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Surgical Technique

Elbow Uncemented Hemiarthroplasty: Surgical Technique

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Management of elbow arthritis in younger and higher demand patients is challenging and may benefit from a distal humerus hemiarthroplasty that employs a noncemented method of implant fixation and stabilizes the elbow through ligament reconstruction. By not replacing both articulating surfaces, hardware longevity may be improved. We describe a novel system that may be indicated for the treatment of posttraumatic or primary osteoarthritis of the distal humerus. The step-by-step technique for surgical implantation of this uncemented distal humerus hemiarthroplasty is described and illustrated.

Elbow arthritis is challenging to manage with current surgical options, including debridement efforts and interposition as well as total elbow arthroplasty.[1] Implant failure and elbow instability remain substantial challenges. Treatment of elbow arthritis is proposed using a method that replaces the distal humerus while sparing the proximal ulna. Implant fixation is derived through the placement of an intramedullary (IM) screw, and ligamentous stability is provided through a simultaneously tightened medial and lateral ligament reconstruction.

Elbow hemiarthroplasty using a primitive acrylic prosthesis was first reported as a salvage procedure for extensive injuries to the distal humerus.[1] Custom vitallium and nylon prostheses were also used.[2,3] Distal humerus hemiarthroplasty has been performed for a variety of indications, including primary, posttraumatic, and rheumatoid arthritis, and for tumor management.[4–9]

Hemiarthroplasty may be valuable in the management of younger patients given the shortfall of cemented, linked total elbow arthroplasty secondary to aseptic loosening and implant failure. Given that loosening rates of the humeral component are less than that of the ulnar component, isolated distal humerus replacement may provide durability advantages when compared with standard total elbow arthroplasty.[5–7] By only replacing the distal humerus and avoiding a mechanical linkage, a risk of elbow instability exists, which mandates restoration of ligamentous integrity.

We previously reported a novel system for total elbow replacement and demonstrated its mechanical stability and strength through cyclic loading in a cadaver study.[8] We sought to employ this system as a distal humerus hemiarthroplasty for managing patients with intact cartilage of the proximal ulna. We describe the indications, technical approach, and pitfalls of implanting this device as an alternative approach for the treatment of complex distal humerus trauma and isolated distal humerus arthritis.

Indications

Hemiarthroplasty of the elbow may be particularly suited for patients with substantial durability requirements and where damage to the distal humerus has occurred with relative sparing of the proximal ulna, such as a low condylar shearing fracture of the articular surface, or for patients who have undergone a faiiled open reduction internal fixation effort. Moreover, performing distal humerus hemiarthroplasty with a system that can be later converted to a total elbow arthroplasty may be beneficial.

Declaration of interest: R.A.K. owns Arrch Orthopaedics that has developed a novel elbow arthroplasty employed in this study. No benefits in any form have been received or will be received by the other author(s) related directly to this article.

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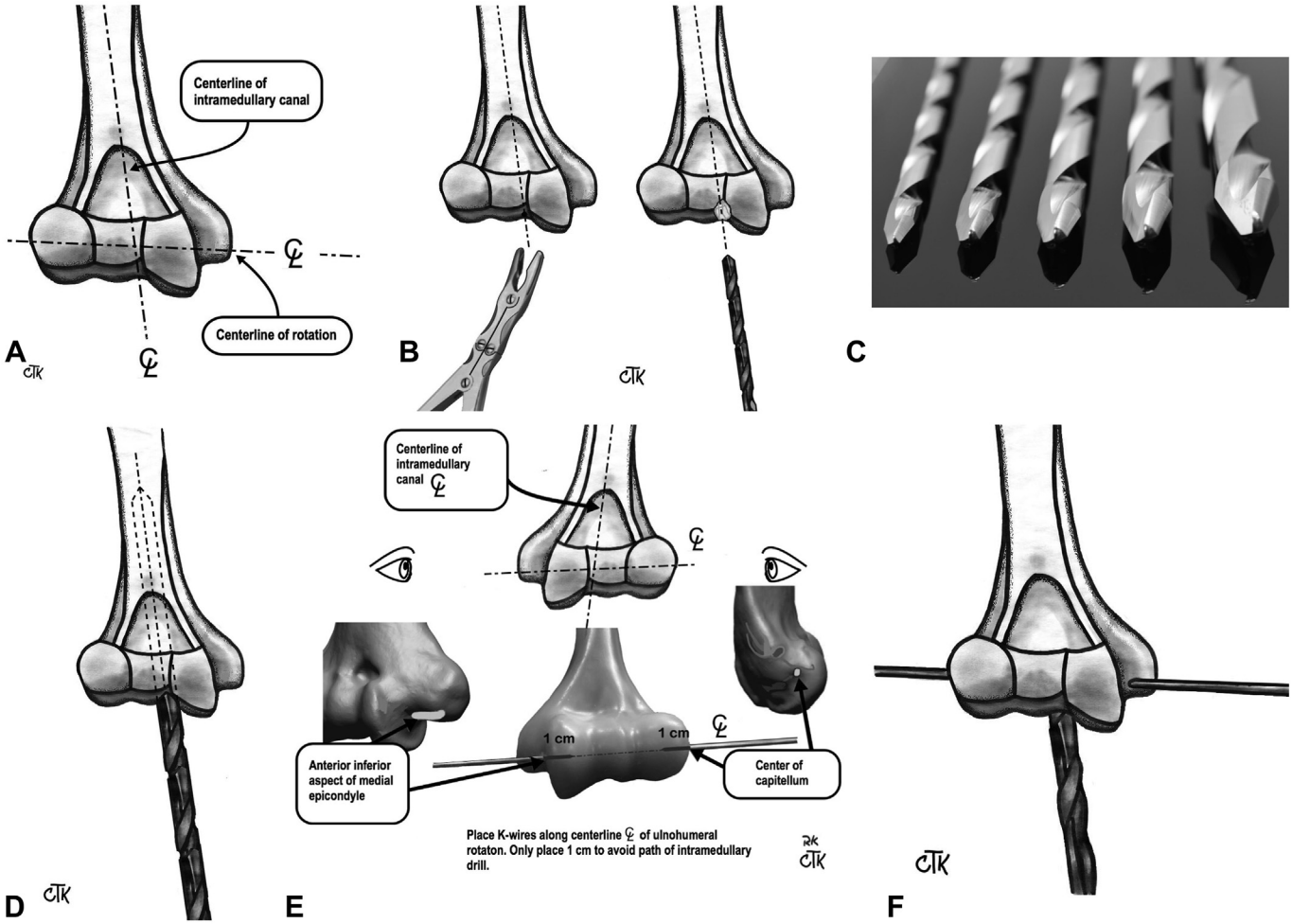

Figure 1. Identification of the centerline of the IM canal and centerline of ulnohumeral rotation are the two critical steps to distal humerus hemiarthroplasty implantation. **A** Identification of the centerline of the IM canal and centerline of ulnohumeral rotation. **B** A rongeur and pilot drill bit are used to identify the canal. **C, D** Custom drill bits are used to identify and widen the IM canal along its axis. **E** The centerline of ulnohumeral rotation is identified and marked with K-wires. **F** The final construct prior to distal humeral resection is achieved.

Contraindications

A relative contraindication for distal humeral replacement is lower demand in elderly patients who have been shown to have reasonable outcomes after conventional total elbow arthroplasty.

Surgical Anatomy

Pertinent anatomical features include the following: (1) the valgus alignment of the centerline of ulnohumeral rotation relative to the centerline of the IM canal, which is incorporated into the implant; (2) the centerline of ulnohumeral rotation occurs along an axis that is located at the center of the capitellum on the lateral side and on the anterior inferior aspect of the medial epicondyle on the medial side And (3) the supinator crest can be palpated on the lateral side or referenced as 24.4 mm (95% confidence interval, 22.7–26.1) from the radiocapitellar joint line and represents the site of origin for the lateral ulnar collateral ligament.[9]

Surgical Technique

The authors recommend positioning the patient laterally with the arm over an arm holder. A posterior midline incision is made, and thick flaps are created both on medial and lateral sides (Video, available online on the Journal's website at https://www.jhsgo.org.). The ulnar nerve is identified and transposed anteriorly. A triceps-sparing approach to the elbow is pursued to gain exposure of the distal humeral articular surface. In order to maintain elbow stability, the radial head should not be resected.

The first step is the accurate identification of the humeral shaft IM canal and the centerline of ulnohumeral rotation (Fig. 1A). A rongeur and a pilot drill bit are used to create a hole within the trochlea that roughly corresponded to the course of the IM canal of the humeral shaft (Fig. 1B). Custom drill bits are employed thereafter. The drill bit diameters are 1/4", 5/16", letter U drill (0.368"), 27/64", and 17/32" (Fig. 1C). These custom drill bits have a smooth leading edge that prevents penetration of the inner cortex and remains within the IM canal. The five different sizes correspond to varying IM canal diameters. The smallest bit (1/4") is used first. While drilling, the dorsal and volar humeral shafts are palpated to provide proprioceptive feedback. Sequentially larger drill bits are used until chatter is achieved. Once the last drill bit has been employed (Fig. 1D), the larger diameter drill bit is replaced with the 5/16" diameter drill bit to act as an IM guide. The 5/16" diameter drill bit is advanced approximately 4" within the IM canal of the humeral shaft to prevent toggling of the drill bit.

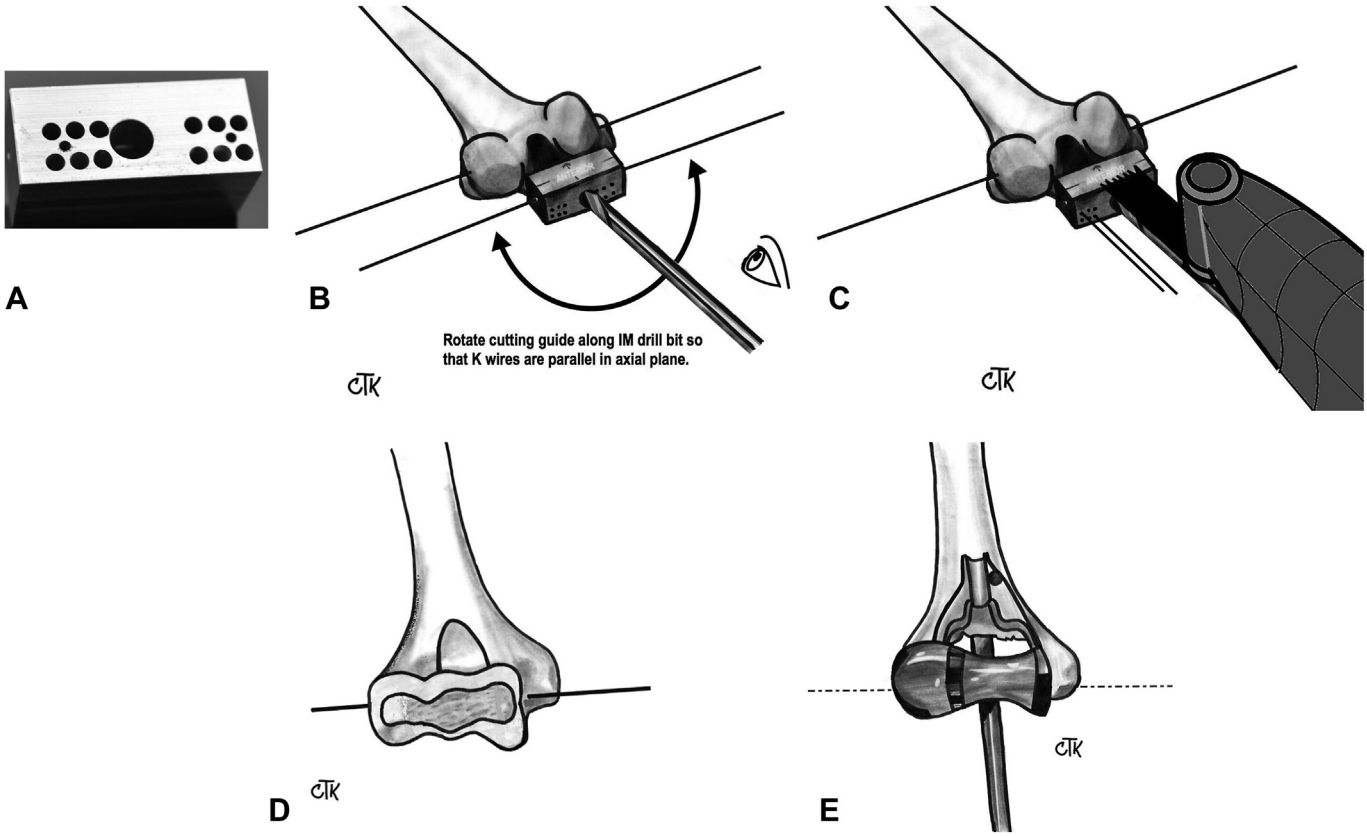

Figure 2. **A** Custom distal humeral cutting block is shown. **B** Cutting block is placed over IM guide and oriented to the ulnohumeral centerline of rotation. **C, D** A sagittal saw is used to remove the anterior distal humerus flush to the cutting block and in line with the ulnohumeral centerline of rotation. **E** The distal humerus is again sized to an appropriate implant.

The ulnohumeral centerline of rotation is located at the center of the capitellum on the lateral side (Fig. 1E). The anterior inferior aspect of the medial epicondyle is used on the medial side. K-wires are drilled into bone, ensuring that they do not interfere with the IM drill bit. The results of the aforementioned steps should demonstrate a 5/16" diameter drill bit that is advanced substantially within the IM canal as well as two K-wires along the ulnohumeral centerline of rotation (Fig. 1F). These two steps ensure proper placement of the distal humeral resection cutting block.

The next step entails resecting the distal humeral bone through use of a custom cutting guide. Right and left cutting blocks exist in sizes small, medium, and large, corresponding to the chosen humeral implant size (Fig. 2A). The cutting block is placed over the IM drill bit and medial and lateral K-wires are placed in holes within the cutting block. These K-wires then function to align the cutting block parallel to the ulnohumeral centerline of rotation (Fig. 2B). The cutting block is then pinned into the distal humerus and a sagittal saw is used to cut the anterior bone (Fig. 2C). The cutting block is then removed, and parallelism between the ulnohumeral centerline of rotation and the cut surface is visualized (Fig. 2D). The appropriate size implant is then placed on this surface to ensure that the morphology of the distal humerus is reproduced by the implant dimensions (Fig. 2E).

After confirming appropriate implant size, the cutting block is set on the anterior distal humerus with its long axis grooves in line with the K-wires that mark the ulnohumeral centerline of rotation and the arrow in line with the IM drill bit. If minimal medial or lateral bone is present on each side of the cutting guide, a smaller implant size must be chosen. Once this orientation is established, a marking pen is used to note the position of the cutting guide (Fig. 3A). A sagittal saw is used to cut the bone within the confines of the pen marks, making sure to be careful with the proximal extent of the cuts to avoid compromising the medial and lateral epicondyles (Fig. 3B). After the cuts have been made, the cutting block should fit nicely in this cavity, and the IM drill bit should fit comfortably within the cutting block (Fig. 3C). Finally, the sagittal saw is used to remove excess distal bone flush with the distal extent of the cutting block (Fig. 3D), completing the distal humerus resection (Fig. 3E).

After contouring the distal humerus to the appropriate dimensions for the implant, the distal humeral metaphyseal bone medially and laterally is sequentially broached to accommodate the implant size. Custom designed interchangeable linear broaches (Fig. 4A) are used to remove medial and lateral bone (Fig. 4B), starting with the smallest (XS) and sequentially increasing to match the chosen implant size. Once the broaching is completed, the IM canal is tapped with custom taps that correspond to the drill bit size that was used (Fig. 4C, D). An appropriate screw length is chosen depending on the depth of the tap with 1.75", 2.75", and 3.75" options available for each screw diameter (Fig. 4E).

A cylindrical ligament retention device (CLRD) is employed for ligamentous reconstruction (Fig. 5A). A device shorter than the width of the implant is chosen to ensure that the CLRD is confined to the interior of the distal humerus implant. The tendon graft is next harvested for ligament reconstruction. Suitable options for tendon graft include palmaris longus, contralateral palmaris longus, half of the flexor carpi radialis or flexor carpi ulnaris, toe extensors, plantaris, semitendinosus, gracilis, or a strip of triceps

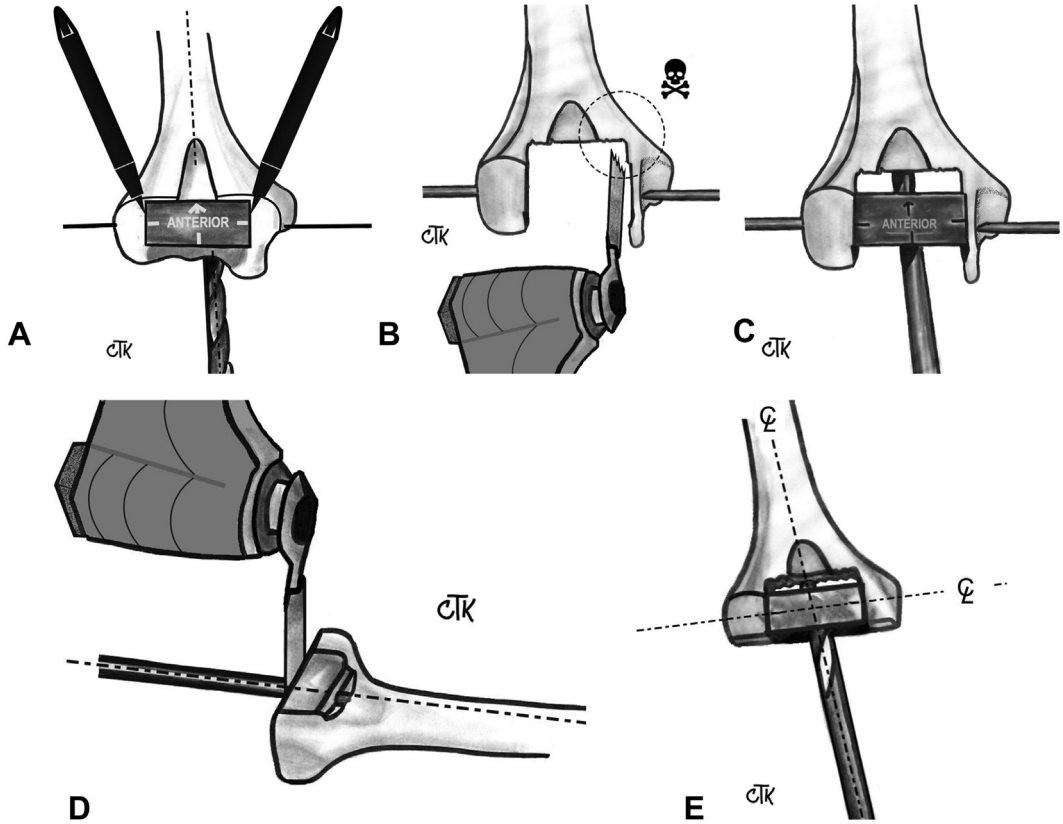

Figure 3. **A** Cutting block is used to guide distal humeral resection. **B** Care is taken to not remove too much medial or lateral bone proximally. **C** After resection, the cutting block fits well in the resection bed and in line with the IM drill bit. **D** Bone distal to the cutting block is removed. **E** The final product of the distal humeral resection is obtained.

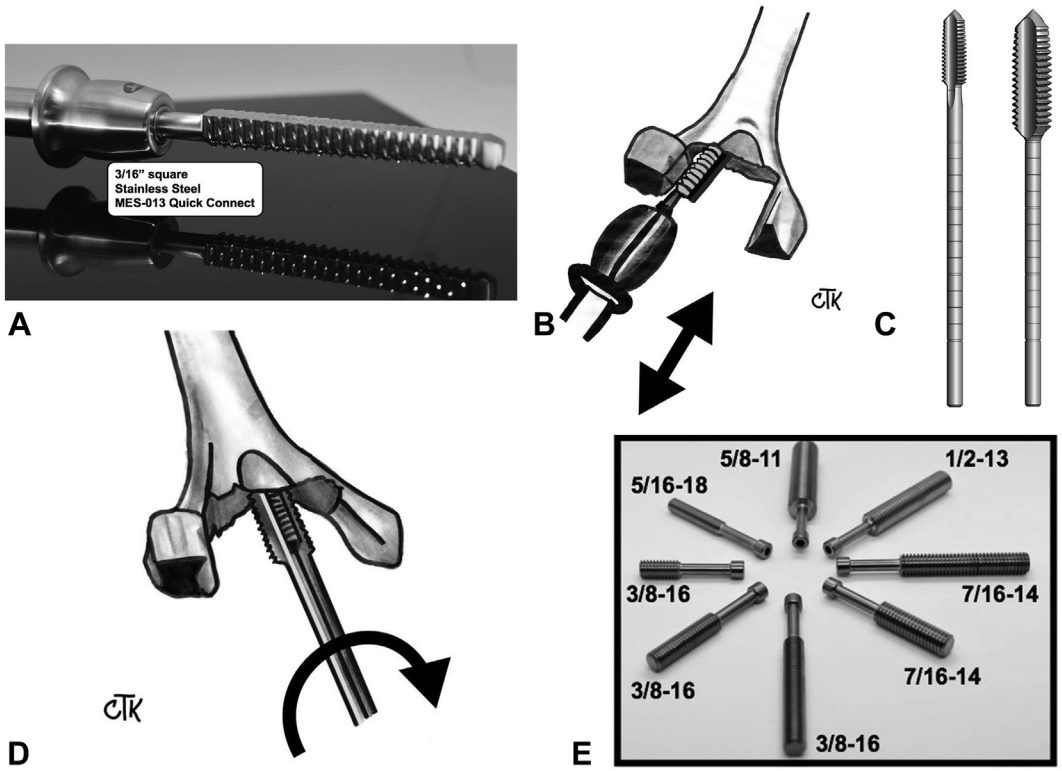

Figure 4. **A, B** Custom linear broaches are used to carefully remove medial and lateral metaphyseal bone to accommodate the implant. **C** Custom IM taps are shown. **D** Custom IM taps are used to tap the humeral diaphysis for IM screw fixation. **E** IM screws are shown.

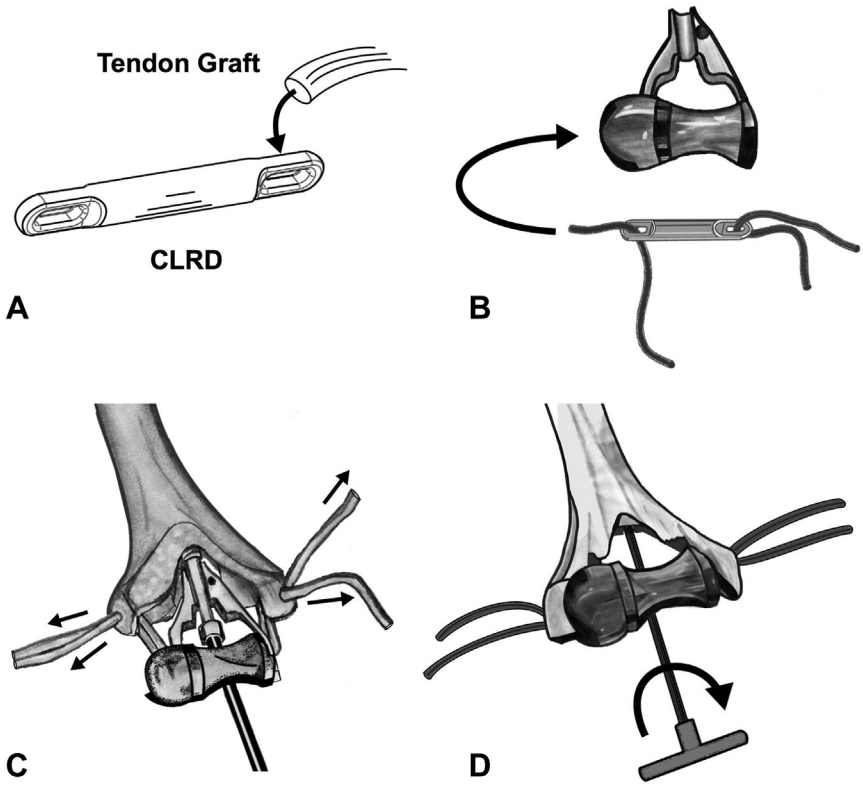

Figure 5. **A** A custom CLRD is employed for ligamentous reconstruction. **B** Tendon grafts are passed through the CLRD on both sides and inserted into the distal humeral prosthesis. **C** Holes are drilled in the medial and lateral epicondyles to pass tendon graft from central to external. **D** The IM screw is tightened to two-finger tightness to fully seat the distal humerus hemiarthroplasty on the distal humeral surface.

tendon. Should insufficient tendon material be present, an allograft tendon, such as an Achilles allograft, can be employed. Similarly, should sufficient tendon material be present but be deemed of poor quality, a #1 polydioxanone (PDS) suture can be woven into the graft to enhance tensile strength. After harvesting, the tendon graft is passed through the CLRD opening on what will be the medial side of the implant. The CLRD is then passed into the implant, exposing the lateral opening on the CLRD through which the second tendon graft is passed (Fig. 5B). The CLRD is positioned centrally in the implant during implantation, and its ability to slide within the bone allows equal tension to be imparted to the grafts when medial and lateral forces are applied. The holes for the ligament reconstruction are drilled through the medial and lateral epicondyle. The process begins with a small pilot drill bit and is dilated just enough to accommodate passage of the tendon grafts. Subsequently, the ligament grafts are passed through these holes in the medial and lateral epicondyles (Fig. 5C). While keeping the ligament limbs taut, the implant is securely seated by tightening the IM screw with a long handle socket wrench (Fig. 5D). It is imperative to not overtighten the IM screw as this may lead to a fracture. Two-finger tightness is recommended. The implant is now securely seated.

The next step entails securing the tendon grafts to complete the ligamentous reconstruction. A targeting guide or freehand technique can be used to make parallel drill holes in the proximal ulna, with the two holes located just proximal and distal to the supinator crest on the lateral side (Fig. 6A). The custom plate fixation system comprises two plates and transulnar bolts, which gain purchase and distribute force evenly over the tendon grafts with their aggressive teeth (Fig. 6B). The plates and screws are assembled through the drill holes in the proximal ulna (Fig. 6C), and then the tendons are passed under the plates and tensioned with 80 N total force (40 N per side) (Fig. 6D). Prior to fixation, should graft tissue be deemed of poor quality, one #1 PDS can be woven into the tendon grafts to impart further tensile strength (Fig. 6E).

Prior studies have demonstrated that tensioning the medial ulnar collateral ligament and lateral ulnar collateral ligament at 20 N or 40 N during ligament repair reproduces native elbow biomechanics.[10,11] Although higher amounts of tension may result in excessive joint loading and valgus alignment, insufficient tension may lead to residual laxity and elbow instability. Prior studies have demonstrated the maximum tension applied with a single hand pull to be in the range of 99 N.[12] As such, the amount of tension in each limb that we recommend is slightly less than maximal pull. Should reproducible accuracy be desired, a tensioner may be employed; however, prior studies have not shown a demonstrable benefit.[13]

After tensioning and securing the tendon grafts beneath the compressive plates, substantial compression between the ligament graft and bone is achieved. This promotes graft to bone healing, which recreates elbow stability. The transulnar bolts are cut with a bolt cutter after nut tightening to minimize bolt protrusion. When PDS suture augmentation is used, the suture ends are tied over the dorsal aspect of the elbow. Although absorbable suture augmentation will increase tensile strength initially, its eventual degradation will allow the ligament grafts to experience the full forces across the elbow, which mitigates stress shielding of the grafts.[14]

After the implantation has been completed and the ulnohumeral joint is reduced with ligamentous reconstruction, the elbow is taken through a range of motion (ROM) to ensure adequate stability. A posterior drawer is performed to see if the ulna can be unseated from the distal humeral implant. With a properly tensioned ligamentous reconstruction, this should not occur. The

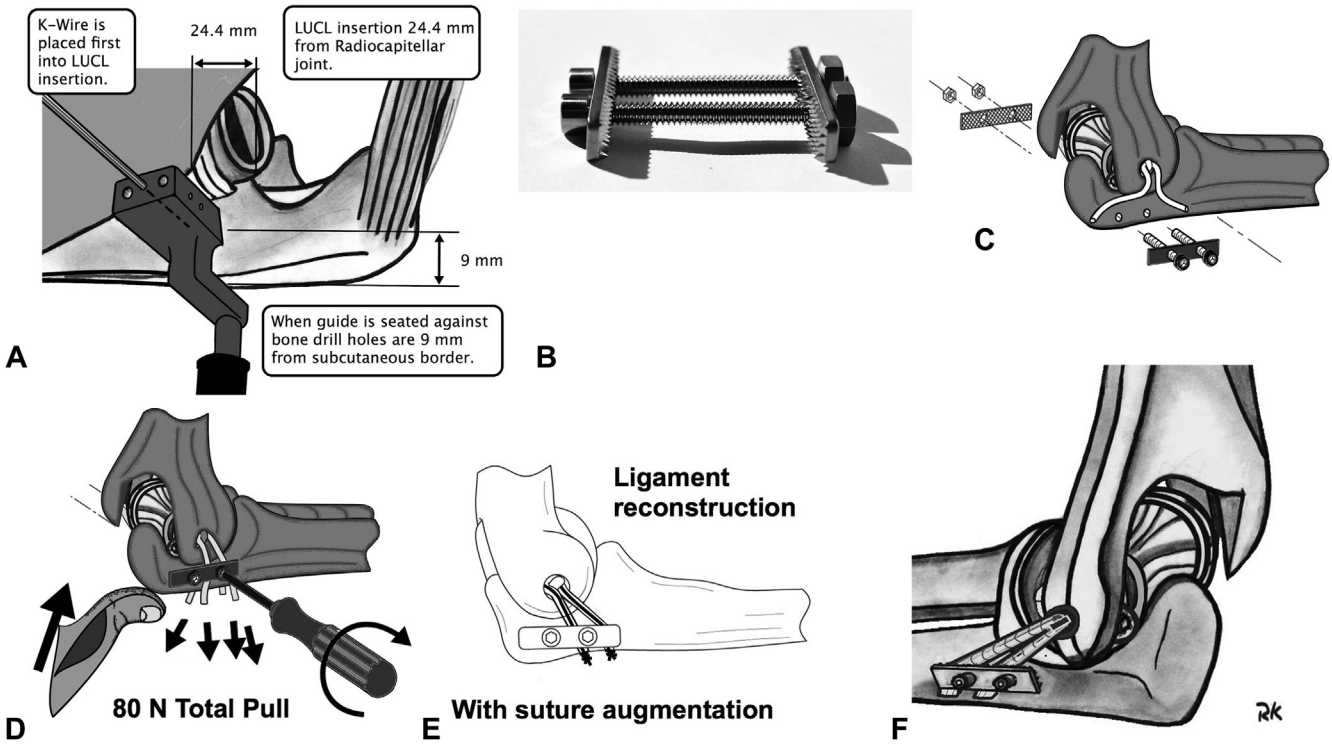

Figure 6. **A** Finalization of ligament reconstruction begins with identifying the landmarks of the lateral ulnar collateral ligament on the proximal ulna. **B** A custom toothed plate is used to apply force and compress the tendon graft to the bone. **C** The two plates and provisionally placed on the proximal ulna. **D** The tendon grafts are passed deep to the plates and tensioned with 80 N total pull. **E** For grafts with poor quality tissue, ligament reconstruction can be augmented with a #2 PDS. **F** Final implant and ligament reconstruction produces a stable elbow.

elbow should move with a full range of flexion and extension, taking into consideration the patient's preoperative motion. With the ligamentous reconstruction, elbow stability is restored after distal humeral hemiarthroplasty (Fig. 6F).

Postoperative Management

After surgery, the arm is placed in a splint in 90° of flexion. The patient should be admitted for observation and pain control overnight and can then be discharged on the first postoperative day. The postoperative rehabilitation course after distal humerus hemiarthroplasty is similar to the commonly performed medial ulnar collateral ligament reconstruction. The sutures are removed 10–14 days after surgery and the patient is placed into a hinged elbow brace for a total of 3 months after surgery. The hinged brace will allow motion between 45° and 140° of flexion for postoperative weeks 2–6. At 6 weeks after surgery, the brace will be unlocked to allow full range of flexion and extension. At three months after surgery, the ligament to bone healing is thought to be sufficient, and the patient may discontinue their brace.

Alternatively, noncompliant patients will be immobilized in a long arm cast for postoperative weeks 2–6. At 6 weeks after surgery, the patient is then placed in a removable thermoplastic splint that is removed four times per day to do overhead ROM exercises in the supine position. During these activities, varus torque is prevented by the patient supporting the weight of the forearm with the contralateral hand. The goal in both of these treatment strategies is for the patient to achieve full ROM by 3 months after surgery.

At 3 months after surgery, the focus of rehabilitation is shifted toward strengthening elbow flexors, extensors, pronators, and supinators. Unrestricted activity and return to sport are determined by patient characteristics and activity level, and are generally allowed between 6 and 12 months after surgery. Formal hand therapy is generally not instituted but may be applicable to certain patients. In contrast to total elbow arthroplasty, where common lifting restrictions of 5 pounds are employed, patients after distal humeral hemiarthroplasty are encouraged to go back to their daily activities with no substantial lifting restriction.

Pearls And Pitfalls

During implantation, the implant needs to sit within the bone, which requires hand broaching that requires persistence and patience. The implant must be seated so that medial and lateral bone is present where the ligament reconstruction limbs will heal to bone. The ligament reconstruction limbs must be appropriately tensioned on medial and lateral sides while the plates are tightened against bone so as to lock in the symmetric graft tension.

Complications

Given that the humeral component is pulled into the distal humerus through advancement of the IM screw, it is imperative not to tighten this screw to two-finger tightness and to avoid a force that would lead to distal humerus fracture.

References

1. Mellen RH, Phalen GS. Arthroplasty of the elbow by replacement of the distal portion of the humerus with an acrylic prosthesis. *J Bone Joint Surg Am.* 1947;29(2):348–353.
2. Venable CS. An elbow and an elbow prosthesis; case of complete loss of the lower third of the humerus. *Am J Surg.* 1952;83(3):271–275. https://doi.org/10.1016/0002-9610(52)90255-9
3. Macausland WR. Replacement of the lower end of the humerus with a prosthesis; a report of four cases. *West J Surg Obstet Gynecol.* 1954;62(11):557–566.

4. Burkhart KJ, Nijs S, Mattyasovszky SG, et al. Distal humerus hemiarthroplasty of the elbow for comminuted distal humeral fractures in the elderly patient. *J Trauma*. 2011;71(3):635–642. https://doi.org/10.1097/TA.0b013e318216936e
5. Thillemann TM, Olsen BS, Johannsen HV, Søjbjerg JO. Long-term results with the Kudo type 3 total elbow arthroplasty. *J Shoulder Elbow Surg*. 2006;15(4):495–499. https://doi.org/10.1016/j.jse.2005.09.002
6. Hildebrand KA, Patterson SD, Regan WD, MacDermid JC, King GJ. Functional outcome of semiconstrained total elbow arthroplasty. *J Bone Joint Surg Am*. 2000;82(10):1379–1386. https://doi.org/10.2106/00004623-200010000-00003
7. Ramsey M, Neale PG, Morrey BF, O'Driscoll SW, An KN. Kinematics and functional characteristics of the Pritchard ERS unlinked total elbow arthroplasty. *J Shoulder Elbow Surg*. 2003;12(4):385–390. https://doi.org/10.1016/s1058-2746(02)86885-9
8. Coutinho DV, Fatehi A, Nazzal EM, Baratz ME, Kaufmann RA. Comparing static stability of native elbow with static stability of novel bidirectional ligament reconstruction at different degrees of elbow flexion. *J Hand Surg Glob Online*. 2023;5(3):318–324. https://doi.org/10.1016/j.jhsg.2023.02.003
9. Bernholt DL, Rosenberg SI, Brady AW, Storaci HW, Viola RW, Hackett TR. Quantitative and qualitative analyses of the lateral ligamentous complex and extensor tendon origins of the elbow: an anatomic study. *Orthop J Sport Med*. 2020;8(10):2325967120961373. https://doi.org/10.1177/2325967120961373
10. Pichora JE, Fraser GS, Ferreira LF, Brownhill JR, Johnson JA, King GJW. The effect of medial collateral ligament repair tension on elbow joint kinematics and stability. *J Hand Surg Am*. 2007;32(8):1210–1217. https://doi.org/10.1016/j.jhsa.2007.05.025
11. Fraser GS, Pichora JE, Ferreira LM, Brownhill JR, Johnson JA, King GJW. Lateral collateral ligament repair restores the initial varus stability of the elbow: an in vitro biomechanical study. *J Orthop Trauma*. 2008;22(9):615–623. https://doi.org/10.1097/BOT.0b013e3181886f37
12. Cunningham R, West JR, Greis PE, Burks RT. A survey of the tension applied to a doubled hamstring tendon graft for reconstruction of the anterior cruciate ligament. *Arthroscopy*. 2002;18(9):983–988. https://doi.org/10.1053/jars.2002.36102
13. Sherman SL, Chalmers PN, Yanke AB, et al. Graft tensioning during knee ligament reconstruction: principles and practice. *J Am Acad Orthop Surg*. 2012;20(10):633–645. https://doi.org/10.5435/JAAOS-20-10-633
14. Nguyen DM, Murawski CD, Fu FH, Kaufmann RA. Stress shielding of ligaments using nonabsorbable suture augmentation may influence the biology of ligament healing. *J Hand Surg Am*. 2022;47(3):275–278. https://doi.org/10.1016/j.jhsa.2021.09.014