. There were no cases of glenoid component loosening (108).

Conclusion

A thorough understanding of the most likely reasons for failure will help direct the surgeon to evaluate the patient with a painful shoulder arthroplasty. An organized and directed patient work-up will help define the

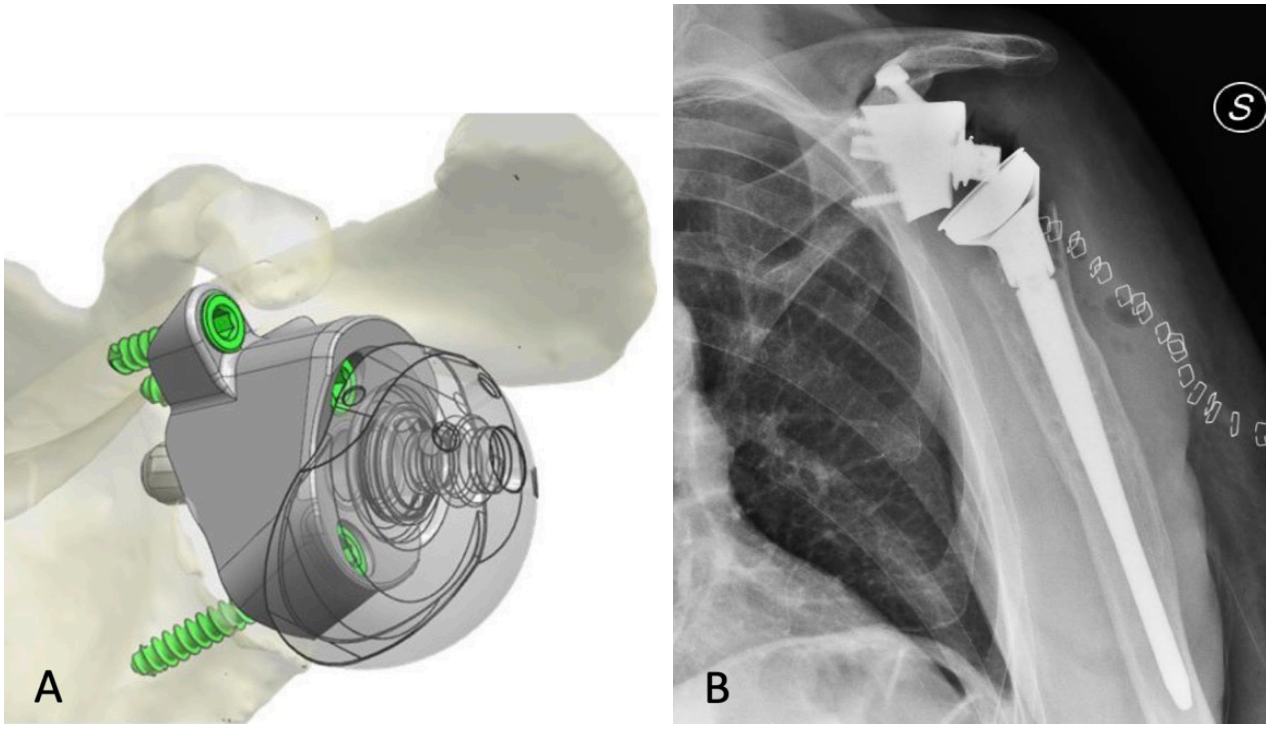

Figure 11: Reverse total shoulder arthroplasty with custom glenoid component for severe glenoid bone deficiency (Promade, Lima, San Daniele del Friuli, Italy). A, Preoperative implant configuration of screws and baseplate position using 3D computed tomography model; B, Postoperative X-ray.

multiple causes for failure. Careful planning is necessary including the availability of a breadth of components to manage associated glenoid and humeral bone deficiency. Over the past years, there has been a clear shift away from the use of bone graft and to the use of metal to make up for bone deficiency. As the volume of shoulder arthroplasty continues to grow as well as the number of procedures being done in young patients, bone preservation in the primary surgery is becoming increasingly important as well for the surgeon to consider.

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