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Reverse shoulder-allograft prosthetic composite reconstruction for a failed reverse total shoulder arthroplasty with massive proximal humeral bone loss and a fractured modular humeral stem: a case report

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The improved outcomes and widened indications for reverse total shoulder arthroplasty (RTSA)[9] and the increased demand in younger patients[19] have catalyzed the increased utilization of shoulder arthroplasty. The increased shoulder arthroplasty volume has been followed by a growing complication burden and need for revision shoulder arthroplasty. One potential challenge at revision shoulder arthroplasty surgery is proximal humeral bone loss, which can be attritional or acute and intraoperative, such as during extraction of a well-fixed humeral component. Proximal humeral bone loss may also be encountered during shoulder arthroplasty for complex proximal humeral fractures and fracture sequelae and following proximal humeral tumor resection.[3,15] Modern options for managing proximal humeral bone loss during shoulder arthroplasty include reverse shoulder-allograft prosthetic composite (RS-APC) reconstruction[13] as well as tumor or mega prostheses. Reconstruction with allograft provides structural support for the humeral component, restores humeral length and offset, and soft tissue attachments may facilitate repair of the native soft tissues. Revision reverse shoulder arthroplasty performed in the setting of severe humeral bone loss without allograft reconstruction has been associated with postoperative instability and gross humeral stem loosening.[4] Reservations over the use of RS-APC including the additional cost, increased operative time, the potential for graft resorption and failure of incorporation, and the additional risk of infection, humeral loosening, and instability.[6,14]

To address the growing revision burden, manufacturers have introduced convertible modular humeral stems designed to facilitate revision between anatomic and reverse shoulder arthroplasty. These modular implants consist of a proximal body for either anatomic or reverse shoulder arthroplasty attached to a distal humeral stem so that the proximal body can be exchanged at revision surgery without removing the well-fixed humeral stem.[16] As with any modular implant, there is potential for junctional failure, in this case between the humeral body and stem. In their review of the U.S. Food and Drug Administration MAUDE (Manufacturer and User Facility Device Experience) database, Somerson et al reported on accounts of fractured humeral stems. However, the database did not enable the authors to directly attribute failures to implant design.[23] Other modular humeral stem failures have been reported in the literature.[18]

The purpose of this article is to describe the surgical technique for addressing a broken and retained screw in a failed modular humeral component followed by RS-APC reconstruction for profound proximal humeral bone loss. The patient was informed and gave consent for her data to be used in this case report.

Clinical vignette

A 63-year-old woman presented to our facility for left shoulder pain and dysfunction. She had undergone RTSA at an outside facility 15 months earlier for an acute left proximal humerus fracture

Institutional review board approval was not required for this case report. The patient was informed and gave consent for her data to be used in this case report.

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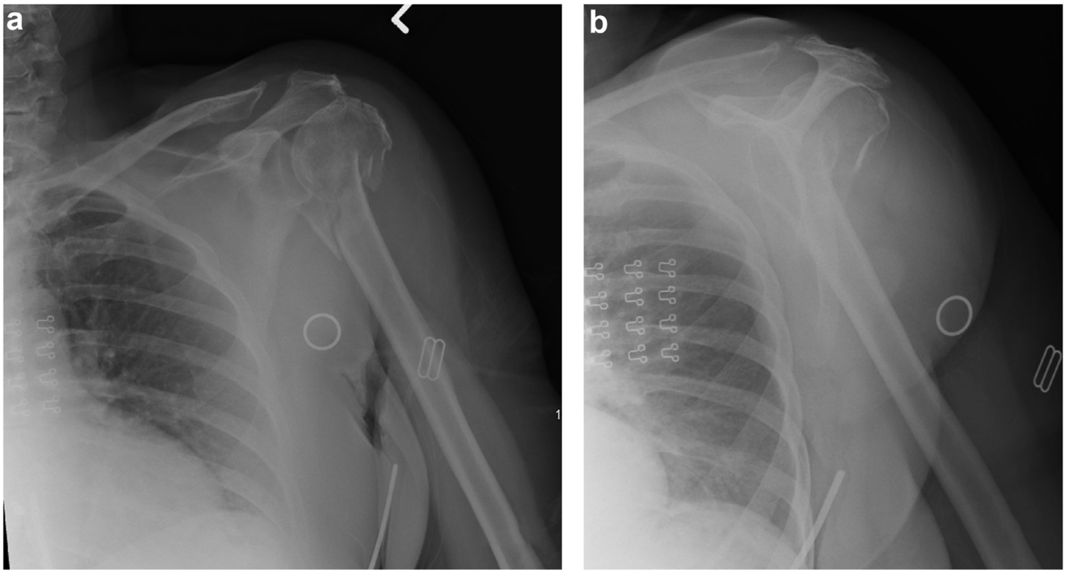

Figure 1 (**a**, **b**) Initial plain radiographs demonstrating the proximal humerus fracture.

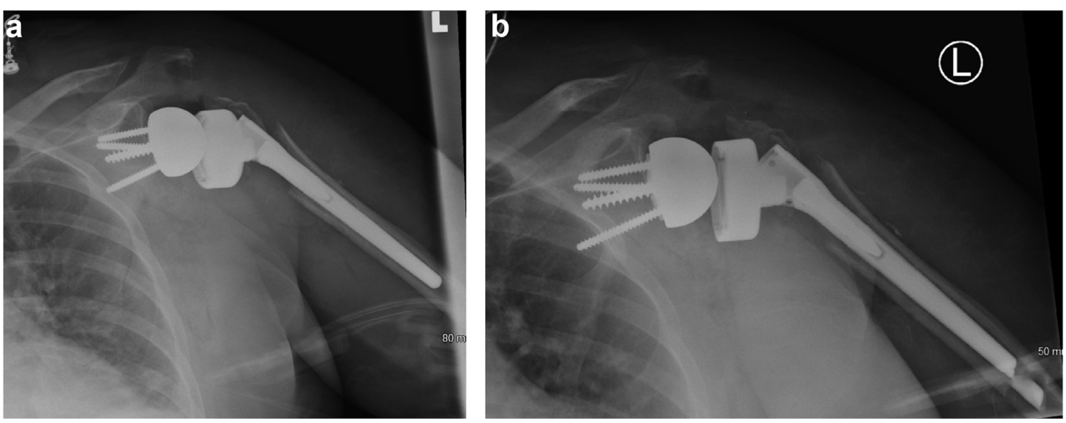

Figure 2 Plain radiographs demonstrating RTSA for the proximal humerus fracture: (**a**) true anteroposterior, (**b**) axillary-lateral radiographs. *RTSA*, reverse total shoulder arthroplasty.

(Fig. 1) sustained in a fall from a horse (Figs. 1 and 2). Postoperatively, she regained comfort at rest but complained of relatively poor function with painful limitations in elevation and rotation. She was involved in a motor vehicle accident 3 months postoperatively, resulting in increased shoulder pain and declining shoulder function. Available office notes from visits 6 months following the motor vehicle accident documented limited active forward elevation to 60° and external rotation to 10°. Plain radiographs obtained at that time were interpreted as unchanged except for a “slight gap” between the modular humeral stem components. She resumed physical therapy with modest benefit until she experienced a popping sensation and sharp pain while reaching for a glass of water. She was referred to our clinic after plain radiographs revealed a periprosthetic fracture with failure of the modular humeral stem.

Physical examination revealed no obvious deformity, but any passive motion was exquisitely painful. She could not initiate active left arm elevation and demonstrated a positive external rotation lag sign. The incision was well healed without erythema or drainage. Her neurovascular exam, including her axillary nerve, was intact. Plain radiographs demonstrated a proximal humeral periprosthetic fracture at the metadiaphysis and junctional failure of the modular humeral stem at the level of the fracture (Fig. 3). The radiographs also demonstrated severe proximal humeral bone loss. An infection workup including serologies was normal. The patient was ultimately indicated for revision RTSA with APC, as well as tissue biopsy to rule out occult infection.

Operative technique

The patient underwent an interscalene nerve block followed by general anesthesia and was placed in a semi-sitting position with the trunk elevated 45°. The prior deltopectoral incision was used for the approach and extended distally for increased exposure. The cephalic vein was identified and retracted laterally. The periprosthetic fracture and junctional implant failure were identified and exposed. No gross purulence was noted, but metallosis was encountered and thoroughly débrided. Scar tissue was sharply excised, and multiple specimens were sent for culture. Electrocautery was used to shell out additional scar, and a greater tuberosity osteotomy was performed. The subscapularis was peeled and tagged for later incorporation into the tendinous attachments of the allograft. The shoulder was dislocated, the deficient proximal humeral bone was resected, and the proximal implant body and liner were removed.

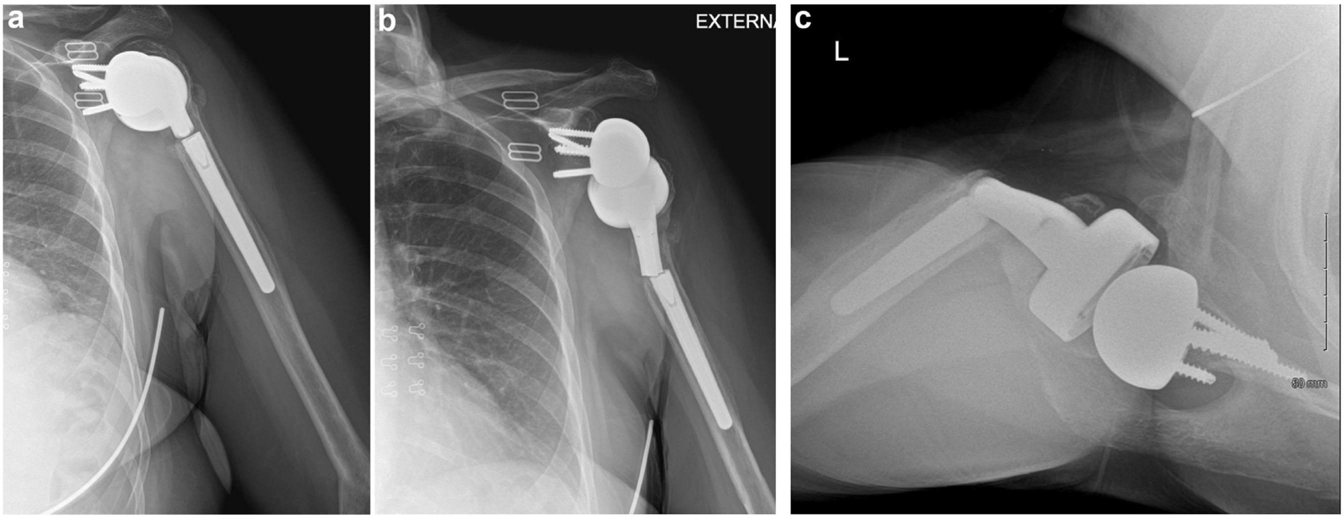

Figure 3 Plain radiographs demonstrating the humeral periprosthetic fracture and failure of the modular stem: (**a**, **b**) AP radiographs, (**c**) axillary-lateral radiographs.

Attention was then turned distally, and additional soft tissue releases were performed, including a release of the pectoralis major tendon. The host bone was mobilized, and additional peri-implant scar was resected. The broken screw was identified at the tip of the stem, and it was apparent that the screw was not properly seated. A high-speed pneumatic drill (Midas Rex, Medtronic, Minneapolis, MN, USA) with a needle tip was used to drill a hole to a depth of about 3-4 mm precisely at the center of the exposed shaft of the screw. A reverse threaded inserter from the universal screw removal tray was used to successfully extract the screw. A ¼ inch flexible osteotome was used at the interface to carefully separate the proximal humeral bone from the humeral stem. The stem was extracted without difficulty after securing the extraction tool to the stem.

We measured approximately 7 cm of bone loss medially and 5 cm of bone loss laterally, which further justified the use of an APC.[7] The host bone was prepared to accept the implant. The canal was instrumented with a canal finder and reamed by hand up to 8 mm. We trialed an 8 mm × 175 mm monoblock revision humeral stem (Enovis, Austin, TX, USA) and obtained good provisional fixation even prior to allograft reconstruction (Fig. 4).

We employed a proximal humeral allograft, including soft tissue attachments. The graft was prepared ex vivo to accept the revision implant. An oscillating saw was used to resect the humeral head, the canal was exposed with an oval burr, followed by a canal finder, and then reamed manually to accommodate a size 8 mm stem. A metaphyseal reamer was then used to prepare the allograft for the inlay humeral implant. The humeral implant was impacted into the allograft to ensure it seated well, and we obtained excellent scratch-fit fixation.

Next, the allograft prosthetic composite was impacted into the host bone and length was assessed. A burr was used to resect a few millimeters of host bone to get the implant to seat appropriately with a nearly perfect fit between the allograft and host bone. The allograft-host junction was confirmed to be flush on fluoroscopy (Fig. 5). The construct was also rotationally stable. Following a stable trial reduction with a 36 mm neutral liner mated to the existing 36 mm glenosphere, the definitive liner was inserted, and the shoulder was reduced. A burr was used to partially decorticate the allograft to accommodate the osteotomized greater tuberosity fragment. Two #2 nonabsorbable sutures were placed at the host bone interface, and then the greater tuberosity fragment was reduced and fixed with high-strength nonabsorbable braided suture cerclage around the implants and the allograft. The shoulder was reduced a final time with the 36 neutral liner and the nonabsorbable sutures were then tied to complete the greater tuberosity repair.

A 12-hole 3.5 mm limited contact dynamic compression plate (Synthes, West Chester, PA, USA) was precontoured to accommodate the metaphyseal flare and placed anterolaterally. The plate was fixed proximally and then distally with a couple of skive screws to avoid the implant. Additional screws were placed proximally, taking care to avoid the implant. A cable passer was carefully placed between the radial and axillary nerves, and a braided cable was used for supplemental fixation (Fig. 6).

The subscapularis tendon was repaired to the host tendon and muscle with multiple nonabsorbable figure-of-eight stitches and the pectoralis major tendon was repaired in a similar fashion. The wound was irrigated, a gram of vancomycin powder was placed around the allograft and the wound was closed in layers. A sterile dressing was applied and the arm was placed in a padded soft brace. The patient was admitted overnight for observation and discharged the following day.

Postoperative course

The patient maintained strict immobilization for 4 weeks and for an additional 2 weeks outside of the home. Plain radiographs were obtained at her one-week follow-up visit and demonstrated a stable construct with no evidence of postoperative complications (Fig. 7). Physical therapy for her shoulder was initiated at approximately 4 weeks postoperative and focused initially on gentle shoulder motion, including pendulum exercises. At 6 weeks postoperative, she was allowed to progress with active-assisted motion as well as progressive inclined deltoid strengthening. At 3 months postoperative, the patient demonstrated 90° of active and 120° of passive forward elevation. At 6 months postoperative, her active forward elevation had improved to 120°, with 40° of active external rotation and internal rotation to L2. She reported minimal pain with activity and no significant pain at rest.

At two years following RS-APC, she continued to report good function with no shoulder pain. Repeat plain radiographs (Fig. 8) demonstrated intact hardware without any evidence of complication such as loosening, fracture, or instability. The host-allograft junction appeared consolidated, with the interface no longer clearly visible on plain radiographs, suggesting incorporation of the allograft. Her active shoulder range of motion at the final follow-up

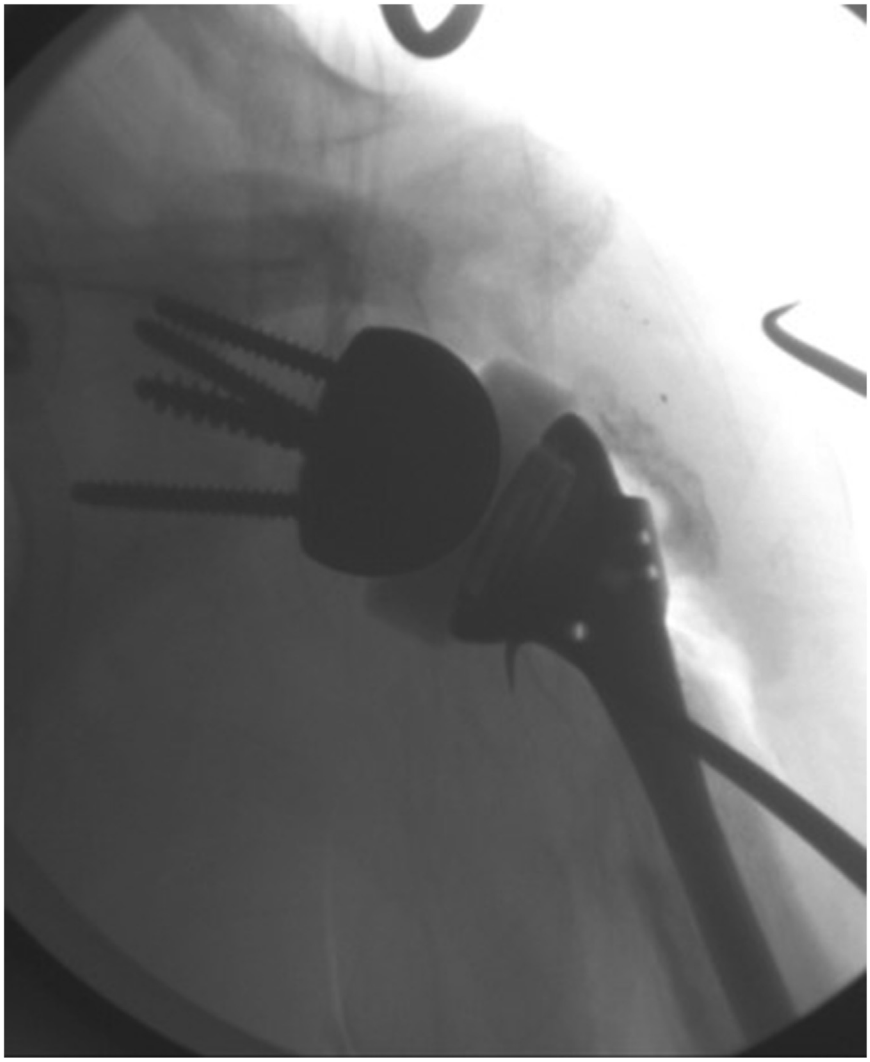

Figure 4 Intraoperative fluoroscopy showing distal humerus preparation.

included 140° of forward elevation, 130° of abduction, 45° of external rotation, and internal rotation to L1 (Fig. 9). She had returned to her normal activities to include horseback riding.

Discussion

Review of the available literature regarding outcomes for RS-APC demonstrates acceptable complication rates and reliable healing at the allograft-host interface when modern techniques are employed.[1] One series evaluating RS-APC reconstructions for non-tumor-related revision shoulder arthroplasty reported an 8% instability rate.[7] Instability in the setting of tumor reconstructions has been reported to be higher, with instability documented as high as 20%-30%.[5,24] Boileau et al reported their series of 25 consecutive patients undergoing RS-APC for severe proximal bone loss, and while there were 6 patients with postoperative instability, only one required revision surgery.[4] The same series reported incorporation of the allograft-host in 96% of cases. Sanchez-Sotelo et al reported on their results of 26 patients undergoing RS-APC, also with relatively low complication rates and no revision surgery required for nonunion at the host-allograft junction. The mean duration to allograft union was 7 months in their cohort.[21] Strategies to improve healing at the allograft host bone interface include compression planting [21,22] and meticulous removal of cement from that interface.[21,22] More recently, the senior author has employed off-label use of recombinant human bone morphogenetic protein-2 in select patients to accelerate and improve allograft union.

Regarding clinical outcomes, a recent systematic review reported a high rate of patient satisfaction at 86% following RS-APC.[13] Several authors have reported improvements in both shoulder range of motion and functional outcome scores.[22] Cox et al published their results on 73 patients treated with RS-APC with a minimum of 2 years of follow-up. Range of motion significantly improved in forward flexion (49°-75° and abduction (45°-72°). Good to excellent results were reported in 70% of patients and the reoperation-free survival rate of all reconstructions was 88% at 5 years.[10] Frankle et al reported their results on 25 patients who underwent RS-APC, with 76% of patients reporting an excellent or good result, and average ASES score improvement from 32 preoperatively to 69 postoperatively.[7]

There is debate surrounding the use of APC versus tumor megaprosthesis for the management of substantial proximal humeral bone deficits.[8] Reported revision rates for both techniques are varied in the literature and may relate to the etiology of bone

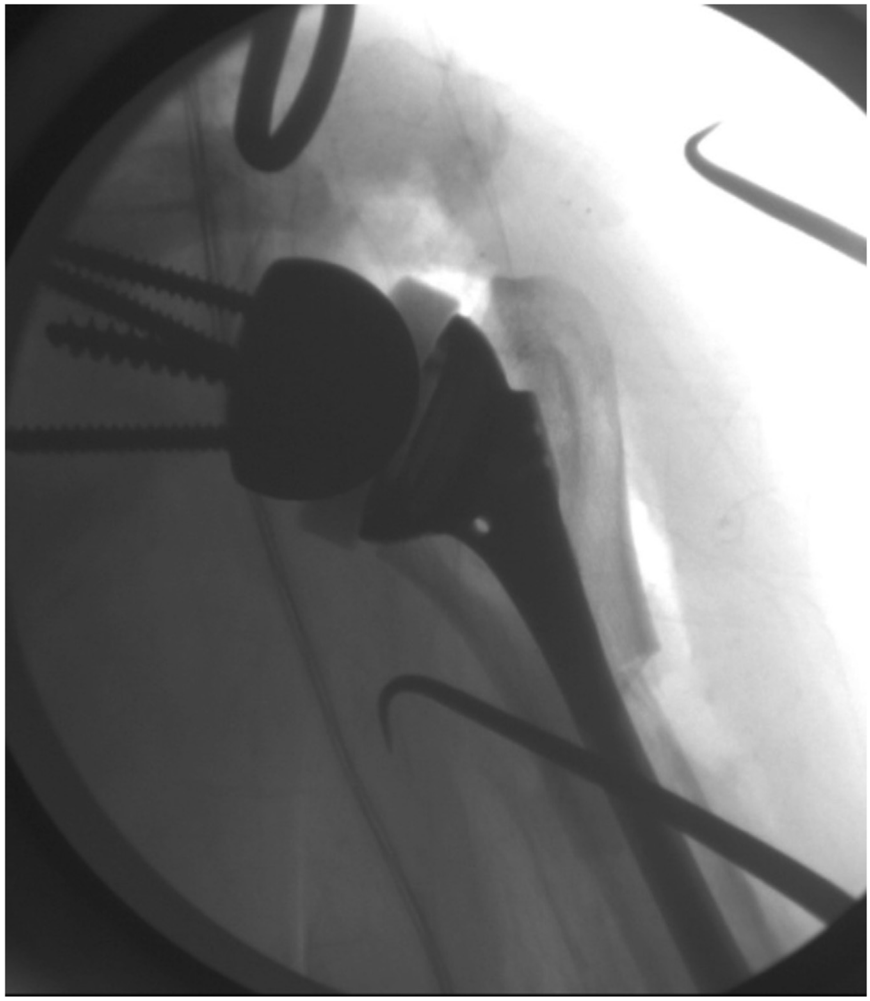

Figure 5 Intraoperative fluoroscopy demonstrating good allograft fit.

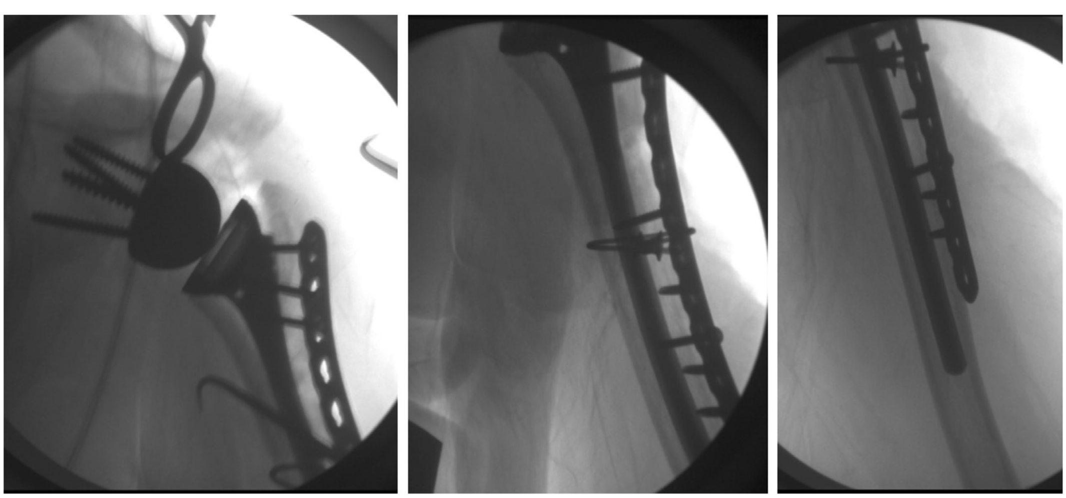

Figure 6 Intraoperative fluoroscopy demonstrating the final construct with plate fixation.

loss. A recent meta-analysis comparing both APC and megaprostheses demonstrated higher revision rates in the APC group (19% in APC versus 11% in megaprosthesis), but this conflicts with other reports[20,25] as well as a systematic review demonstrating an overall revision rate following RS-APC of 10%.[13] Additionally, the aforementioned meta-analysis reported that functional outcomes as well as postoperative motion were significantly improved in patients undergoing APC relative to those in the megaprosthesis group.[2] An additional advantage of allograft reconstruction is that the soft tissue envelope can be repaired to the graft.[11] Breakage,

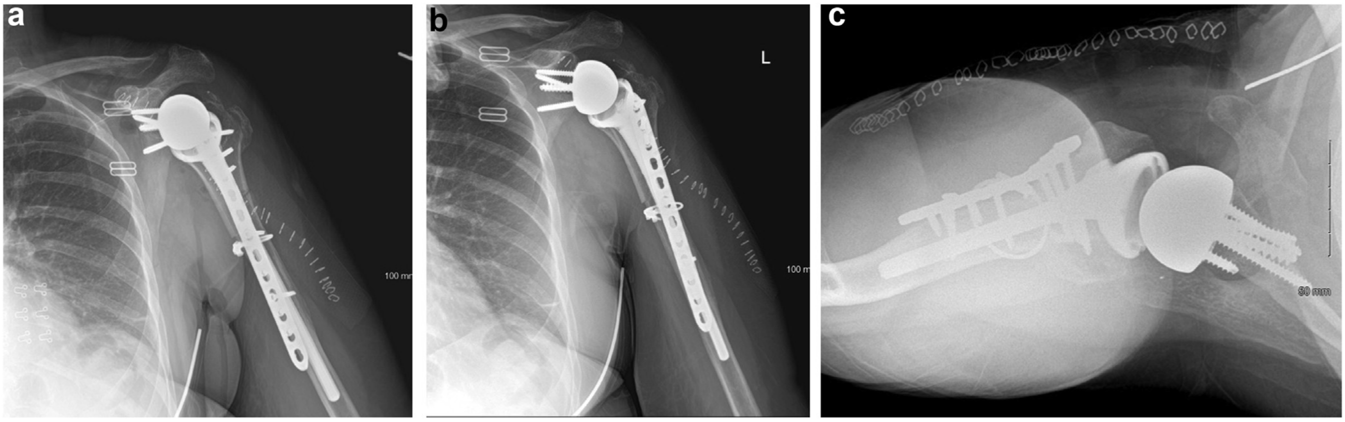

Figure 7 Initial postoperative plain radiographs at one-week follow-up (**a**) Anteroposterior-internal rotation radiograph (**b**) Anteroposterior-external rotation radiograph, (**c**) axillary-lateral radiograph.

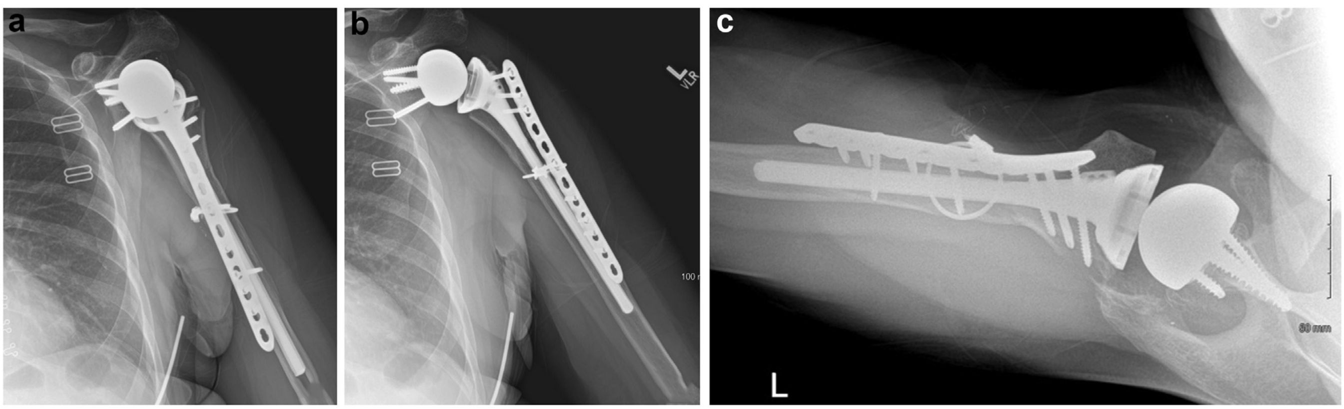

Figure 8 Postoperative plain radiographs at 2 years postoperative (**a**) Anteroposterior-internal rotation radiograph (**b**) Anteroposterior-external rotation radiograph, (**c**) axillary-lateral radiograph.

Figure 9 Still images from a video demonstrating the patient's (**a**) active forward elevation, (**b**) active abduction, (**c**) active external rotation, and (**d**) active internal rotation at 2 years postoperative.

implant failure, and loosening of the humeral megaprosthesis have also been reported in the literature.[11,12]

Chacon and Frankle described the use of a step-cut on the lateral aspect of the graft to improve rotation stability and facilitate fixation.[7] In their technique, the allograft was typically fixed initially to the native humerus with two 1.7 mm cables, and the humeral component was then cemented into the construct.[7] Appropriate sizing of the graft is important and can be achieved using preoperative imaging, including full-length anteroposterior radiographs of both arms, as well as intraoperatively by placing a broach in the native canal, reducing the joint, and assessing the distance from the medial aspect of the humeral shaft to the inferior aspect of the polyethylene liner. More recently, Sanchez-Sotelo has advocated plate fixation of the allograft to host bone for better structural rigidity of the RS-APC construct.[17] The senior author previously employed the step-cut technique but currently employs plate fixation preferentially for RS-APC constructs except for short allograft fragments (2 cm or less medially). Plate fixation offers biomechanical advantages over cable or suture cerclage, and the use of narrower and shorter humeral stems facilitates screw fixation, including the use of skive screws as necessary.

Conclusion

RS-APC is an attractive option for managing challenging cases with significant proximal humeral bone loss, including periprosthetic fractures when the proximal humeral bone is deficient and precludes internal fixation. We present a unique case of a failed RTSA resulting from junctional failure of a modular humeral stem and associated substantial proximal humeral bone loss. We present systematic surgical technique details for implant removal as well as allograft reconstruction in this challenging clinical scenario.

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