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T E C H N I Q U E

Stabilization of the Unstable Distal Ulna: The Linscheid–Hui Procedure

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HISTORICAL PERSPECTIVE

Instability of the distal ulna at the distal radioulnar joint (DRUJ) can result from dislocations, radius and ulna fractures, malunions, and ligament injuries. Often unrecognized, acute injuries result in chronic instability of the DRUJ. The unstable distal ulna most commonly presents with dorsal displacement of the ulnar head and a carpal supination deformity (4,16,18).

Essential features related to the DRUJ and the distal ulna are (a) joint kinematics, (b) joint architecture, and (c) ligamentous stabilizers (static and dynamic). The radius and ulna have complex curvatures, which result in a mild cubitus valgus position at the elbow. This architecture allows the radius to rotate around the ulnar head distally. With maximal pronation, there is a 1-mm lengthening of the ulna (1,8,15,19). The axis of rotation of the radius about the ulna falls within a narrow cone, with the radial head at its apex and the ulnar head at its base. Although this axis changes slightly during DRUJ motion, it essentially remains within the foveal region of the distal ulna (18). The ulnar head has a small arc of curvature compared with that of the of the radius (10). As such, the ulnar head undergoes a rolling or sliding motion within the sigmoid notch during pronation and supination (8,17,18).

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Malalignment alters the normal kinematics of the DRUJ and can result in attenuation and laxity of the stabilizing ligaments, arthritic changes, and pain. The articular surface of the ulnar head encompasses a 90–135° arc, and the articular surface of the sigmoid notch is much smaller, encompassing 47–80°. The radius of curvature is greater in the sigmoid notch than in the ulnar head (2,3,15). The combination of a shallow sigmoid notch and differing radii of curvature imparts an inherent instability to the joint. In pronation, the ulnar head rests against a small area of dorsal rim on the sigmoid notch and is dorsally displaced with respect to the carpus. The ulnar head rests against a similar area in the palmar rim of the sigmoid notch in supination. The inclination of this articular surface is slightly greater, imparting increased restraint to palmar subluxation (17,18).

The primary stabilizers of the DRUJ include the palmar and dorsal radioulnar ligaments (PRUL and DRUL), which are components of the triangular fibrocartilage complex (TFCC) (7,16,18,21,23). These ligaments have dual attachments on the ulna, with insertion points in the fovea and on the styloid, and remain in a relaxed position until near the end point of pronation or supination. This configuration permits dorsal and palmar translation of the ulnar head over a distance of several millimeters. Secondary stabilizers of the DRUJ include the pronator quadratus, extensor carpi ulnaris (ECU) tendon and its subsheath, interosseous membrane (IOM), ulnocarpal ligaments (ulnotriquetral and ulnolunate), and the DRUJ capsule.

Controversy exists regarding which components of a DRUJ are taut in pronation and supination. Ekenstam and Hagert (3), by using cadaver models, showed the PRUL is tight in pronation and the DRUL in supination. Conversely, Schuind et al. found the DRUL under maximum tension in full pronation and the PRUL in full supination

(21). Stuart et al. demonstrated the PRUL contribution to be the greatest passive restraint to a dorsal ulnar subluxation (18,22). The restraint to palmar subluxation is more evenly divided among the DRUL, PRUL, and IOM and ECU subsheath. It is believed that the foveal and styloid components of the DRUL and PRUL act in different fashions, allowing one portion of each to be tight in all positions of forearm rotation (18,22). This would explain the conflicting results seen by different researchers. Further investigation is necessary to fully evaluate this complex relation.

The management of DRUJ instability and resulting unstable distal ulna must include several factors before determining treatment options. Factors include the chronicity, degree of soft tissue injury, presence of fractures (ulnar styloid), and condition of articular surfaces. Distal radius fractures with an ulnar styloid fracture are the most common acute injury. Most styloid fractures do not result in an unstable distal ulna. However, attention is directed to the distal radius fracture rather than to the ulnar styloid fracture, with the unrecognized ulnar instability becoming a more difficult chronic problem. Assessment of the stability of the DRUJ after fixation of the distal radius fracture allows one to determine whether stabilization of the DRUJ is necessary. Ulnar styloid base fractures typically represent a peripheral detachment of the TFCC and require stabilization by open reduction and internal fixation (ORIF) or percutaneous pinning. Identification of complex fracture–dislocations such as the Galeazzi and Essex–Lopresti injuries should increase suspicion of acute distal instabilities (11). Radiographs of the elbow should be routinely performed when there is suspicion of proximal radioulnar joint injury.

Factors to be considered in choosing which procedure to use include the direction of instability, the presence or absence of arthrosis, incongruity of the joint, the presence of impaction, and ulnar length abnormalities. Chronic DRUJ instability with no or minimal osteoarthrosis in ulnar impaction syndrome are best treated with ulnar shortening osteotomy and a ligamentous repair if the ligaments remain loose or unstable after the shortening. The severity of the arthrosis may preclude the possibility of ulnar shortening and may necessitate a salvage procedure, such as a hemiresection interposition arthroplasty, Sauve–Kapandji, or Darrach with tenodesis. In the absence of arthrosis, DRUJ instability can be treated by several methods including radioulnar sling procedures, reconstruction of the DRUL, PRUL, repair of the TFCC, and tenodesing procedures.

It has been recognized that subluxation of the ulnar head most frequently occurs with the forearm in pronation (7,9,12,16,18,20). To determine the structures involved with dorsal subluxation of the ulnar head, Linscheid and Hui evaluated a cadaveric model (13). They found that with the forearm in pronation the DRUL became taut, whereas the PRUL became lax. The ulnocarpal ligaments twisted upon themselves to form a thick cordlike structure palmarly, producing a slinglike arrangement under the ulnar head (13,17,18). When Linscheid and Hui sectioned the DRUL and placed the forearm in maximal pronation, the dorsal restraint was removed, and the taut ulnocarpal ligaments forced the ulnar head into the dorsally displaced position. They also noted that the radiocarpal complex developed a supination deformity at the DRUJ and dorsal instability secondary to the pull of the ulnocarpal ligaments. Based on their cadaveric findings, Linscheid and Hui developed a ligament reconstruction using a distally based strip of flexor carpi ulnaris tendon placed through the distal ulna to correct both the dorsal displacement of the ulnar head and the carpal supination deformity (13). It is this technique that is described.

INDICATIONS/CONTRAINDICATIONS

The primary indications for reconstruction of the DRUJ are pain, weakness, snapping, and loss of rotation secondary to chronic dorsal subluxation/dislocation of the distal ulna. Contraindications include acute dorsal wrist DRUJ stability, arthrosis of the DRUJ, ulnocarpal impaction/impingement, malalignment of the forearm bones, collagen disorders, and rheumatoid disease. Initial attempts should be made to manage acute injuries by primary repair of either bony or ligamentous structures that have been injured followed by appropriate immobiliza-

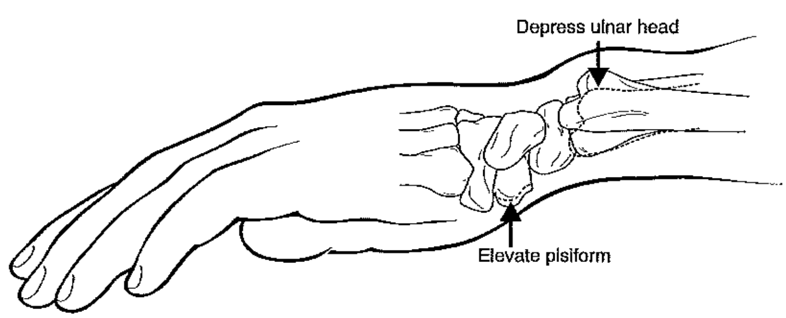

FIG. 1. Lateral view of the dorsally prominent distal ulna, with accompanying carpal supination. Relocation is found with volar pressure over the dorsal aspect of the distal ulna and elevation of the pisiform.

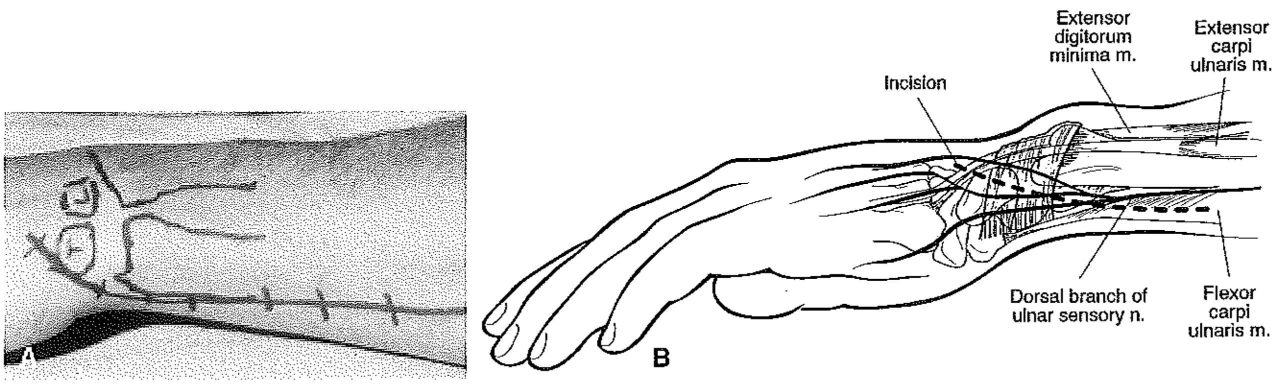

FIG. 2. **A:** Surgical approach is made along the subcutaneous border of the distal ulna, with radial extension in the distal aspect. **B:** Dorsal sensory nerves are easily found in the subcutaneous tissues. The hand is pronated during most of the procedure.

tion. If adequate tissue does not remain, augmentation or reconstruction is necessary.

EVALUATION OF THE DRUJ

A thorough medical history and physical examination are required to isolate the problematic region. The history of a fall with the hand in the pronated and extended position is common. Patients often complain of a painful snap and a loss of rotation. Evaluation by rotating the injured wrist through full pronation and supination and comparing the motion to the contralateral uninjured side are essential to detect the subtle subluxation or instability. The patient will frequently have a prominent ulnar head in full pronation, with aggravated pain during rotation. A positive "piano key" test is frequently noted with pain when the ulnar head is depressed and then released (7,16,18). Depressing the ulnar head with the thumb dorsally while elevating the pisiform with the fingers may give a sense of relocation and relief of pain in a patient with both carpal supination and dorsal subluxation of the distal ulna (Fig. 1) (13,18). The remainder of the wrist should be evaluated for associated carpal instability.

Standard wrist radiographs may be helpful in evaluating DRUJ arthrosis or ulnar impaction. Motion series with pronation and supination may assist in determining etiologies of ulnar-sided wrist pain. The sigmoid notch articular congruity is most effectively evaluated with computed tomography, with coronal, sagittal, and axial views in full supination, neutral, and full pronation positions. The uninvolved wrist is included for comparison. The differential diagnosis for ulnar-sided wrist pain includes ulnar styloid nonunions, TFCC injuries, ECU tendon subluxation, ulnocarpal impingement, lunotriquetral ligament injury, associated synovitis, dorsal sensory nerve injury, and inflammatory arthropathies. Appropriately placed injections of anesthetic frequently will aid in the diagnosis.

SURGICAL TECHNIQUE

After the patient is anesthetized, the arm is abducted onto the hand table, and a pneumatic tourniquet is placed on the upper brachium. The surface anatomy, including the distal radius, ulna, and location of the dorsal sensory branch of the ulnar nerve, is drawn out (Fig. 2A). The dorsal instability of the DRUJ is reconfirmed under anesthesia in pronation, supination, and neutral rotation. The extremity is exsanguinated, and the tourniquet is elevated. The incision is made with the forearm in pronation. The incision starts in the mid-forearm over the subcutaneous border of the ulna and extends distally to approximately 2 cm proximal to the distal ulna, where it is curved dorsally over the ulnocarpal joint for approximately 4–5 cm (Fig. 2B). The dorsal sensory branch of the ulnar nerve is identified and protected (Fig. 3). The flexor carpi ulnaris tendon is exposed, and a distally based ulnar strip is created.

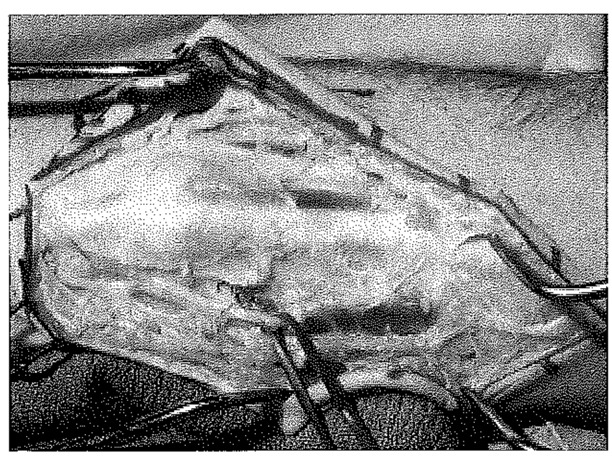

FIG. 3. Exposure continues with isolation of the dorsal sensory branch of the ulnar nerve in the vessel loop at the bottom of the incision and identification of the extensor carpi ulnaris tendon and extensor retinaculum.

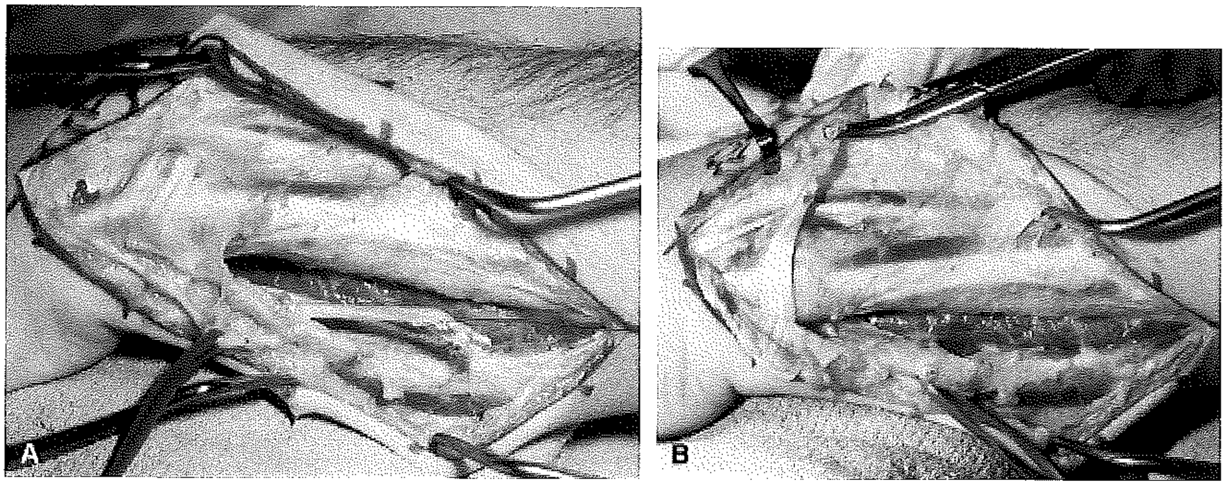

FIG. 4. **A:** The distally based flexor carpi ulnaris tendon is harvested, showing a wire suture controlling the proximally based free end. This allows for ease of passage through the arthrotomy in the pisotriquetral capsule later in the procedure. **B:** It is important to dissect the tendon all the way down to the pisiform in the depths of the distal aspect of the wound.

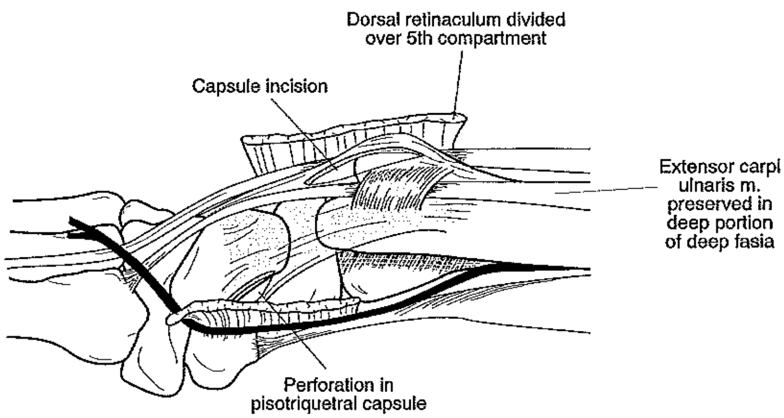

FIG. 5. A small perforation is made in the pisotriquetral capsule for passage of the tendon graft. The retinaculum is longitudinally split over the fifth compartment, creating an ulnar flap while taking care not to disturb the extensor carpi ulnaris and its subsheath. The longitudinal capsular incision is made to identify the distal and proximal aspects of the distal radioulnar joint.

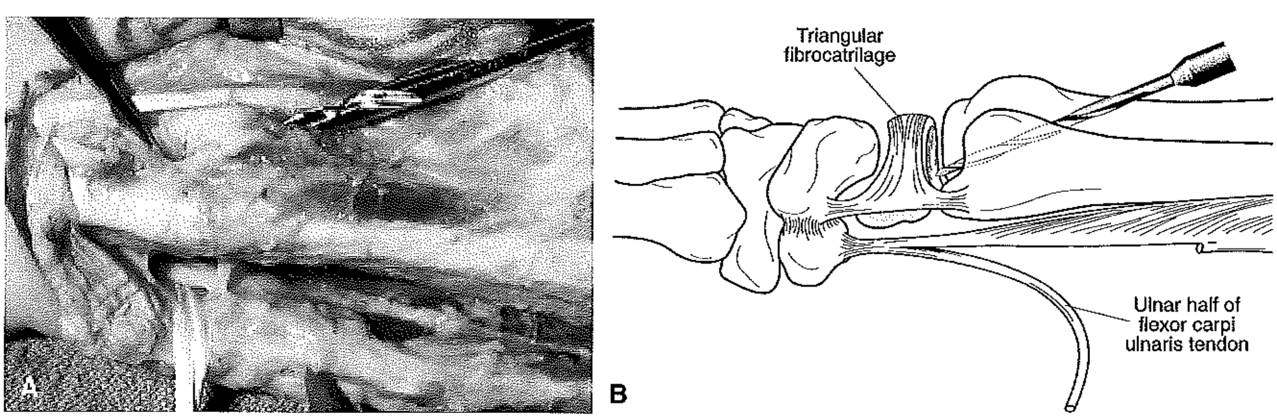

FIG. 6. **A, B:** An oblique drill hole is made initially with Kirschner wires, which are then serially dilated up to a 4–5-mm-diameter-sized hole exiting into the foveal region of the distal ulna. Fluoroscopic image can also assist in exact placement of the drill hole. An appropriate soft tissue sleeve will usually protect the surrounding soft tissues from strangulation.

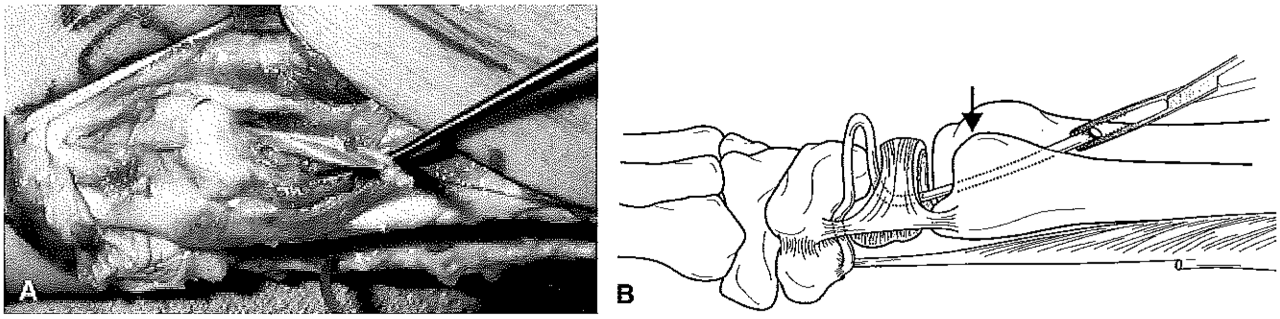

FIG. 7. A, B: A hemostat placed dorsal to volar will then pass the tendon through the pisotriquetral capsulotomy, exiting dorsally and either through or dorsal to the triangular fibrocartilage complex. This creates a volar reducing force on the ulnar head. This is then passed from distal to proximal through the oblique tunnel.

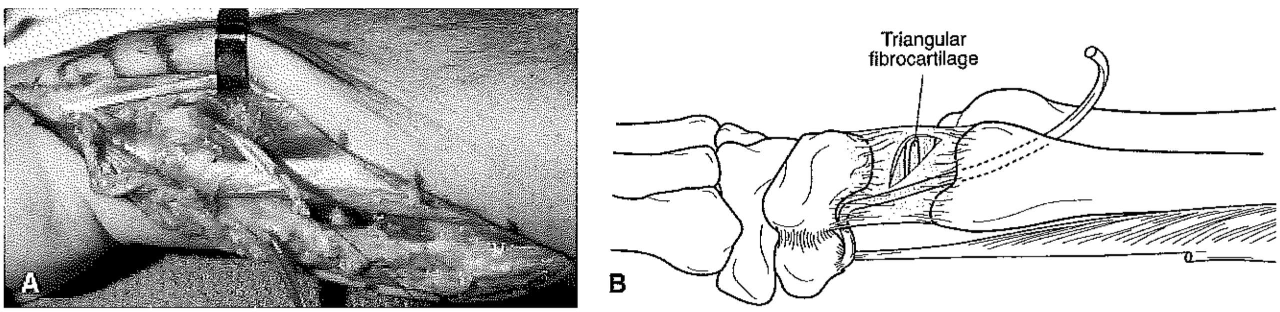

FIG. 8. A, B: Tension is placed on the flexor carpi ulnaris tendon, reducing the carpal supination and dorsal dislocation while suturing the tendon stump to bone and periosteum over the distal ulna and triangular fibrocartilage complex.

FIG. 9. Before suturing the tendon in supination, two Kirschner wires are used to help hold the reduction of the distal ulna.

The flexor carpi ulnaris tendon is relatively short and is located deep within the muscle proximally. Identification of the tendon can be facilitated by identifying it distally and tracing it into the muscle belly (Fig. 4A). Approximately 10 cm of tendon graft is required. The flexor carpi ulnaris tendon graft is dissected to its insertion onto the pisiform and is then placed in a moistened sponge (Fig. 4B). Care is taken to prevent injury to the ulnar nerve and artery during the preparation of the tendon graft.

The exposure of the ulnocarpal joint and distal ulna is made by incising the extensor retinaculum in line with the fifth extensor compartment. An ulnar-based flap of extensor retinaculum is created by elevating the extensor retinaculum over the sixth compartment, preserving the extensor carpi ulnaris subsheath. The extensor tendons are retracted, exposing the capsule over the ulnocarpal joint and distal ulna. A longitudinal incision is made in the capsule, preserving the DRUL (Fig. 5). The triquetrum, distal ulna, and TFCC are inspected for chondral injury or tears. If the TFCC is disrupted from the ulnar styloid, it should be repaired at this point. The bone tunnel through the distal ulna is created by passing a 0.0625-inch Kirschner wire obliquely from the dorsal ulnar neck to the fovea of the distal ulna. Placement of this Kirschner wire is confirmed with direct visualization. The Kirschner wire is removed, and a series of sequential hand awls are used to create a 4–5-mm bone tunnel (Fig. 6A, B).

A perforation is made in the pisotriquetral capsule from dorsal to volar with the aid of a hemostat placed

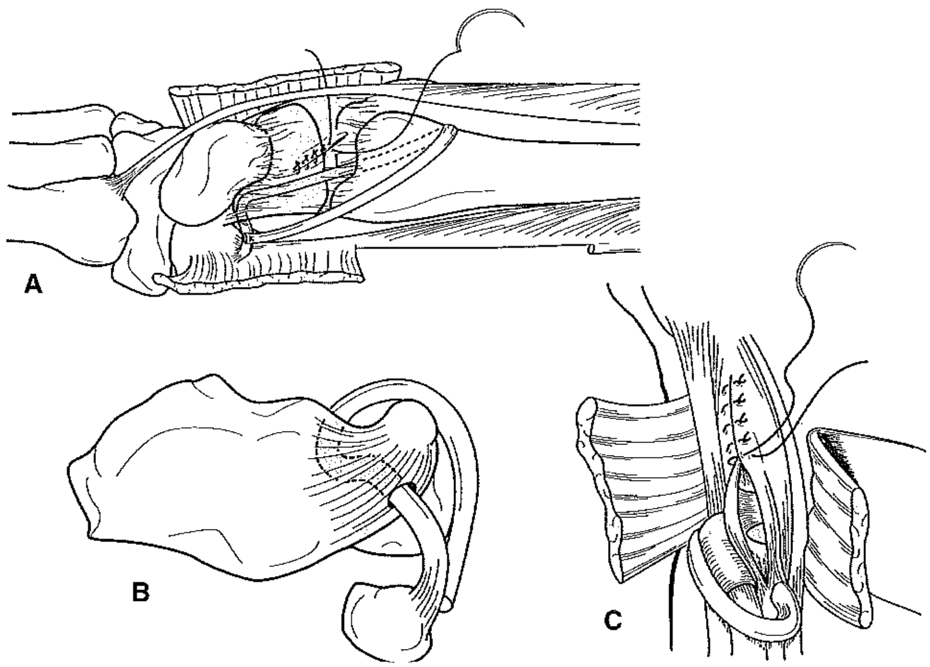

FIG. 10. **A:** The distal radio-ulnar joint capsulotomy is closed with 3.0 nonabsorbable suture. **B:** Cross-sectional view of the path of the flexor carpi ulnaris tendon graft. **C:** Plication of dorsal capsular tissues.

through the dorsal ulnocarpal articulation. A 26-gauge wire is tied to the end of the flexor carpi ulnaris tendon graft and passed through the pisotriquetral arthrotomy with the aid of the hemostat. It is important to inspect the ulnar artery and nerve and ensure that the tendon graft is not placing any tension or pressure on the neurovascular structures. After the tendon graft is passed through the pisotriquetral arthrotomy and ulnocarpal joint, it is passed

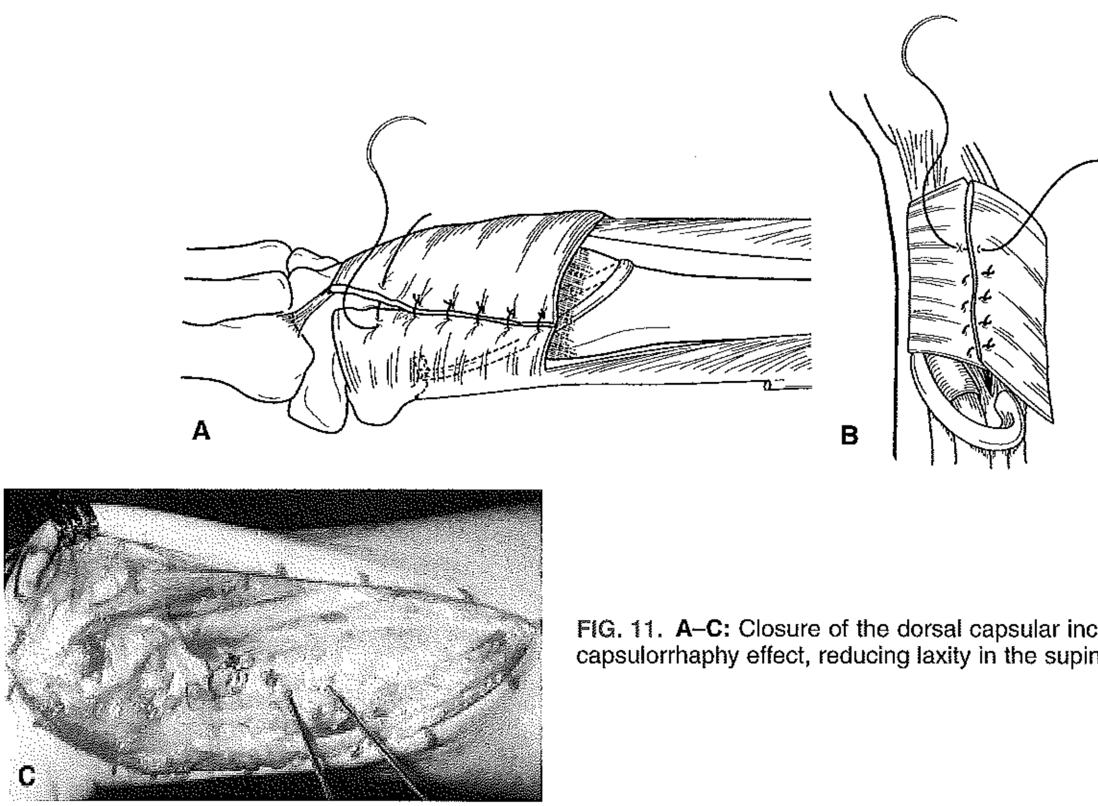

FIG. 11. **A–C:** Closure of the dorsal capsular incision allows for a capsulorrhaphy effect, reducing laxity in the supinated position.

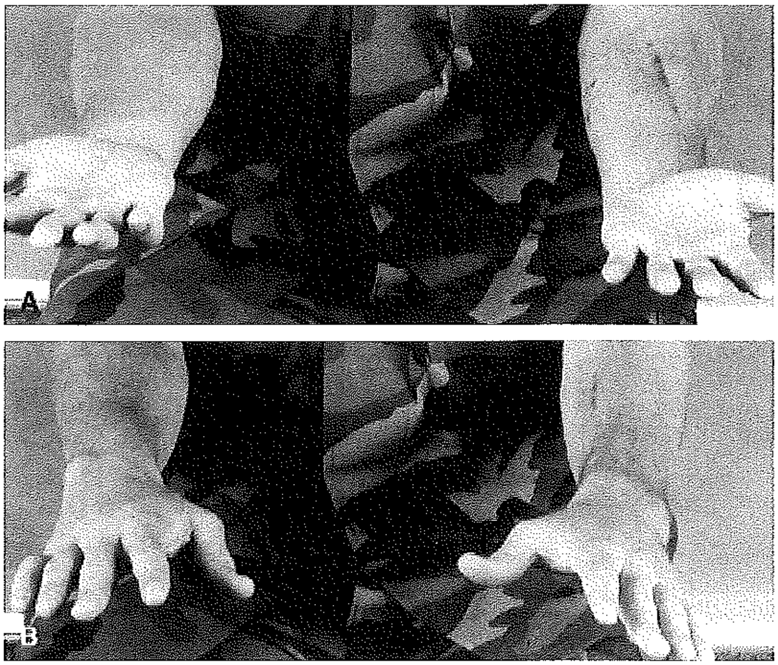

FIG. 12. A, B: Five-month postoperative views show 80° of pronation and full supination postoperatively. Left side=operative side.

through the TFCC if a perforation exists or over the dorsal limb of the TFCC if intact (Fig. 7A, B). The tendon graft is finally passed through the bony tunnel created in the distal ulna. The graft is pulled taut to reduce the ulnar head and elevate the carpus via the pisiform (Fig. 8A, B). The capsular incision/arthrotomy is reapproximated with 3-0 nonabsorbable suture. The forearm is supinated, and two parallel 0.0625-inch Kirschner wires are placed across the ulna into the radius to hold the ulna in the reduced position (Fig. 9). The tendon graft is pulled taut and is secured with a nonabsorbable 2-0 suture to the periosteum or bone adjacent to the bone tunnel, and the end of the tendon graft is then sewn to its proximal limb (Fig. 10A–C). The retinaculum is reapproximated with nonabsorbable 3-0 suture, and the tourniquet is deflated (Fig. 11A–C). Hemostasis is obtained, and the wound is reapproximated over a suction drain. A plaster-reinforced long arm compressive postoperative dressing is applied.

POSTOPERATIVE MANAGEMENT AND REHABILITATION

Digital range of motion and edema control are initiated on the first postoperative day. The suction drain is also removed on the first postoperative day. The dressing and sutures are removed 7–10 days after surgery, and a long arm cast is applied. The extremity is immobilized for 5 weeks, at which time the cast and Kirschner wires are removed. A custom-molded orthoplast ulnar gutter splint is fabricated, and motion is initiated. Initially motion, especially pronation, is limited but continues to improve over the next 2 months. Active assisted exercises are performed under the direction of a hand therapist. Maximum improvement typically occurs within 3–4 months. If progress is slow in obtaining pronation, a dynamic pronation splint may be useful.

COMPLICATIONS

Complications include loss of pronation secondary to the prolonged immobilization and soft tissue contracture from the surgery. Recurrence of the dorsal instability may occur secondary to an inadequate repair or progressive attenuation of the tendinous material with time and overuse. Degenerative changes at the DRUJ and in the ulnar carpus may occur with time, requiring salvage procedures such as a Sauve–Kapandji, hemiresection, or limited wrist fusion (5,14,24). Superficial ulnar sensory nerve irritation and neuroma formation may occur if inappropriate attention is paid to the ulnar sensory nerve during the procedure.

ILLUSTRATIVE CASE

A 24-year-old male Naval officer sustained a fall that resulted in a radial shaft fracture and radial head dislocation, which were treated with ORIF of the radius and reduction of the radial head dislocation. Five months postoperatively, the patient demonstrated dorsal subluxation of the distal ulna, with pain and limitation of pronation to 20°. He underwent a Linscheid–Hui DRUJ ligamentous reconstruction and was immobilized for 5 weeks. Four months after reconstruction with therapy, pronation was 80° and supination was 90°. Grip strengths are normal, and the patient has returned to full duty without pain or instability. He continues to be asymptomatic at 2.5 years (Fig. 12A, B).

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