JSES Reviews, Reports, and Techniques 2 (2022) 369–375

Contents lists available at ScienceDirect

JSES Reviews, Reports, and Techniques

journal homepage: www.jsesreviewsreportstech.org

Revision total elbow arthroplasty using intramedullary strut allograft for aseptic loosening of the humeral stem

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ARTICLE INFO

Keywords:
Total elbow arthroplasty
Revision
Fibular allograft

Level of evidence: Level V; Technical article

Total elbow arthroplasty (TEA) has become a well-accepted treatment option for many pathologies of the elbow joint. Its use in distal humerus fractures in elderly patients has become increasingly popular and has good clinical results. However, with the aging population and the increasing number of TEAs performed, so comes the potential for an increasing number of revision TEA cases. Revision TEA can be extremely challenging. In addition to the technical difficulties of safe exposure and implant removal, reimplantation of a cemented humeral component with loss of bone stock can be a challenging step in this procedure. The purpose of this article was to describe a novel technique to address aseptic loosening of the humeral stem and loss of humeral bone stock with revision of the humeral component using a long-stemmed cemented implant and intramedullary allograft fibular strut bone grafting.

With the evolution of modern implant technology combined with surgeon education and experience, an increasing number of total elbow arthroplasties (TEAs) are being performed[4,8]. With the increasing use of TEA comes an expanding need for orthopedic surgeons to be able to perform revision surgeries. Although the success of primary TEA for all indications is noteworthy[23], the revision rate for TEA has been reported to be as high as 12% for patients with rheumatoid arthritis and roughly18%-19% for post-traumatic causes.[3,10,21]

Aseptic loosening is one of the most common modes of failure after primary TEA.[19,22]During revision TEA, there is often osteolysis that can be quite severe on the humeral side. If the cortical shell is intact, revision cementation of the humeral component can be performed, but this often requires a very wide cement mantle that may lack long-term stability. *Impaction bone grafting* is a described technique to address cavitary bone loss in the setting of revision TEA. This technique uses allograft cancellous bone to provide structural support and enhance the bone–cement interface. The cancellous chips, however, must be thoroughly impacted and are not ideal to provide rigid structural support to the bone-implant construct[11]. The purpose of this technique article was to describe a novel approach to address cavitary humeral bone loss through the utilization of intramedullary fibular strut allograft.

Case presentation

An 80-year-old female had a ground-level fall and sustained a low supracondylar/intracondylar distal humerus fracture. She was taken to the operating room and underwent an uncomplicated primary TEA using a triceps-on approach; she was noted to have extremely poor bone stock at the time of surgery. Her immediate postoperative course was uneventful, and she achieved an excellent result with decreased pain compared with preoperatively, excellent range of motion (10 degrees short of full extension to 130 degrees of flexion with full pronation/supination, and no signs of post-operative infection). Approximately 1 year later, she developed progressively increasing lower arm pain with activity. Her examination revealed preserved range of motion but crepitus throughout the arc of motion of the elbow. She continued to have no evidence of infection and remained neurovascularly intact in the left upper extremity. Radiographs were taken, which displayed evidence of humeral loosening with cavitary humeral bone loss, very thin humeral cortices, fractures in the humeral cement mantle, and ectopic bone around the anterior distal humeral flange (a radiographic

Institutional review board approval was not required for this technique article.

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https://doi.org/10.1016/j.xrrt.2022.02.004

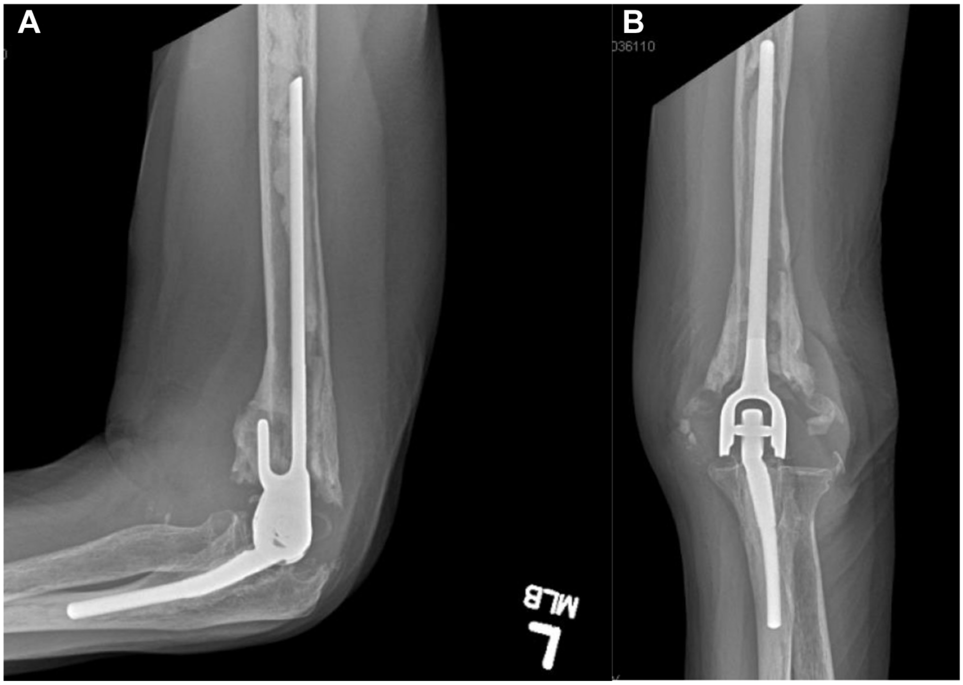

Figure 1 (**A**) AP and (**B**) lateral radiographs 12 months postoperatively showing loosening of the humeral component, cavitary bone loss, cement mantle fractures, and ectopic bone around the anterior distal humeral flange; the ulnar component appears well fixed.

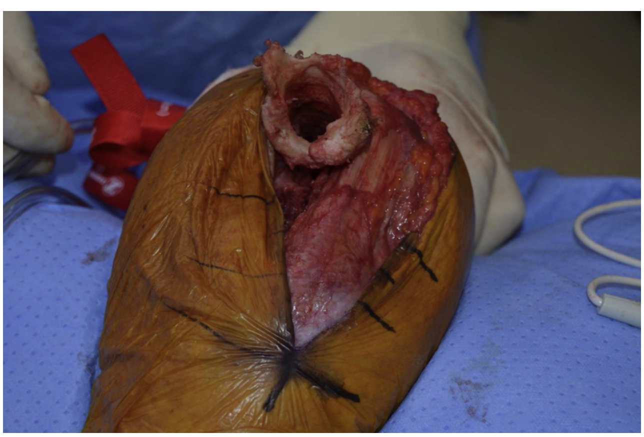

Figure 2 Demonstration of large humeral canal diameter.

finding consistent with humeral loosening). The ulnar component appeared to be well fixed (Fig. 1*A* and *B*).

The patient underwent a thorough infectious workup, which included left elbow aspiration, which yielded normal appearing fluid, a normal cell count, and no bacteria on gram stain or culture.

Surgical technique

With each of our revisions, we enter the operating room planning for exploration, deep cultures, and possible resection arthroplasty vs. revision TEA with bone grafting based on intraoperative findings. We begin by using the original midline incision that was made for the primary arthroplasty. We prefer to use a triceps sparing approach for both our primary and revision elbow arthroplasty to allow for early active range of motion postoperatively. Before making mobilizing the triceps, it is of critical importance to carefully identify and protect the ulnar nerve. We loosely secure a

Figure 3 Preparation of the fibular allograft strut. The fibula was split longitudinally using a microsagittal saw to be press-fit within the humeral canal.

Penrose drain around the nerve once it is identified so that it is easily identified and manipulated throughout the duration of the procedure. Care is taken to avoid pulling traction on the nerve to reduce the risk of postop neuropraxia. Next, the extensor mechanism is elevated first medially, then laterally, with care taken to maintain its insertion on the proximal ulna.

Next, we disengage the articulating portion of the elbow, and the elbow is unlinked. It is at this point in the case that we obtain fluid and tissue samples for culture and microbiology. Based on our intraoperative suspicion of infection, we decided to either proceed with revision vs resection arthroplasty.

Even with a low suspicion for infection, multiple synovial and joint-lining biopsies are obtained and sent to surgical pathology. If there is an equivocal concern for infection based on preoperative

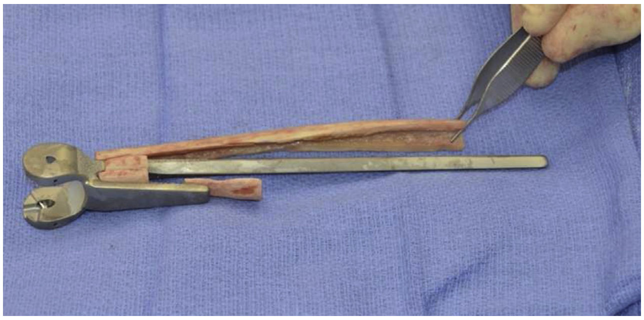

Figure 4 Example of final construct. Posterior intramedullary allograft strut with circumferential grafting around the base of the implant and an anterior flange allograft in place.

Figure 5 Trialing the intramedullary allograft strut and the humeral stem. Microsagittal saw is used to fashion strut to achieve a tight fit.

workup or intraoperative findings, then we may elect to send frozen pathological sections to aid in decision-making.

All loose prosthetic components are then removed (in the case above, the humeral stem was removed by hand, with most of the cement mantle still adhered to the humeral stem). We remove all remaining cement with traditional drilling technique and reverse curettes with the assistance of fluoroscopy. We sometimes use ultrasonically driven tools, but we take extreme caution to avoid thermal necrosis and radial nerve injury. We copiously irrigate the canal with high-pressure pulse lavage and repeat the previously mentioned steps until nearly all cement is removed to get to healthy bone to allow for proper cementation of the humeral component. Depending on the degree of osteolysis seen, the decision may be made to perform impaction grafting with structural allograft. In the case presented, there was severe humeral osteolysis with a very large canal diameter, which would have made it difficult to fit a stem without augmentation (Fig. 2).

During the preparation of the humerus, a fibular allograft is selected for the intramedullary strut and is prepared on the back table. The fibula is then fashioned using a microsagittal saw to the appropriate size/configuration (Fig. 3). When performing impaction grafting for humeral osteolysis, we prefer to create a construct with 3 components that bolster implant fit and rotational stability: a posterior strut running up the length of the humeral stem, circumferential bolster around the base of the stem (often the largest area of osteolysis), and a cortical fragment between the anterior flange and the anterior humeral cortex (Fig. 4).

First, the fibula is split longitudinally. Based on expected stem length, the posterior allograft can be cut to the ideal length

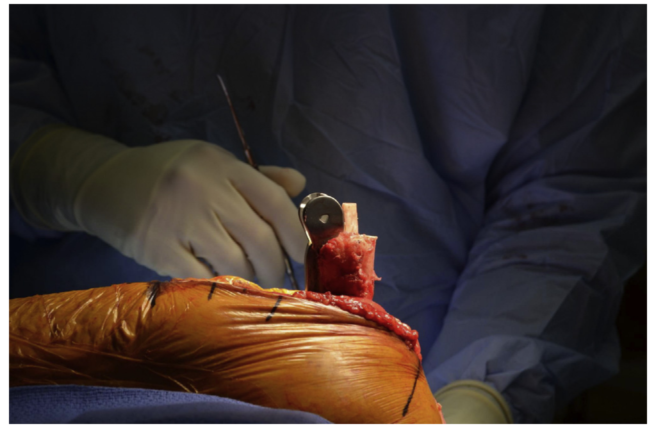

Figure 6 Intraoperative photograph of final humeral stem with intramedullary allograft strut and anterior phalange allograft.

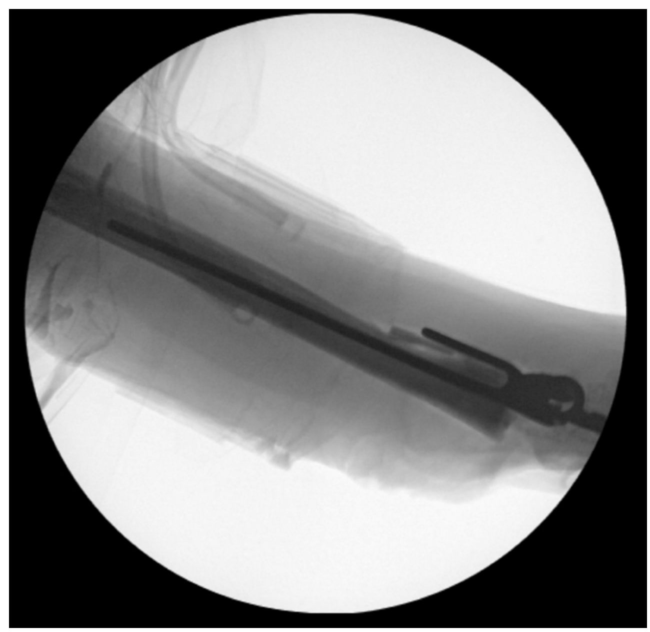

Figure 7 Intraoperative fluoroscopy after revision.

(2-4 cm shy of the tip of the stem). Next, from the remaining half of allograft, 4 smaller pieces of cortical bone are cut and placed around the base of the stem and within the anterior flange. The size of these pieces is determined by the volume of the distal humerus defect and the distance between the anterior cortex and the flange. The allograft and implant are then trialed to assess fit (Figs. 5 and 6). If cut appropriately, a secure fit can be obtained of the intramedullary bone graft strut and the implant.

Next, the implants and allograft are removed (a well-sized posterior strut should have a relatively snug fit and should be removed with care), and the canal is irrigated again and dried with clean sponges. A cement restricting plug is then placed to facilitate pressurization and prevent cement from traveling further than the desired mantle length, roughly 1 cm proximal to the stem. Next, the posterior strut is reimpacted flush with the posterior cortex of the humerus, maintaining good endosteal contact. Once the allograft is in the desired position, cement is pressurized into the canal using a

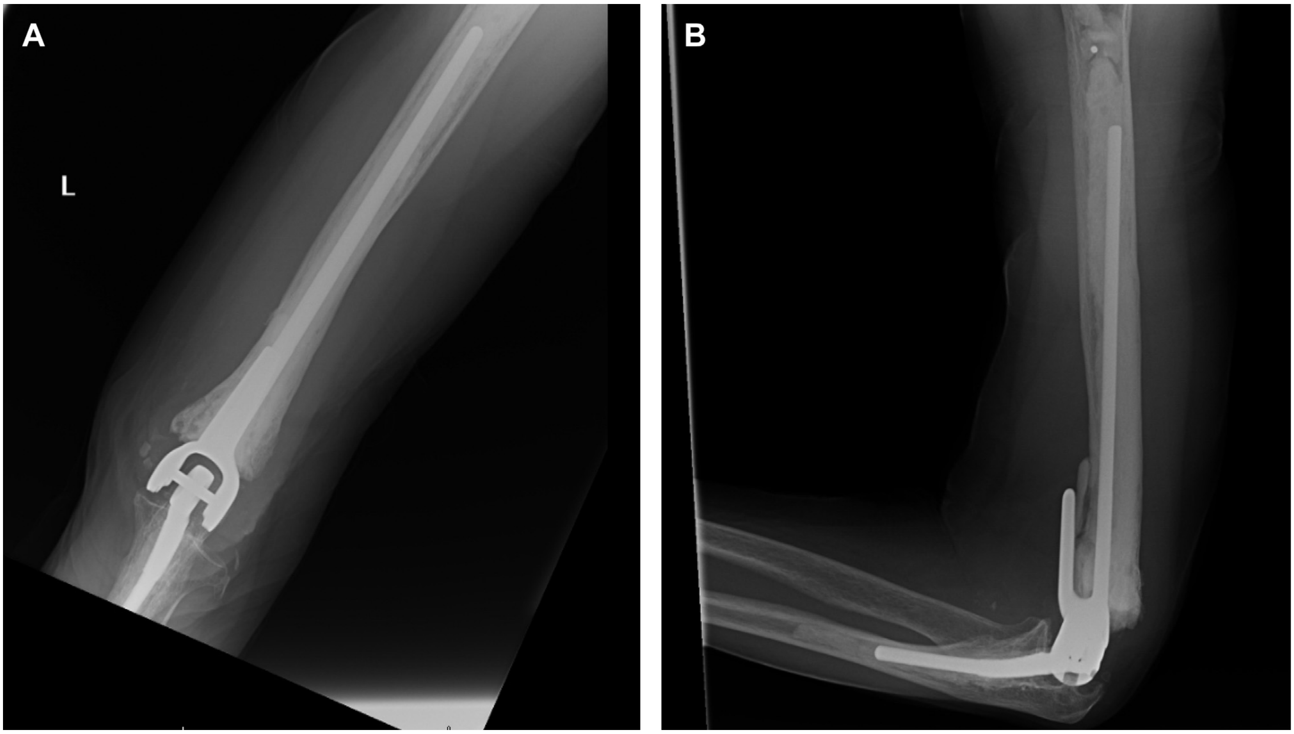

Figure 8 (**A**) AP and (**B**) lateral radiographs at 4-month postoperative visit demonstrating well-fixed humeral component. Allograft strut well placed in the humeral canal. Ulnar component remains stable.

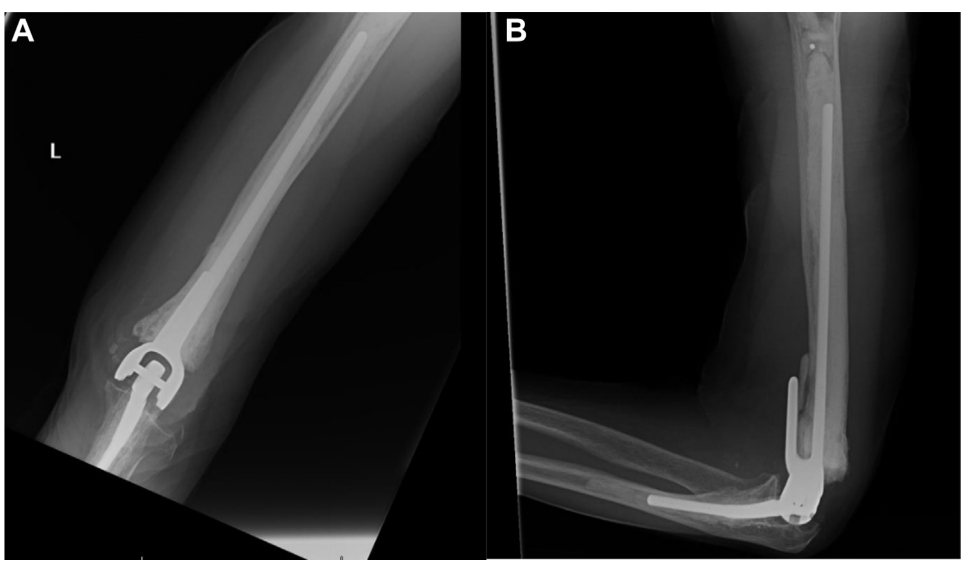

Figure 9 (**A**) AP and (**B**) lateral radiographs at 12-month postoperative visit demonstrating well-fixed humeral component without change from prior images. Ulnar component remains stable.

cemented gun and a pressurizer. Finally, the new humeral stem is then cemented into place with the use of a posterior based allograft intramedullary strut graft and the circumferential strut grafts at the distal aspect of the humeral component.

Importantly, at any of the above portions of the procedure (débridement, impaction, trialing, and final component placement), this thin osteolytic bone is at a high risk for iatrogenic fracture. During the entire procedure, we monitor closely using orthogonal fluoroscopic images to assess for fracture. If fracture occurs before final instrumentation, we would plan to upsize our stem length and length of impaction strut to span the fracture site. Depending on the stability of this new construct, we may or may not augment fixation with an extramedullary strut or large fragment plate. If a fracture develops after cementing, we would only be left with the option of extramedullary augmentation in the form of a strut or plate.

The polyethylene components are then replaced in the ulnar component surface and bearing surface, and the elbow is then relinked. The elbow is taken through a full range of motion to ensure that there are no blocks. Final fluoroscopic x-rays are taken

Figure 10 Clinical photos demonstrating patient at 1-year follow-up. Has regained nearly full range of motion with 3 degrees of extension to 110 degrees of flexion with full pronation and supination of the forearm.

(Fig. 7). Following closure and dressing, the elbow is placed into a volar extension splint to be removed on postop day 2 for initiation of early range of motion.

Postoperative course

In our case, the previously mentioned surgical technique was followed. Six-week postoperative radiographs were taken and demonstrated a stable humeral component with allograft struts in place and no changes in appearance from fluoroscopy taken in the operating room (Fig. 7). The patient has very little pain with a 110 arc of motion with full pronation and supination

Results

A patient was seen at 4-month and 12-month postoperative visits. Radiographs were obtained at both visits, which revealed the components to be in stable alignment (Figs. 8 and 9). Although no definitive conclusions can be made about allograft incorporation on these films, the humeral components remain well fixed with stable alignment. At her 1-year follow-up, she maintained painless range of motion from 3 degrees of extension to 110 degrees of flexion with full pronation and supination of the forearm (Fig. 10). Her Mayo Elbow Performance Score was 100 at this visit as well.

Discussion

Clinically significant loosening after primary TEA has been reported to occur at a rate of 7%-15%[1,9,22]. This often leads to revision TEA, and the surgeon may be faced with technical challenges related to significant bone loss from osteolysis. Several adjuncts are often used to address bone loss in revision TEA, including impaction allograft bone grafting, extra-medullary allograft cortical strut grafting, allograft-prosthesis composites, and custom-made implants.

Impaction bone grafting is an option to specifically address cavitary humeral or ulnar osteolysis during revision TEA. Loebenberg et al[11] reported their experience with this technique in 12 patients. They used a “double tube” apparatus in which allograft bone is tightly packed around in an outer tube (within the canal) before the humeral stem is inserted. All patients were followed for a minimum of 2 years. They found improved range of motion, pain, and functional outcomes. They found 8 of 12 patients to have stable, revision-free prosthesis. In another cohort, Rhee et al[17] reported on their experience with impaction grafting in the setting of revision TEA due to aseptic loosening. They reported that 15 of 16 patients in their cohort had satisfactory radiographic outcomes and good to excellent results. However, this technique has limitations. It relies on using a substantial amount of cancellous bone allograft that is susceptible to collapse during implant placement. In addition, in cases of severe cavitary bone loss, it can be very difficult to narrow the canal adequately to create an ideal cement mantle width with cancellous allograft. Even in the most experienced hands, this technique was found to have a relatively high rate of implant loosening[11].

The novel technique we have described offers an alternative to impaction bone grafting to address cavitary humeral bone loss. It uses an intramedullary allograft strut to obtain a "tight-fit" for the humeral stem, which improves rotational instability. Papadonikolakis et al[15] sought to address this in a similar fashion by using an intramedullary allograft when faced with both humeral and ulnar osteolysis after TEA. However, their described technique differs from ours in several important ways. First, they impacted their structural allograft after placing their cement/prosthesis in the humeral canal. We pressurized cement into our canal after impacting our posterior strut. By cementing second, we hoped to improve direct contact surface area/contact pressure (without intervening cement) between the endosteum and the allograft. This, in theory, would permit more "creeping substitution" and ingrowth of the allograft[18]. Second, the authors only used one structural graft in their technique either behind the humeral stem or the ulnar stem. As seen in Fig. 5 of our technique, not only did we place a posterior strut, we also built up the base of the humeral implant circumferentially with cortical allograft and placed a small strut within our anterior flange. On preoperative imaging, we can see that the distal humerus was the site of greatest osteolysis. By narrowing the intramedullary canal with our technique, we provide 2 benefits in these cases of severe osteolysis. First, we increase cortical contact with the implant stem, which improves rotational stability. Second, a properly sized cement mantle can be used, which can optimize long-term stability.[6,14,15]

As shown in the adult hip and knee literature, the appropriately sized cement mantle limits micromotion at the implant-cement or cement-bone interface, which decreases wear particles and ultimately decreases aseptic loosening[13]. It was long believed that at least a 3-5 mm cement mantle was appropriate in the arthroplasty setting[12,16]; however, Skinner et al [20] evaluated 10-year survivorship of femoral stems in total hip arthroplasty comparing 2 cementing techniques. They found longer survivorship and less vertical migration in the cementing technique that used only a broach to prepare the femoral canal "line to line" compared with over reaming by 2 mm to create an oversized cement mantle. They concluded that a press-fit stem supplemented with cement was better than an oversized cement mantle. We have extrapolated this to TEA, and a press-fit stem with a cement mantle has become the standard technique used in the primary and revision settings at our institution. In addition, the most critical component for union when using allograft is the host-allograft contact surface area.[7] The current technique creates a large surface area of contact between allograft and host bone. For these reasons, the authors favor this technique as an alternative to impaction bone grafting in cases of severe humeral cavitary bone loss.

The use of an intramedullary allograft strut has also been used in other clinical conditions. Chow et al[5] performed a cadaveric study looking at fixation of proximal humeral fractures with and without intramedullary allograft augmentation. They found that none of the augmented fractures collapsed, and 6 of the 8 nonaugmented fractures collapsed. They concluded that the use of intramedullary allograft aids in the stability of proximal humeral fractures and prevents varus collapse. In a clinical study, Badman et al[2] reported on a cohort treated with intramedullary allograft for proximal humeral nonunions. They found a 94% union rate at the final follow-up. In addition to these studies, Willis et al[24] reported on 20 patients with humeral shaft nonunions treated for atrophic nonunions of the humeral shaft. They were treated using an intramedullary allograft strut, fashioned in a similar manner to our technique, along with compressive locked plating. They reported high union rates, with only one patient in their cohort with residual nonunion at the final follow-up. An important distinction between the aforementioned studies and our technique is the use of cement. Cement interposition between the strut and native bone would likely prevent the osteoclast/osteoblast invasion that is essential for host incorporation of osteoconductive bone graft substitutes[18]. Although we have attempted to address this issue with our system of impaction followed by cementing, we cannot draw a direct comparison to studies using cementless constructs.

There are several limitations of this technique. First, there is no long-term follow-up to demonstrate the longevity of this technique. Second, this technique is only indicated for well-contained, cavitary humeral bone loss. Although similar techniques have been described in the ulna, we have no experience using this technique for cortical defects or ulnar-sided osteolysis. Third, if infection occurs, removing the strut allograft may be very difficult and may require an extensile osteotomy. However, we believe that the benefits of improved cortical contact with rotational control, decreased cement mantle width, and the potential for increasing host bone volume make this a very useful technique. In addition, extramedullary allograft is frequently used in prosthetic revision with a similar risk of infection.

Conclusion

Revision TEA is a challenging problem that is often complicated by severe osteolysis. This novel technique uses an intramedullary strut allograft with a long, cemented humeral implant to maximize construct stability in revision TEA. Further long-term studies are needed to validate this technique.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: N.H. receives consulting fees from Biomet not related to the subject of this article. The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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