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Interposition arthroplasty and bidirectional stabilization of the elbow: a novel surgical technique

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Elbow arthritis is an uncommon but potentially debilitating condition which has limited treatment options.[8] Interposition arthroplasty may be considered for young or high-demand patients, thereby avoiding the lifting restriction and high complication rates of total elbow arthroplasty.[11] Current methods invariably destabilize the elbow as the articular surface is accessed, often requiring ligament reconstruction and postoperative external fixation.[19] In addition, clinical results have implicated instability as a determinant of poor outcomes.[4,16] Instability can be present preoperatively or result from insufficient intraoperative/postoperative stabilization efforts. Arthroscopic methods and epicondylar osteotomies have been described in an effort to avoid postoperative instability, but these techniques are associated with their own difficulties and are technically challenging.[3,15,26]

We propose an interposition arthroplasty technique that reconstructs the collateral ligaments utilizing a single Achilles allograft (Video 1). This approach employs a novel ligament retention device that allows simultaneous tensioning of medial and lateral ligament grafts. This form of ligament reconstruction has previously been studied and was found to closely mimic native elbow ligament biomechanics.[6,13] It has also been shown to successfully stabilize a total elbow arthroplasty in a dynamic cadaver testing model as well as a hemiarthroplasty in a static cadaver testing environment.[5,24] The benefit of the proposed technique is that postoperative external fixation is not necessary.

This technique is indicated for young or high-demand patients with recalcitrant elbow arthritis who are not candidates for total elbow arthroplasty. This technique is contraindicated in patients with severe deformity of the distal humerus and proximal forearm, in patients with active infection, and in patients who are unable or unwilling to comply with postoperative rehabilitation and restrictions.

Surgical technique

Exposure

The patient is placed in a lateral decubitus position with the humerus supported by an arm holder. A posterior midline incision is made and thick subcutaneous flaps are created both medially and laterally. The ulnar nerve is identified, dissected free, and transposed anteriorly. With the ulnar nerve transposed and protected, a triceps-sparing approach to the elbow joint is pursued to gain exposure to the distal humeral articular surface. The proximal ulna is exposed by elevating the extensor carpi ulnaris and anconeus laterally and the flexor carpi ulnaris medially. The lateral ulnar collateral ligament complex (LUCL) and medial collateral ligament complex (MCL) are sharply elevated off bone and left in continuity with the extensor/flexor-pronator masses, which are also sharply elevated off bone. The lateral and medial aspects of the triceps are then released and the triceps is bluntly elevated from the posterior capsule and distal humerus.

Institutional review board approval was not required for this technical note.

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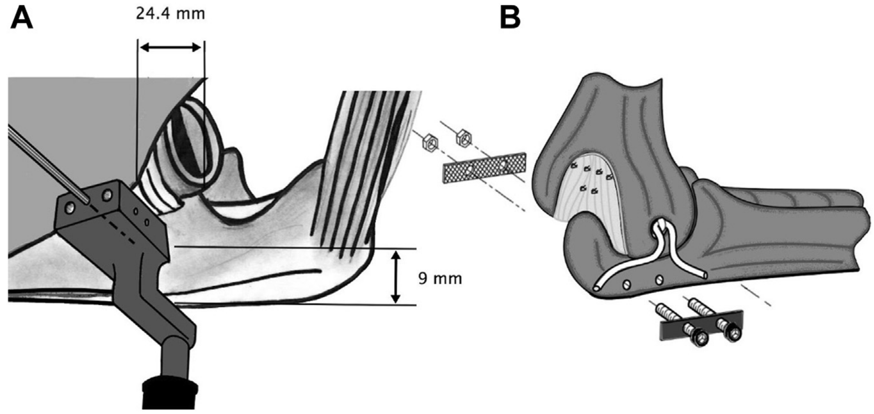

Figure 1 (**A**) A drill guide is employed to facilitate accurate drill hole placement in the proximal ulna. (**B**) The ulnar plates and associated bolts and splined nuts are placed but not fully tightened until subsequent ligament graft placement.

Placement of ligament reconstruction holes in ulna

Transverse drill holes are made in the proximal ulna for the placement of ligament reconstruction plates. First, the supinator crest is identified by palpating the bony prominence on the lateral side of the proximal ulna approximately 24.4 mm (95% CI: 22.7-26.1) distal to the radiocapitellar joint line.[2] This represents the insertion site of the LUCL.

The drill guide has a small central hole that is used for the placement of a K-wire through the supinator crest (Fig. 1, *A*). The K-wire should be placed such that the distance from the subcutaneous border of the ulna to the K-wire is equal both medially and laterally (ie, the wire trajectory should not be anterior or posterior but rather transverse across the ulna). Once the K-wire is in acceptable alignment, the drill guide then allows parallel drilling of two holes across the proximal ulna. The plates are secured with trans-ulnar bolts and splined nuts, which are passed through these holes but not tightened at this stage (Fig. 1, *B*).

Placement of ligament reconstruction hole in humerus

The distal humerus is dislocated posteromedially to decrease tension on the ulnar nerve. In order to maintain bony stability after interposition arthroplasty, the radial head and annular ligament are left in place. The centerline of ulnohumeral rotation is identified medially as the origin of the MCL, which lies on the anterior inferior surface of the medial epicondyle (Fig. 2).[1,9,14] The center of rotation for the LUCL occurs around an axis that passes through the center of the capitellum.[18,20,23]

Isometric graft placement ensures that the ligament reconstruction is not subjected to undue stretch during elbow motion. Because the drill holes are larger than the grafts themselves, the drill holes must be placed proximal and posterior to the centerline of ulnohumeral rotation to accommodate for the size mismatch between the cylindrical ligament retention device (CLRD) drill hole and the ligament graft limbs.

Two K-wires are placed, one medial and one lateral, at the corresponding isometry points. The drill guide is used to place a second parallel K-wire proximal and posterior to the centerline (Fig. 2). A 7 mm cannulated drill is placed over this second K-wire to create lateral and medial drill holes. Care must be taken medially to preserve the anteromedial cortex of the medial epicondyle, which supports the medial ligament graft when stressed. The holes are connected, allowing future CLRD placement at the centerline of rotation.

Achilles allograft sizing and ligament graft harvest

With the distal humerus exposed, the Achilles allograft is draped over the articular surface with the midline of the graft centered on the exposed cartilage. The approximate size of the necessary interposition graft is marked with a pen. The graft should start posteriorly at a point superior to the olecranon fossa and end anteriorly at the corresponding level. The graft width should cover the width of the trochlea at a minimum. Our preference is to leave excess graft on both ends (ie, to supracondylar humerus or further) and to trim excess graft after placement.

While staying outside of the marked boundaries, two strips of graft approximately 3.5-4 mm in width are then sharply excised from the margins to be used for collateral ligament reconstruction (Fig. 3). Care should be taken to stay in line with the allograft fibers and to harvest as long of a graft as allowable. A minimum graft length of 11 cm is recommended. If the width of the Achilles allograft does not allow for ligament graft harvest, independent tendon allografts (eg, semitendinosus) may be used.

Distal humerus preparation

The distal humerus articular surface is then denuded of cartilage using burrs and/or rongeurs (Fig. 4, *A*). Care should be taken to preserve the subchondral bone and to maintain the contour of the articular surface. Four bone tunnels are drilled from posterior to anterior with a 2 mm drill bit approximately 1 cm proximal to the olecranon fossa (Fig. 4, *B*). Two additional 2 mm bone tunnels are drilled from posterior to anterior within the olecranon fossa (Fig. 4, *C*).

Interposition graft suture placement and passing

The proximal aspect of the interposition graft is loaded with three locked nonabsorbable, braided (#2-0 FiberWire; Arthrex, Naples, FL, USA) horizontal mattress sutures, which will reside on the posterior aspect of the distal humerus at the level of the four drill holes (Fig. 5, *A*). The suture limbs are passed through these holes from posterior to anterior with a suture passer such that each "pair" of suture tails is separated by a bone bridge. The medial- and lateral-most bone tunnels will have one suture tail each. The two middle tunnels will have two suture tails each, both from a different suture. This method ensures that all sutures are tied over a bony bridge (Fig. 5, *B-F*). An additional suture is placed through the graft at a level corresponding to the olecranon fossa bone tunnels and passed from posterior to anterior (Fig. 6).

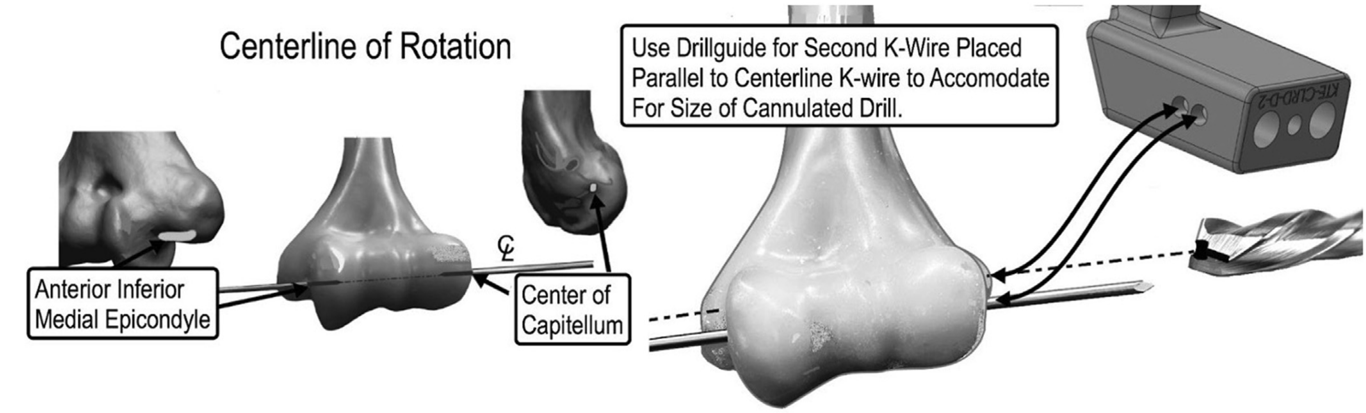

Figure 2 Bony landmarks are used to identify the centerline of ulnohumeral rotation. Two K-wires are drilled along this centerline position from medial and lateral sides. The side holes of the drill guide allow for placement of a second parallel K-wire to accommodate for the radius of the cannulated drill bit.

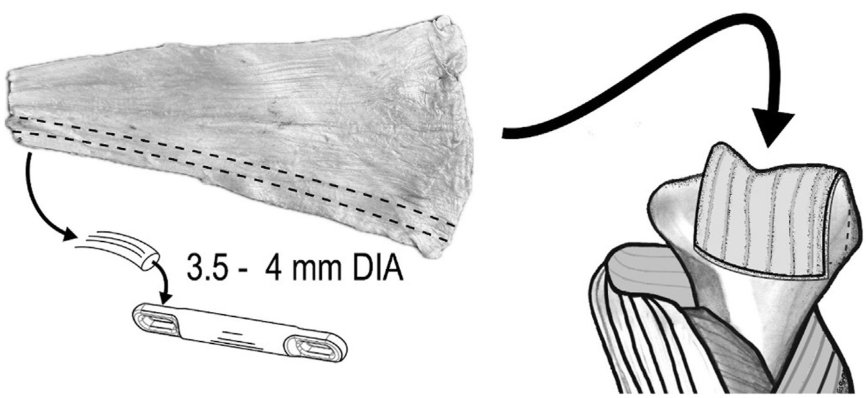

Figure 3 Two strips of allograft (3.5-4 mm in diameter) are harvested to obtain the ligament grafts. The grafts are tested by passing them through the cylindrical ligament retention device (CLRD) eyelets to ensure free passage. The interposition graft is draped over the distal humerus to make sure it is of adequate size. *DIA*, diameter.

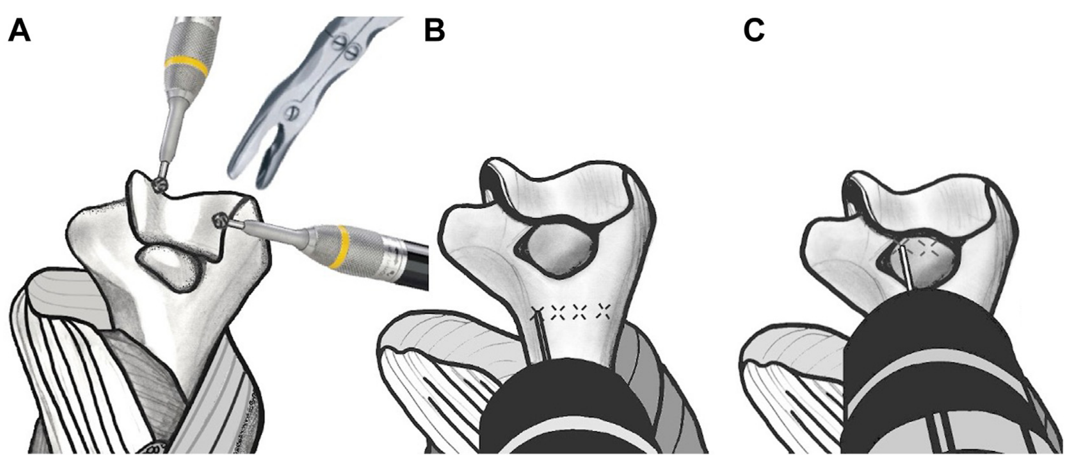

Figure 4 (**A**) The distal humerus articular surface is prepared with a burr and/or rongeurs with care to preserve subchondral bone. (**B**) Four drill holes are placed in the distal humerus 1 cm proximal to the olecranon fossa. (**C**) Two additional drill holes are made within the olecranon fossa.

Once all sutures have been passed, the graft is ready to be tied. First, a free needle is used to pass the olecranon fossa sutures through the anterior aspect of the graft (Fig. 7). To find the appropriate location to pass the suture, the graft is held flush against the distal humerus and the point corresponding to the bone tunnel can be marked with a marking pen. This suture is passed and tied, effectively cinching the graft down to be flush to the fossae. The original three locking horizontal mattress sutures are then also passed with a free needle through the graft. Once all the sutures are located anteriorly, the limbs are tightened and the Achilles interposition graft is secured (Fig. 8). The interposition graft is now trimmed to prevent overhang as necessary.

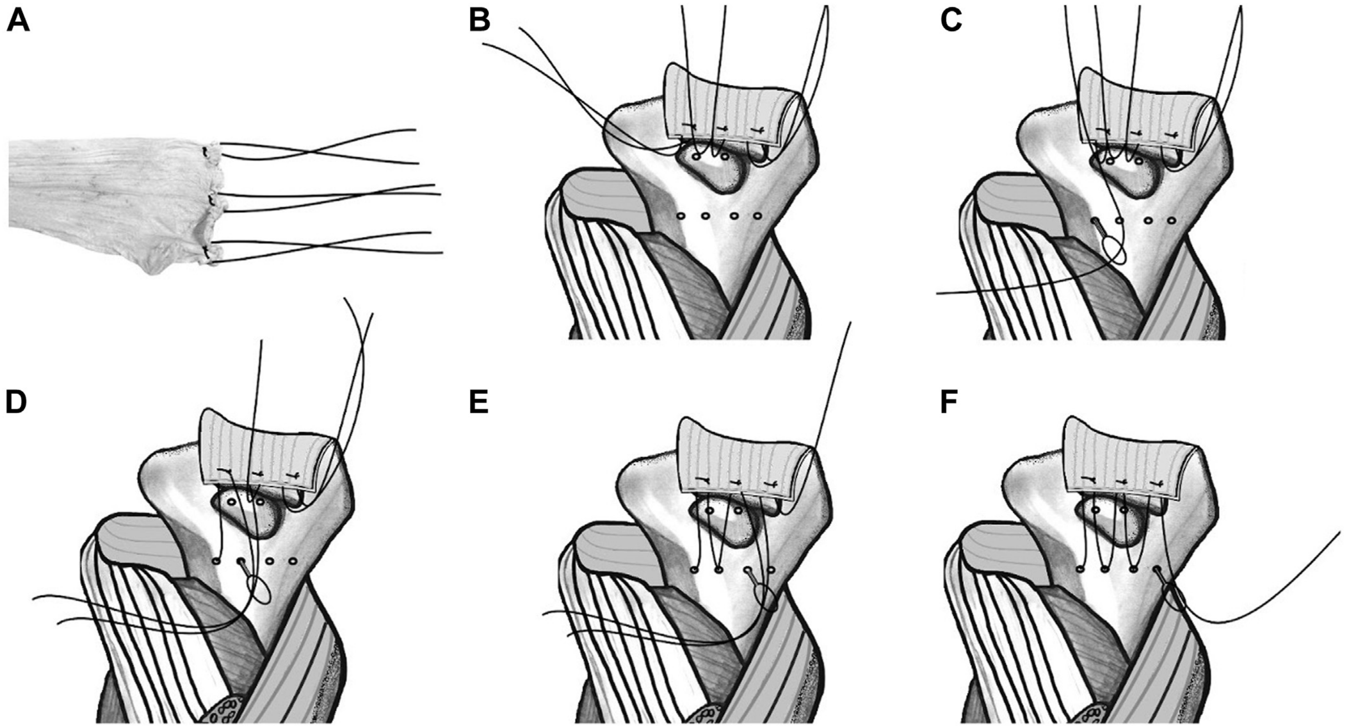

Figure 5 (**A**) The interposition graft is secured with three locking horizontal mattress sutures. (**B**) The graft is draped over the distal humerus and sutures separated as shown. (**C**) Using a suture passer, the medial-most suture limb is passed from posterior to anterior through the medial-most bone tunnel. (**D**) The next two suture limbs are passed through the second bone tunnel. (**E**) The following two suture limbs are passed through the third bone tunnel. (**F**) The lateral-most suture limb is passed through the fourth bone tunnel.

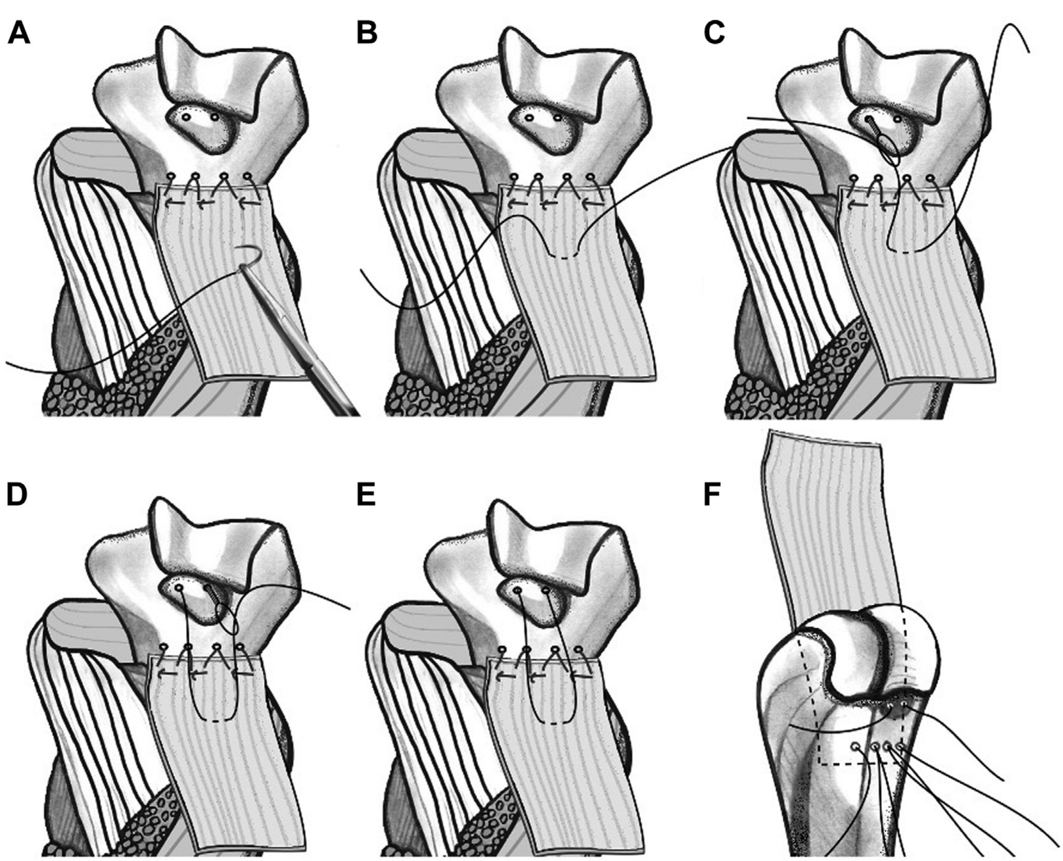

Figure 6 (**A**) A suture is placed to match the olecranon fossa holes. (**B**) The suture limbs are ready to be retrieved. (**C**) Using a suture passer, the medial-most suture limb is passed from posterior to anterior through the medial fossa hole. (**D**) The next suture limb is passed through the second bone tunnel. (**E**) Both suture limbs have been passed. (**F**) The interposition graft is flipped over the distal humerus articular surface.

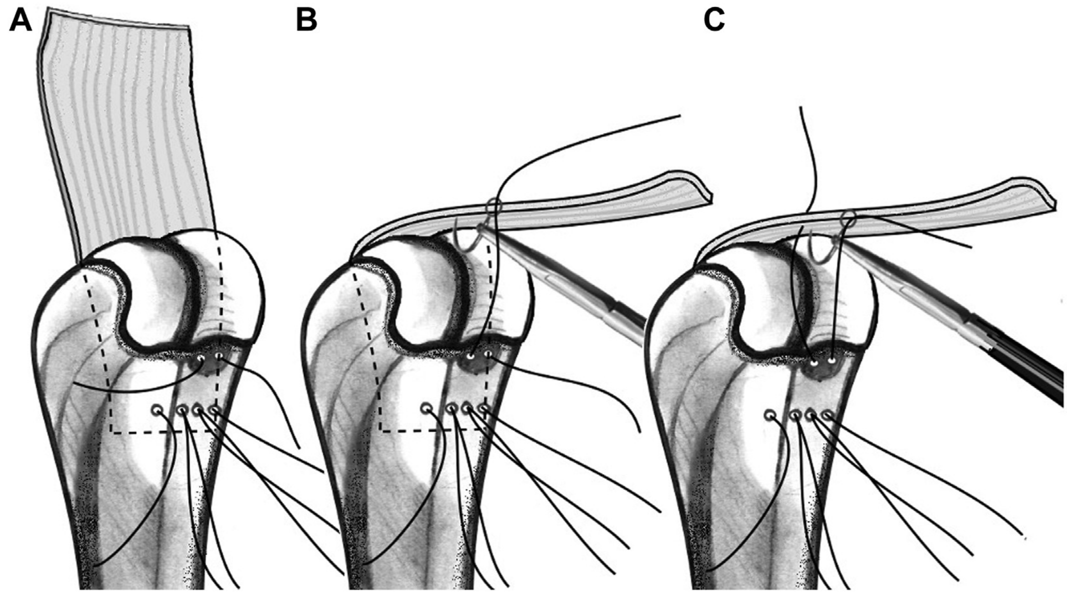

Figure 7 (**A**) All suture limbs have been passed through the distal humerus. (**B**) A free needle is used to pass the lateral olecranon fossa suture through the interposition graft. (**C**) The medial olecranon fossa suture is passed through the graft.

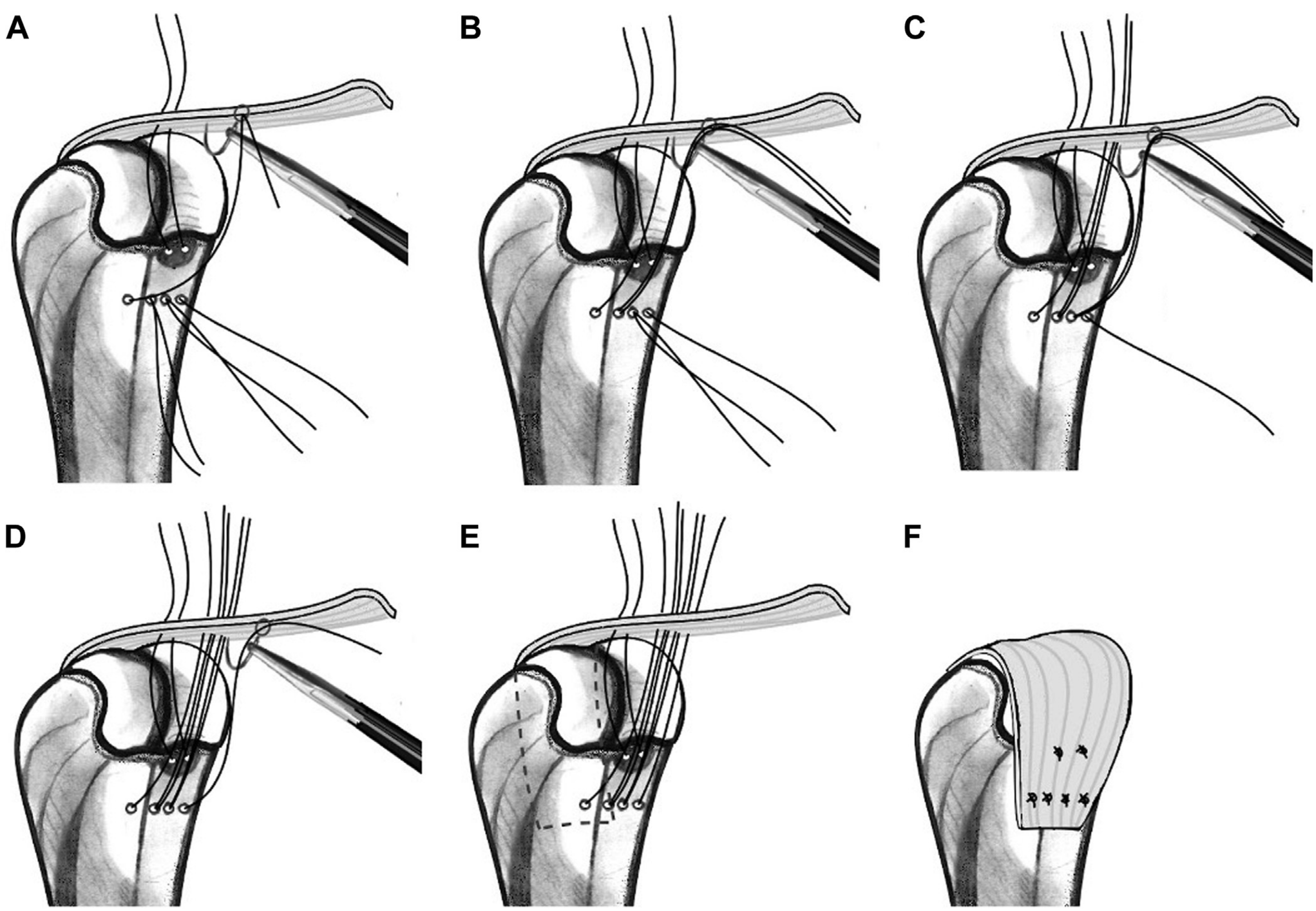

Figure 8 (**A**) A free needle is used to pass the single lateral suture through the interposition graft. (**B**) The lateral paired sutures are passed through the graft. (**C**) The medial paired sutures are passed through the graft. (**D**) The single medial suture is passed through the graft. (**E**) All sutures have been passed through the graft and are ready to be tied. (**F**) The interposition graft is tied and secured to bone.

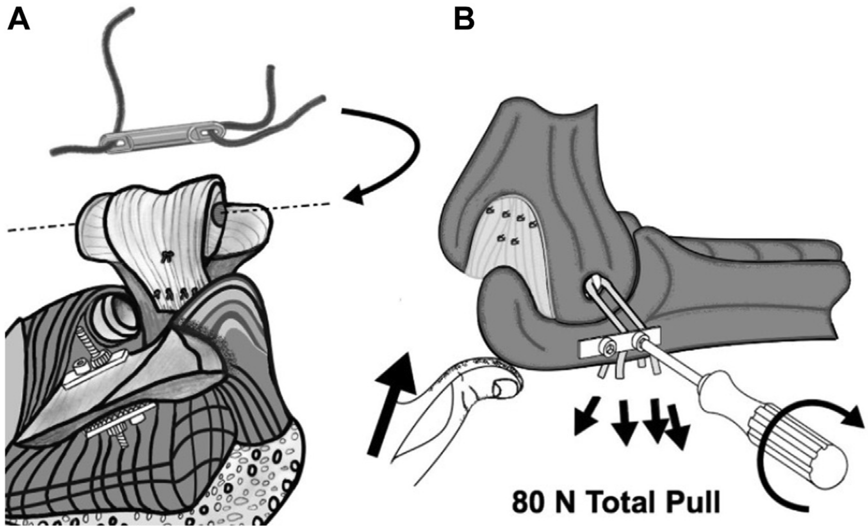

Figure 9 (**A**) With ligament grafts loaded into the eyelets, the CLRD is placed through the distal humerus. (**B**) After the elbow is reduced and the ligament grafts are tensioned, the grafts are secured to the bone by tightening the nuts on the trans-ulnar bolts. *CLRD*, cylindrical ligament retention device.

Cylindrical ligament retention device selection and passage

With the humerus prepared, a CLRD is chosen for ligamentous reconstruction. The CLRD resides within the distal humerus to minimize graft length and allows for equal graft tensioning.[13] Three CLRD sizes (small − 42.8 mm, medium − 47.6 mm, large − 52.4 mm) allow for the surgeon to choose an appropriate size based on the patient's anatomy. The largest CLRD should be chosen that remains fully seated within the medial and lateral cortices. All three CLRDs have the same diameter (5.5 mm). The CLRD is composed of polyetheretherketone material. The grafts are provisionally pulled through the eyelets of the CLRD to ensure that they can glide easily and are trimmed as necessary. A 3.5-4 mm graft will comfortably pass through the CLRD. With the ligament grafts loaded, the CLRD is passed through the humeral drill hole (Fig. 9, *A*).

Graft augmentation

If there is any question about the integrity of the ligament grafts and their ability to resist the varus and valgus forces that the elbow will experience in the acute setting, then an absorbable monofilament suture made from polyester polydioxanone (#1 PDS, Ethicon; Johnson & Johnson, Raritan, NJ, USA) can be woven into the ligament. This increases the tensile strength of the construct by transmitting forces through the augmenting suture and away from the graft, protecting the grafts during their early healing stage. Each #1 PDS suture, when woven through the graft and sutured to itself on the dorsal aspect of the ulna, will add 85 ± 8 N of additional strength in the acute setting. Sixty percent of that strength will be retained at six weeks.[12,17,22] Eventually, once full bony incorporation has occurred, the suture will be absorbed, and the grafts will see the forces experienced by the elbow.

Ligament graft passage and tensioning

The elbow is reduced and the four ligament graft limbs are passed under the ulnar plates. On each side, one limb lies between the bolts and one lies distal to the distal bolt (Fig. 9, *B*). The ligament grafts on each side are pulled with approximately 40 N of force, for a total pull of approximately 80 N of force across all four graft limbs. The average maximum pull that the sports surgeon can create (99 N) when divided over two grafts would provide a graft tension that is 49.5 N on each side.[7] Thus, a substantial but submaximal pull is recommended, which would likely approximate the 40 N that is needed on medial and lateral sides.[25] In reality, elbow kinematics have been shown to be restored when ligaments are tensioned within the range of 20 − 40 N.[10,21] For this reason, similar to other ligament reconstructions, no formal tension measurements are necessary, and the surgeon is simply asked to create a substantial but submaximal pull that is evenly distributed across all four graft limbs.

With the elbow reduced and positioned at ninety degrees, the ligament grafts are tensioned, and the nuts are sequentially tightened on the threaded bolts by an assistant. As the nuts tighten, a compressive force is exerted between the olecranon and the cross-locking plates, which gain purchase into the ligament graft limbs with their aggressive teeth. The nuts are tightened to two-finger tightness. If absorbable suture augmentation of the ligament grafts was performed, the suture ends are now tied over the dorsal aspect of the ulna.

After the implantation steps, the elbow is taken through a range of motion to ensure adequate stability. The elbow should move with a full range of flexion and extension.

Bolt cutting

After confirmation of graft security and elbow stability, a bolt cutter is used to cut the bolts flush to the nuts and minimize bolt protrusion (Fig. 10, *A*). A standard 21.6 cm length double-action wire cutter with angled side cutting blades is well suited for this purpose. If additional graft security is desired, the ligament grafts can be secured to the epicondyles using bone tunnels, as seen in Figure 10, *B*-*F*.

Soft tissue closure

During the exposure, the extensor carpi ulnaris and flexor carpi ulnaris muscles were elevated off the ulna and the native ligaments and extensor/flexor-pronator masses were sharply elevated off bone, resulting in continuous soft tissue sleeves medially and laterally. These sleeves are now repaired after the reconstruction has been performed (Fig. 11). During the repair, the elevated native

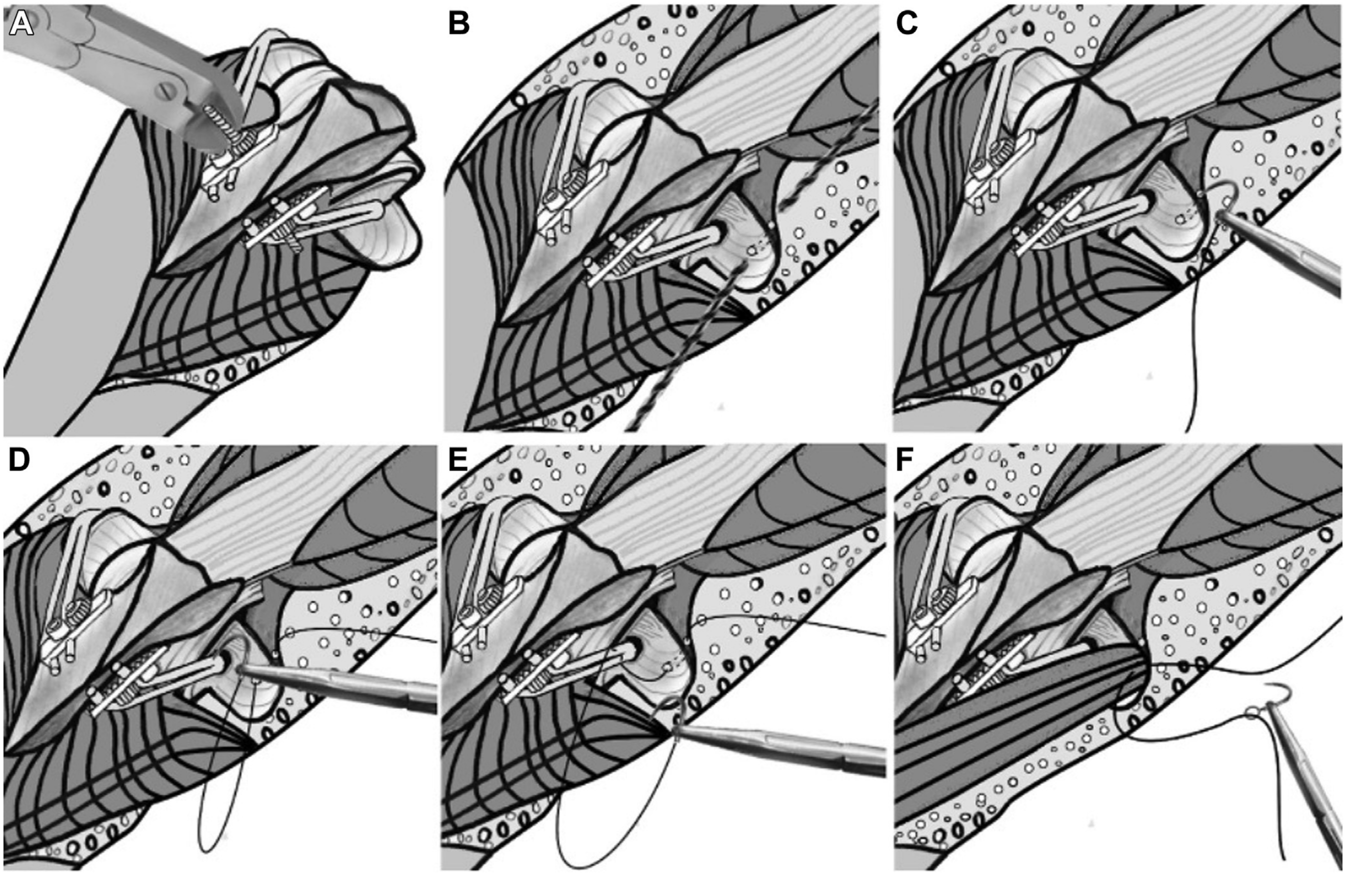

Figure 10 (**A**) The trans-ulnar bolts are cut to reduce hardware prominence. (**B**) A hole can be drilled in the medial epicondyle for extra graft security. (**C**) A needle and suture are passed through the bone bridge. (**D**) The suture is passed through the limbs of the reconstructed ligaments. (**E**) The suture is passed through the confluence of the FCU and native collateral ligaments. (**F**) Additional sutures are placed to secure the medial soft tissues. This process is repeated in a similar fashion on the lateral aspect of the elbow. *FCU*, flexor carpi ulnaris.

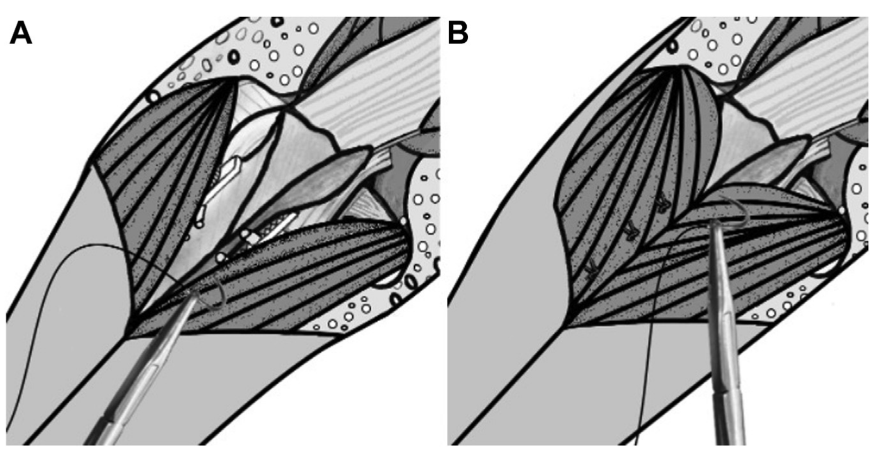

Figure 11 (**A**) The FCU and ECU are repaired over the proximal ulnar plates. (**B**) Soft tissue closure incorporates the remnant native collateral ligaments, which were left in continuity with the common extensor and flexor-pronator masses. *FCU*, flexor carpi ulnaris; *ECU*, extensor carpi ulnaris.

ligaments are sutured into the ligament reconstruction limbs with absorbable sutures (#0 Vicryl; Ethicon, Johnson & Johnson, Raritan, NJ, USA). If there is concern for postoperative fluid collection, a deep drain can be placed per the surgeon's discretion. The ulnar nerve is left transposed in an anterior position to avoid irritation from hardware. The subcutaneous tissues and skin are then closed in a layered fashion.

Postoperative management

Postoperatively, the arm is placed in a splint at 90 degrees of flexion. The patient is admitted for observation and pain control overnight and is often discharged on the first postoperative day. To ensure excellent ligament to bone healing, the postoperative rehabilitation course after distal humerus interposition arthroplasty is similar to the commonly performed MCL 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 120 degrees of flexion for postoperative weeks 2-6. At 6 weeks postop, the brace will be unlocked to allow full range of flexion and extension. At 3 months postop, the ligament to bone healing is thought to be acceptable and the patient may discontinue their brace. The goal is for the patient to achieve full range of motion by three months after surgery.

Three months after surgery, the focus of rehabilitation is shifted toward strengthening of the 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 postoperatively. Formal physical therapy is generally not instituted but may be applicable for certain patients. In contrast to total elbow arthroplasty, where common lifting restrictions of 10 pounds at a time or 1-pound repetitive lifting are employed, patients after interposition arthroplasty are encouraged to go back to their daily activities with no substantial lifting restrictions. It is not recommended for patients to return to certain occupations such as manual labor, as this may place significant and repetitive stress across the interposition arthroplasty and result in failure.

Conclusion

This surgical technique note demonstrates a method for resurfacing the distal humerus with an Achilles allograft. Elbow stability is restored through a simultaneous ligament reconstruction using the same Achilles allograft or separate allograft tendons. No additional elbow stabilization is required.

Disclaimers:

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Conflicts of interest: Robert A. Kaufmann has ownership of Aarch Orthopaedics, which is related to the subject of this work; he also has patent #10,828,147 issued to himself, which is related to the subject of this work. The other 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.

Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.xrrt.2024.02.008.

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