Distal Radius Allograft Reconstruction Utilizing a Step-Cut Technique After En Bloc Tumor Resection

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Abstract

Background: En bloc resection of the distal radius is a common treatment for advanced and recurrent giant cell tumors and less commonly for sarcoma. Various reconstructive options exist, including ulnar transposition, osteoarticular autograft and allograft, and allograft arthrodesis. We present a technique of reconstruction using a distal radius bulk allograft with a step-cut to allow for precise restoration of proper length and to promote bony union. **Methods:** Preoperative templating is performed with affected and contralateral radiographs to assess the size of the expected bony defect, location of the step-cut, and the optimal size of the distal radius allograft required. A standard dorsal approach to the distal radius is utilized, and the tumor is resected. A proximal row carpectomy is performed, and the plate/allograft construct is applied to the remaining host bone. Iliac crest bone graft is harvested and introduced at the graft-bone interface and radiocarpal arthrodesis sites. **Results:** We have previously reported outstanding union rates with the step-cut technique compared with a standard transverse cut. **Conclusions:** The technique described provides reproducible union and stabilization of the wrist and forearm with adequate function following en bloc resection of the distal radius for tumor.

Keywords: distal radius, allograft, step-cut, giant cell tumor, wrist arthrodesis

Introduction

Giant cell tumors and other tumors encountered at the distal radius may be treated with intralesional excision or en bloc tumor resection with wrist reconstruction.^{1,5} We previously reported functional outcomes and recurrence rates following intralesional excision as compared with en bloc tumor resection with either joint preserving or joint sacrificing reconstruction. Our prior study showed drastically reduced recurrence rates with en bloc resection, with no significant differences in functional outcomes between the various procedures.⁶ After resection, many surgeons choose to utilize allograft reconstruction to fill the bony defect. A major complication of this procedure is nonunion of the host-to-graft bone interface, with reported nonunion rates in the literature from 8.3% to 25% when using a transverse cut.^{2,3} In our study, the nonunion rate for distal radius allograft reconstruction with a step-cut technique was 0% at final follow-up in 11 cases with mean follow-up of 153 months.⁶ This is consistent with prior reports of a 0% incidence of nonunion when utilizing a step-cut to promote bony union.⁴ We present a technique of distal radius allograft reconstruction utilizing a step-cut to promote bony union. This can be used for either articulating reconstruction or arthrodesis. This report will summarize the arthrodesis technique we favor due to excellent functional outcome, dura-

bility, and a safe complication profile compared with maintaining the radiocarpal articulation.

Preparation and En Bloc Resection

Prior to graft procurement, formal preoperative templating is performed. Radiographs and computed tomography are utilized to estimate the size of the tumor lesion to be removed. Radiographs are taken of the affected and the unaffected wrist, with a 10-cm magnification ruler in place. The location of the transverse bone cut sufficiently proximal to the tumor margin is estimated along the length of the host radius. The distal radius allograft is subsequently ordered based on these parameters, keeping in mind the goals of filling the resection bed appropriately and ensuring correct laterality. If possible, the radiographs of several

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Figure 1. Complete exposure of the distal radius is shown. Self-retaining retractors are applied proximally and distally while Hohmann retractors protect the volar structures. A Penrose drain is used for gentle retraction of outcropper muscles. A Kirschner wire marks the location of the planned bone cut for tumor excision.

Figure 2. After the step-cut is performed, the distal radius allograft is compressed to the 3.5-mm metaphyseal locked compression plate.

allografts are obtained (with magnification ruler), so a best fit can be chosen. When in doubt, it is better to use a slightly smaller allograft than one that is too large. Notation should be made of the preoperative ulnar variance, so this can be restored with the allograft.

In-Room Preparation and En Bloc Resection

A standard dorsal approach to the distal one-third of the radius, wrist, and hand is used. The dissection is continued radially under the second and first dorsal compartments after which the brachioradialis is sharply released off of its insertion on the radial styloid. The dissection continues ulnar until the head of the ulna is exposed. The radius is now typically sectioned proximally under fluoroscopic guidance and lifted upward to allow sharp release of the pronator quadratus from proximal to distal (Figure 1). The

pronator typically serves as an anterior barrier to the tumor. The distance from the cut to the distal end of the bone is noted and measured. In our experience, this cut tends to be between 3.5 and 5 cm from the dorsal lip of the distal radius. Once this cut is made, the palmar radioulnar ligaments are sectioned, allowing the distal radius to be lifted out of the wound.

The excised distal radius bone is again measured dorsally for confirmation. This will serve as a basis for the length of the subsequent allograft step-cut. The specimen can be bisected on the back table to confirm that the margins appear negative to gross inspection.

Allograft Introduction, Step-Cut, and Plating

A proximal row carpectomy is then performed to simplify the procedure and aid in the fusion process. The middle finger carpometacarpal joint is left undisturbed. For fixation, we prefer to use a 3.5-mm Locked Metaphyseal Compression Plate (LCP; DePuy Synthes, West Chester, Pennsylvania). This implant has a thinner profile on the distal end allowing for less bulky fixation over the middle finger metacarpal. The radial bone cut that has been performed dictates the length of the plate. The length is selected during preoperative templating and confirmed intraoperatively. A slight apex palmar bend is placed in the plate at the location of the radiocarpal joint to place the wrist in approximately 10° of extension, similar to precontoured wrist fusion plates. A burr or rongeur is then used on the allograft to remove Lister's tubercle and any convex dorsal metaphysis so that the plate can lie flat on the radius. The distal articular surface of the allograft is then denuded down to healthy-appearing subchondral and cancellous bone. Care is taken to preserve the sigmoid notch cartilage of the distal radius. The plate is secured to the allograft with serrated bone reduction clamps. Care is taken to have the plate positioned slightly radially along the proximal shaft. This allows the wrist and hand to be positioned in a bit of ulnar deviation, which is favorable for function (Figure 2). The next step is to position the plate and the allograft against the capitate, centered on the third metacarpal. The goal is to achieve 3 screws in the metacarpal, with the proximal screw just distal to the third carpometacarpal joint. Excessive plate length distally makes the plate potentially more prominent on the dorsal hand (Supplemental Figures S1a and S1b).

Once the appropriate position of the plate on the allograft has been confirmed, 2 distal screws are placed into the allograft bone. One can be a locking screw. Next, the step-cut is planned. On the allograft radius, the length of the host radius resection is marked. Typically, a 2.5-cm step-cut is utilized. The ideal design is for 1 to 2 interfragmentary compression screws through the step-cut and 3 bicortical screws in the intact, host radius proximal to this.

The plate is then removed from the allograft. A marking pen is used to design the step-cut resection of the anterior half of the radius over a 2.0- to 2.5-mm distance. Care is taken to center the cut on the rounded radial side of the bone and through the more pointed medial surface at the interosseous membrane attachment. Similarly, the step-cut is planned on the host radius, now removing the dorsal half of the bone over the marked distance with an oscillating saw. Once both cuts have been performed (Supplemental Figures S2 and S3), the plate is reapplied to the allograft utilizing the previously placed clamps and screws (Figure 2). This construct is now reduced and clamped to the host radial shaft by sliding the plate and graft beneath the first compartment muscles and tendons (Supplemental Figure S4). Care is taken to ensure proper fit and alignment of the distal radioulnar joint under fluoroscopy. Adjustments are now made in the step-cuts as needed to provide proper alignment of the allograft relative to the radial shaft and the distal ulna. One can increase radial length by simply gapping the step-cut surfaces a bit proximally and distally. Shortening requires removal of a bone edge along the step-cut.

Once proper plate position has been confirmed, one of the 3 proximal holes is drilled eccentrically to provide compression. This screw is not placed at this time. The allograft/plate construct is now removed from the wound. Nonstructural cancellous autograft is harvested from the anterior iliac crest. The allograft/plate construct is brought back to the wound and slid under the outcropper muscles. The step-cut is approximated, and some of the bone graft is applied to the step-cut (ie, "buttering the junction"). The reduction is now completed, and the previously placed cortical screw is applied through the plate and into the shaft proximally. The reduction and alignment are confirmed utilizing intraoperative fluoroscopy. Additional screws are placed proximally in the shaft, and the step-cut screws are placed. Interfragmentary compression is achieved by lag technique for at least 1 screw.

Next, a large amount of bone graft is applied to the end of the radius allograft (Supplemental Figures S5a and S5b), and the metacarpal and capitate are reduced to the allograft radius and the plate. The carpus is manually compressed into the bone graft and fixed as above into the third metacarpal, ideally with at least 1 screw in compression mode via eccentric drilling. Care is taken to ensure proper relationship of the radiocarpal articulation in the frontal and lateral planes. Often, an additional locking screw can be placed into the capitate. Additional cancellous bone graft is packed dorsally beneath the plate and along the fusion surface. Any remaining graft can be placed around the step-cut proximally. The soft tissue sleeve is closed distally over as much of the plate as possible.

Last, the dorsal retinaculum is repaired, taking care to maintain the ulnar head reduced to the sigmoid notch of the radius at the distal radioulnar joint. As long as the

joint appears reduced, we have tended to repair and tighten the retinaculum and thus the entire soft tissue envelope over the plate and the allograft. We have not added supplemental pins or any type of stabilization procedures for the distal ulna. If forearm rotation is not possible or if the joint is arthritic or incongruous, a distal ulna resection can be performed. The soft tissues are closed in the usual fashion.

Postoperative Protocol

The patient is typically admitted for a 23-hour stay and, at 10 to 14 days, is converted to a long-arm splint or cast at 90° with the forearm in neutral rotation for approximately 3 to 4 weeks to allow for soft tissue healing around the distal radioulnar joint. After this initial period of immobilization, a formal rehabilitation protocol begins with interval splinting.

Summary

Giant cell tumor of bone and other tumors of the distal radius can be effectively treated with en bloc tumor resection and allograft reconstruction. This is most commonly required in more advanced cases and in the setting of recurrent disease after failed curettage procedures. By use of a step-cut technique as opposed to a transverse cut during allograft introduction, the surface area of host-to-graft bone interface is maximized. This also allows for length adjustment intraoperatively. Bony union is predictably achieved with this technique.^{4,6} Meticulous preoperative templating and complete tumor resection have led to low tumor recurrence rates without sacrificing functional outcomes.^{5,6} It is important to achieve a stable fixation construct by appropriately placing screws across the step-cut fusion site and appropriate reconstitution of the length relationship at the distal radioulnar joint.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

Declaration of Conflicting Interests

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