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Coronoid and Radial Head Reconstruction in Chronic Posttraumatic Elbow Subluxation

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Abstract

Chronic elbow subluxation is uncommon but challenging to treat. Although many treatment methods have been described, few clinical outcome studies have been done because of the infrequency of the condition. Reconstruction has been better defined for radial head deficiencies than for the coronoid. Recognizing and repairing or reconstructing any associated soft-tissue deficiencies are important to a good outcome. For some patients, protecting the reconstruction with a hinged external fixator is recommended to allow early range of motion.

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The treatment outcomes of fracture-dislocation of the elbow have markedly improved with advancements in the understanding of elbow biomechanics and pathoanatomy. Current techniques for radial head repair or replacement, coronoid fixation, and ligament repair can be used to successfully treat most patients with a fracture-dislocation of the elbow, including those with the so-called terrible triad injury (elbow dislocation associated with a fracture of the radial head and coronoid). Nonetheless, some patients have persistent elbow subluxation after nonsurgical and surgical treatment.

The acute treatment of dislocations and fracture-dislocations of the elbow has received considerable attention, but the reconstruction of subacute and chronic posttraumatic elbow instability has been less studied and is poorly understood. The methods for collateral ligament reconstruction using tendon grafts are well established, but reconstruction of coronoid and radial head deficiencies in patients with persistent elbow instability has received limited attention.

Coronoid Reconstruction

Anatomy

The greater sigmoid notch of the proximal ulna has two articular portions—the coronoid and olecranon— that are separated by a nonarticular portion that is devoid of articular cartilage. From the lateral side, the coronoid can be seen to project anterior to the olecranon. The tips of the coronoid and olecranon form an angle of approximately 30° relative to the diaphyseal axis.[1] The coronoid is divided into anteromedial and anterolateral portions by the ridge of the greater sigmoid notch, which articulates with the trochlear groove of the distal humerus. The anterior capsule and brachialis attach just distal to the tip of the coronoid. The sublime tubercle projects medially and is the attachment site for the anterior bundle of the medial collateral ligament.

Biomechanics

The force passed across the elbow during some strenuous activities can be as much as four times body weight.[2,3] The load is transferred from the forearm across the elbow to the distal humerus and distributed approximately equally between the proximal ulna and radial head.[4] In addition to its load-bearing function, the coronoid, with the lateral collateral ligament, is a varus stabilizer. The anteromedial coronoid provides posteromedial rotational stability to the elbow. Limited studies have assessed the importance of the coronoid in elbow stability. It is generally believed that the tip of the coronoid contributes little to the stability of the elbow, other than as the attachment of the anterior capsule.[5] Because the coronoid functions as a primary posterior stabilizer, a large coronoid fracture permits posterior elbow subluxation, which is a common type of chronic elbow instability. This instability pattern occurs because of the loss of an anterior buttress against the posterior vector of forces and moments acting across the elbow. A fracture of the sublime

tubercle or anteromedial coronoid contributes to varus or posteromedial instability of the elbow, respectively. Further biomechanical studies are needed to improve our understanding of the coronoid in elbow stability.

Classification

Two classification systems are commonly used for fractures of the coronoid. The three types in the Regan and Morrey[6] system are based on fracture height (Figure 1). A type I fracture initially was described as an avulsion but now is known to be a shearing injury caused by subluxation or dislocation of the elbow. This type of fracture typically is less than 10% of the height of the coronoid. A type II coronoid fracture is as much as 50% of the height of the coronoid, and a type III fracture involves more than 50%.

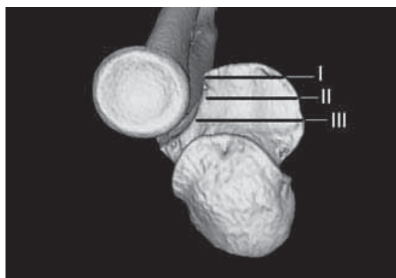

Figure 1 The Regan and Morrey classification of coronoid fractures. A type I fracture is less than 10% of the height of the coronoid, a type II fracture is as much as 50% of the height of the coronoid, and a type III fracture involves more than 50%.

The O'Driscoll classification of coronoid fractures is more detailed[7,8] (Figure 2). Fractures of the tip of the coronoid are believed to be caused by a posterolateral rotatory mechanism of injury; subtype I is less than 2 mm in height and subtype II more than 2 mm. These injuries typically have an associated lateral collateral ligament tear, and approximately 50% have an associated medial collateral ligament tear or elbow dislocation. Anteromedial coronoid fractures are believed to be caused by a varus posteromedial rotatory mechanism. Subtype I includes the anteromedial rim only, subtype II includes both the anteromedial rim and tip, and subtype III includes the anteromedial rim and tip as well as the sublime tubercle. Anteromedial coronoid fractures usually have an associated lateral collateral ligament injury. The radial head typically is spared in these varus posteromedial rotatory injuries. Basal-type coronoid fractures typically involve more than 50% of the coronoid. They may be comminuted, and fixation can be difficult. A subtype I fracture is isolated, and a subtype II fracture has an associated transolecranon fracture. These injuries are caused by a posteriorly directed force and commonly have an associated radial head fracture. Associated ligament injuries typically are less severe because failure has occurred primarily through bone.

Imaging

Complex fractures of the elbow cannot be adequately evaluated using plain radiographs. Sagittal, coronal, and axial CT scans are required for classifying fractures of the coronoid and planning coronoid reconstruction. Three-dimensional CT reconstruction is particularly useful in planning the surgical approach and treatment. The ability to digitally remove the humerus is a helpful feature of three-dimensional CT reconstruction.

Reconstruction

There are no good options for reconstructing a coronoid deficiency, and no coronoid prostheses are commercially available. In a sublux-

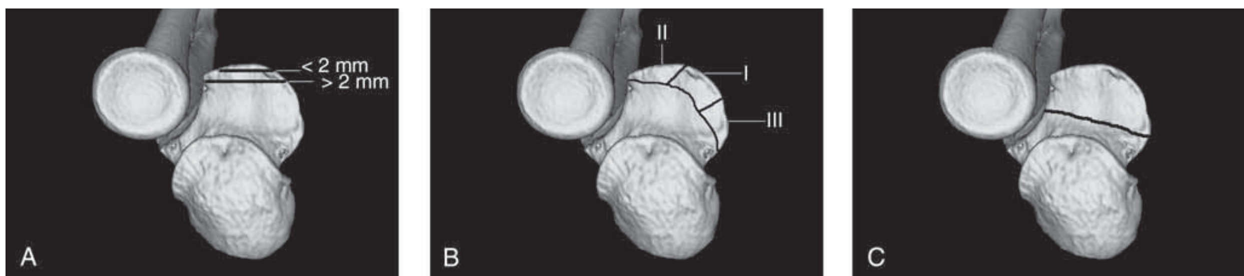

Figure 2 The O'Driscoll classification of coronoid fractures. **A,** A fracture of the tip of the coronoid is categorized as subtype I (height of < 2 mm) or subtype II (height of > 2 mm). **B,** An anteromedial coronoid fracture is categorized as subtype I (anteromedial rim only), subtype II (anteromedial rim and tip), and subtype III (anteromedial rim, tip, and sublime tubercle). **C,** A basal-type coronoid fracture typically involves more than 50% of the coronoid; subtype I (shown) is an isolated fracture of the coronoid, and subtype II has an associated transolecranon fracture.

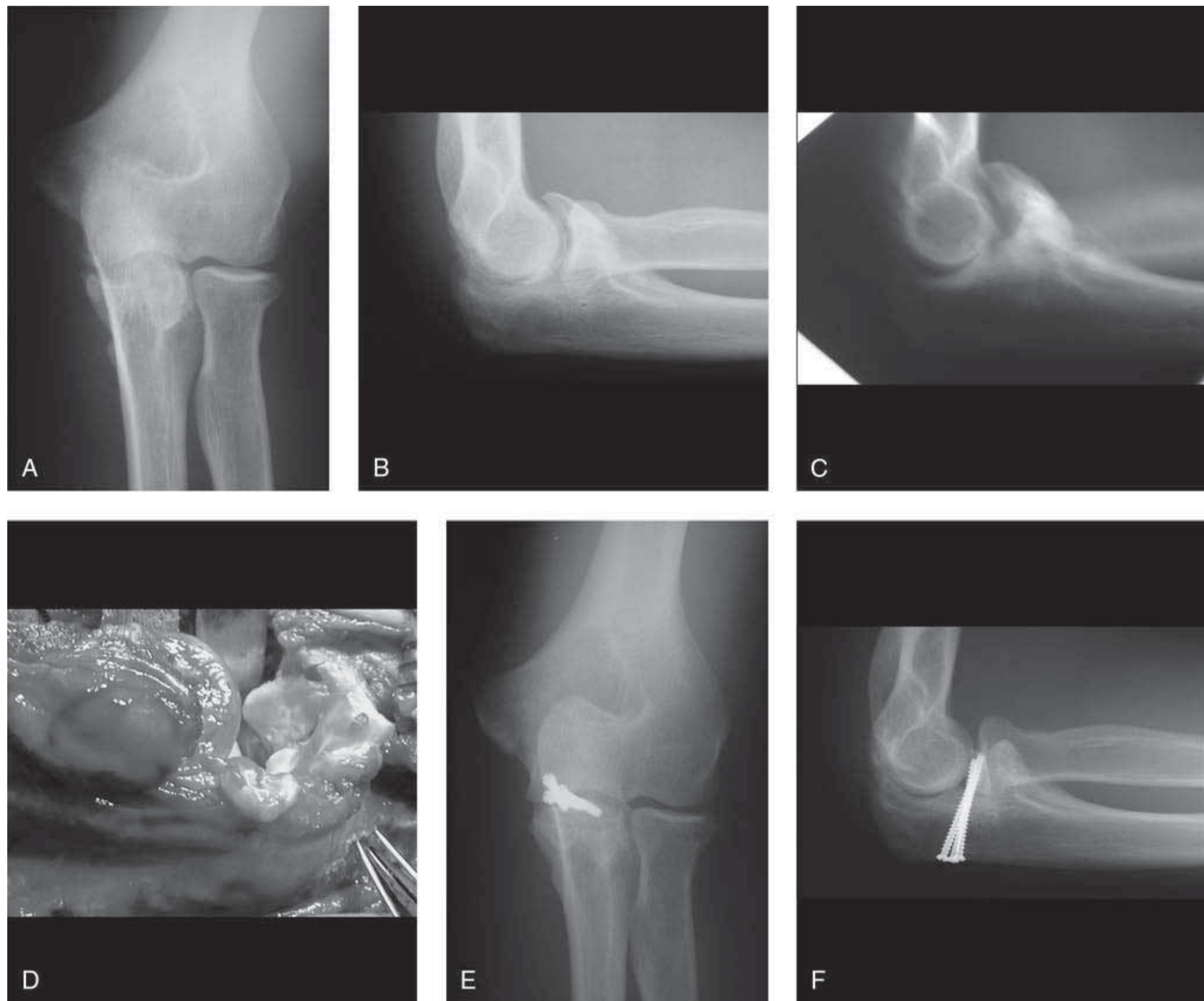

Figure 3 Coronoid reconstruction with osteotomy. AP **(A)** and lateral **(B)** radiographs of the elbow of a 27-year-old man with persistent pain and stiffness after nonsurgical treatment of a fracture-dislocation of the elbow. **C,** Lateral tomogram showing a malunited coronoid with subluxation of the elbow. **D,** Sectioning of the medial collateral ligament provides adequate exposure for osteotomy of the coronoid. AP **(E)** and lateral **(F)** radiographs show healing of the coronoid 6 months after surgery.

ated elbow with a coronoid fracture that has not been fixed, has a failed fixation, or has healed in a displaced position, the best treatment is to reduce and fix the coronoid fragment. Reduction and fixation are not possible, however, if the remaining coronoid is eroded or the displaced fragment is too comminuted to allow successful fixation. The surgical approach and fixation should be chosen based on the size and location of the coronoid fragment as well as associated ligament and osseous injures. A lateral surgical approach generally provides adequate exposure of the coronoid when performing concomitant radial head excision and replacement. A medial approach is used if the radial head is to be preserved. The flexor-pronator muscles are split for access to smaller fragments, and they are elevated through the floor of the ulnar nerve for access to larger fragments. The method of fixing a coronoid fragment depends on its size. Sutures, lag screws, or buttress plates are used (Figure 3).

A deficient coronoid can be reconstructed using a fragment of the ipsilateral native radial head as an osteochondral autograft. This technique is particularly indicated if there is a comminuted radial head fracture for which prosthetic

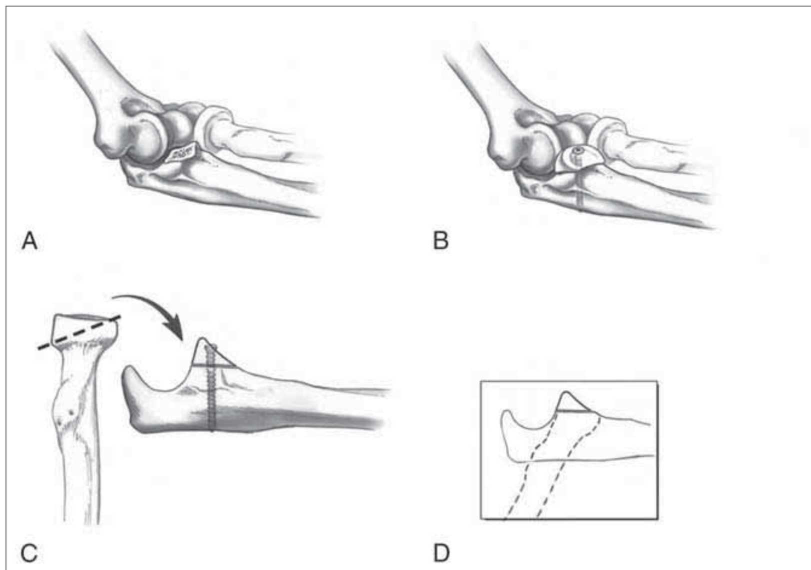

Figure 4 Reconstruction of the coronoid using a fragment of the radial head. Careful orientation and rigid fixation of the radial head fragment ensure that the reconstruction provides a bony buttress sufficient to prevent subluxation of the elbow. **A,** Coronoid deficiency. **B,** Rigid fixation of radial head autograft. **C** and **D,** Osteotomy of the radial head to best replicate the shape of the deficient coronoid. (Reproduced with permission from van Riet RP, Morrey BF, O'Driscoll SW: Use of osteochondral bone graft in coronoid fractures. *J Shoulder Elbow Surg* 2005;14:519-523.)

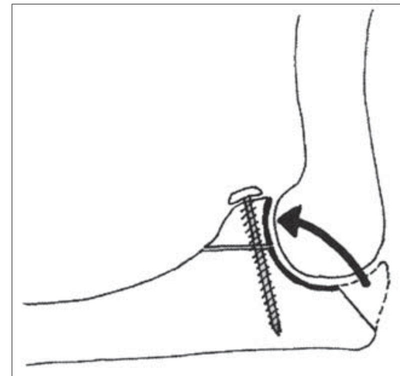

Figure 5 Technique for reconstruction of the coronoid using an osteoarticular graft from the ipsilateral olecranon. (Reproduced with permission from Moritomo H, Tada K, Yoshida T, Kawatsu N: Reconstruction of the coronoid for chronic dislocation of the elbow: Use of a graft from the olecranon in two cases. *J Bone Joint Surg Br* 1998;80:490-492.)

reconstruction is being considered. Careful contouring, orientation, and fixation of the autograft radial head fragment are critical for a successful reconstruction. Van Riet and associates[9] described an oblique osteotomy of the radial head that places the articular circumference of the radial head against the trochlea; at least one small lag screw was used for fixation of the fragment (Figure 4). If there are several comminuted radial head fragments, the choice of a fragment to reconstruct the coronoid is based on size. After the radial head fragments are removed, a lateral approach to the coronoid typically is used. Fixation of the reconstructed fragment is best done retrograde, from the posterior aspect of the ulna. Often, it is helpful to use a cannulated screw system and targeting guides, such as those found in an instrument set for anterior cruciate ligament reconstruction. If a medial approach is used, the fragment can be fixed by placing screws from anterior to posterior or using a buttress plate. Few outcome data are available to show the effectiveness of coronoid reconstruction using the native radial head.[6,10,11]

If native radial head fragments are unavailable, the tip of the coronoid can be reconstructed by using the ipsilateral tip of the olecranon as an osteochondral autograft. Schneeberger and associates[12] used this technique in a biomechanical study (Figure 5). In a clinical study, Moritomo and associates[13] used an anteromedial approach to the coronoid, between the biceps tendon laterally and the neurovascular bundle, and a flexor-pronator mass medially. After careful retraction of the ulnar nerve, the olecranon was approached through the same skin incision. Some of the triceps insertion was reflected, and an oscillating saw was used for osteotomy of a part of the olecranon to match the lost coronoid. Fixation of the olecranon fragment was achieved with an anterior-to-posterior small fragment screw, although buttress plate fixation also can be used. This technique also can be performed using a medial flexor-pronator–splitting approach or a lateral approach that includes radial head resection. The limitation of this method of coronoid reconstruction is that excision of the olecranon contributes to elbow instability, and therefore it is not useful if a larger coronoid reconstruction is required. This method should not be used in patients with a concomitant olecranon fracture. Its effectiveness is unknown, and further clinical and biomechanical studies are required.[14]

Iliac crest autograft has been used

for coronoid reconstruction. Unless concomitant interposition arthroplasty is being considered, iliac crest autograft may not be ideal because of its lack of cartilage surface.[15,16] In two case reports of reconstruction with iliac crest autograft, the results were good. Chung and associates[15] used a medial approach to gain access to the coronoid by subperiosteal elevation and then placed iliac crest autograft (2 cm × 1 cm × 1 cm) onto an unreconstructable 2.5-cm coronoid fracture and fixed it with a 2.5-mm cancellous screw and washer. The brachialis and soft tissues were repaired to the native coronoid base, next to the graft, with a pull-out suture. Kohls-Gatzoulis and associates[16] used two 3.5-mm small fragment screws for fixation but did not otherwise describe their technique.

Reconstruction of the coronoid using autogenous rib osteochondral graft can be considered; however, there is currently no clinical outcome data demonstrating the effectiveness of this approach. This technique has been used by one of the authors (MD) with good short-term outcomes. Autogenous rib osteochondral grafting has been used in other scenarios, such as proximal scaphoid reconstruction and in treating severe elbow osteochondritis dissecans, with good clinical outcomes and little donor site morbidity.[17,18] The advantages of this technique are the ability to reconstruct the coronoid with hyaline cartilage, to accurately contour the graft to replicate the shape of the native coronoid, and to ensure healing of the autograft because of its large bony surface area. An unreconstructable basal coronoid fracture is approached medially by splitting or elevating the flexor-pronator mass. Ipsilateral autogenous rib graft is harvested subperiosteally and subperichondrially. If necessary, the graft can be doubled to provide sufficient height. The graft is secured into position with a buttress plate, carefully shaping the cartilage to replicate the contour of the original coronoid articular surface. Concomitant ligament repair or reconstruction should be performed as needed, and the elbow should be protected with a hinged external fixator for 6 weeks to ensure graft healing (Figure 6).

Allograft coronoid reconstruction is attractive because it avoids the risk of donor site morbidity; however, its success has been unpredictable, and therefore it cannot be recommended.[9] Van Riet and associates[9] reported on three allograft coronoid reconstructions. An allograft radial head fragment was used in one patient; allograft coronoid was used in the other two patients. All three patients were treated with ligament repair or reconstruction with application of an articulated external fixator, and one patient also had interpositional fascial arthroplasty. Two of the patients had allograft radial head reconstruction at the same time. Two patients had a poor result, and one had a good result as measured using the Mayo Elbow Performance Score. One patient underwent revision to a total elbow arthroplasty because of severe pain, and a second patient had significant stiffness caused by heterotopic ossification.

Soft-tissue reconstruction with transfer of the biceps tendon to the base of the coronoid also has been reported to manage coronoid deficiency in patients with elbow instability. Although anatomic reconstructions with bone are more frequently performed, this option should be considered if alternative procedures fail. A review article on recurrent elbow instability included a case report of a patient treated with biceps tendon transfer.[19] An anterior approach was made to the elbow as described by Henry, and the non-united coronoid fragment in the avulsed attachment of the brachialis was removed. The biceps was then transected from the radius and transferred to the coronoid, passing it through a large drill hole in the base of the coronoid and securing it on the dorsal surface of the proximal ulna with sutures through smaller drill holes. It was believed that the tendon transfer would act as a ligament, restraining a tendency to posterior dislocation, and in the event of a fall on the outstretched hand, a powerful contraction in the biceps would prevent posterior dislocation. At 4-month follow-up, the patient had full extension and flexion and reported normal power of supination, although this was not quantified. At 2-year follow-up, there was no recurrence of dislocation.[19]

Concomitant repair or reconstruction of the collateral ligaments and radial head is essential when a deficiency of the coronoid is reconstructed. The use of hinged external fixation should be considered to prevent elbow instability and failure of the coronoid fixation while it heals.[8]

Radial Head Reconstruction

Anatomy

The radial head articulates with the capitellum of the distal humerus and the radial notch of the proximal ulna. The articulating dish is concave, and the radial head itself is slightly oval and offset from the radial neck shaft.[20,21] The anterolateral one third of the articular margin is devoid of articular cartilage; it is essential to identify this area when

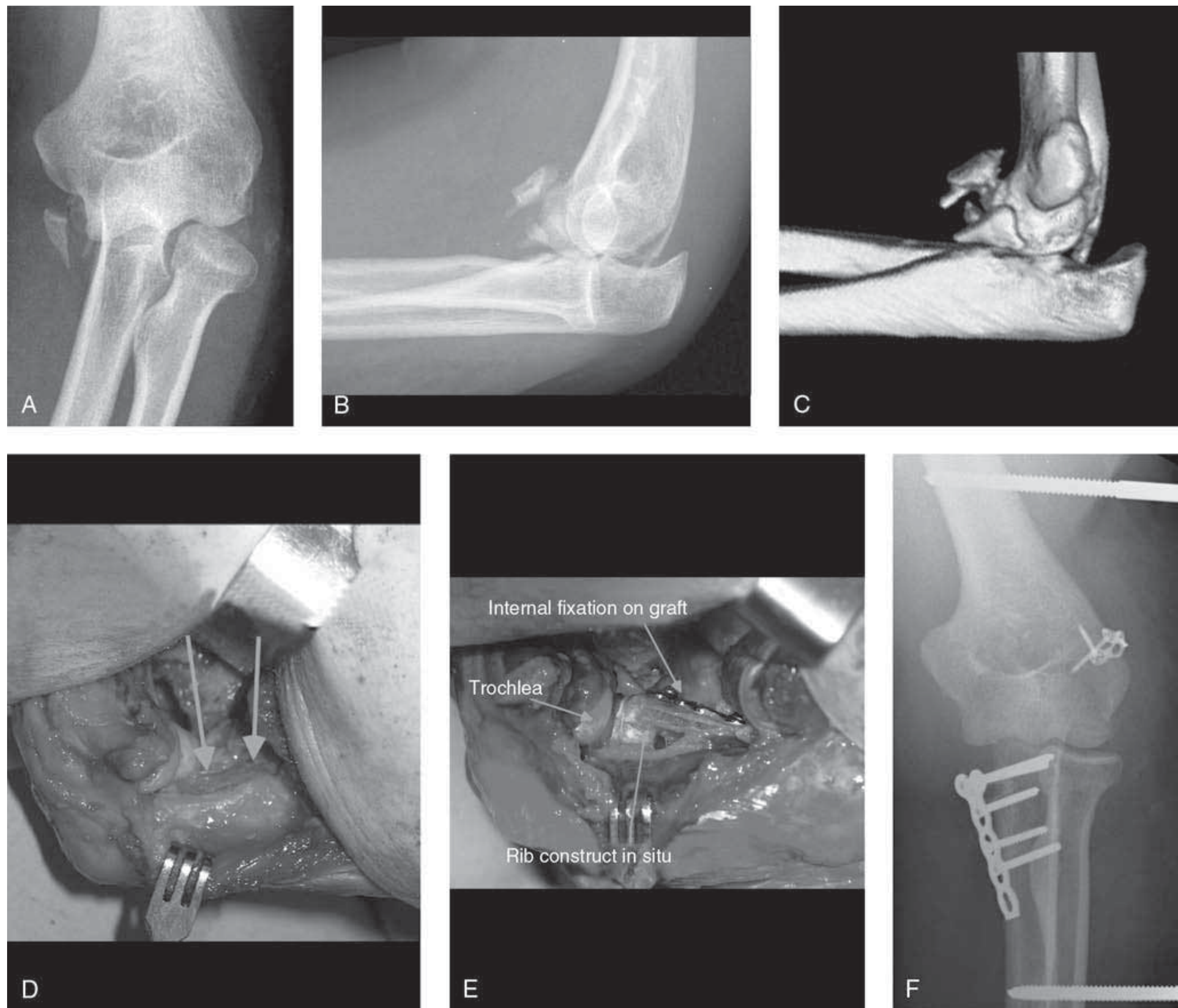

Figure 6 Coronoid reconstruction with rib osteochondral allograft. AP **(A)** and lateral **(B)** radiographs of the elbow of a 48-year-old woman with persistent elbow dislocation 8 weeks after injury. **C,** CT scan demonstrating severe comminution of the coronoid. **D,** Intraoperative photograph demonstrating basal coronoid defect (*arrows*). **E,** Reconstructed coronoid using a doubled autogenous rib graft held in place using a 2.4-mm locking plate. **F,** Postoperative AP radiograph showing the reduced elbow joint with hinged external fixator.

considering plate fixation on the proximal radius.

Biomechanics

The radial head shares load transfer across the elbow with the proximal ulna, and it is a secondary valgus stabilizer of the elbow; the medial collateral ligament is the primary valgus stabilizer. The radial head also is an important secondary stabilizer against posterior subluxation of the elbow (the coronoid is believed to be the primary stabilizer) and against posterolateral rotatory instability (the lateral ulnar collateral ligament is believed to be the primary stabilizer).[22,23]

Biomechanical studies showed the importance of partial articular fractures of the radial head, particularly when elbow instability is present.[24,25] Loss of the articular rim contributes to posterolateral rotatory instability of the elbow because of the lack of capture of the radial head on the capitellum. Reconstructing the radial head with a metallic prosthesis effectively restores the valgus stability of the elbow after

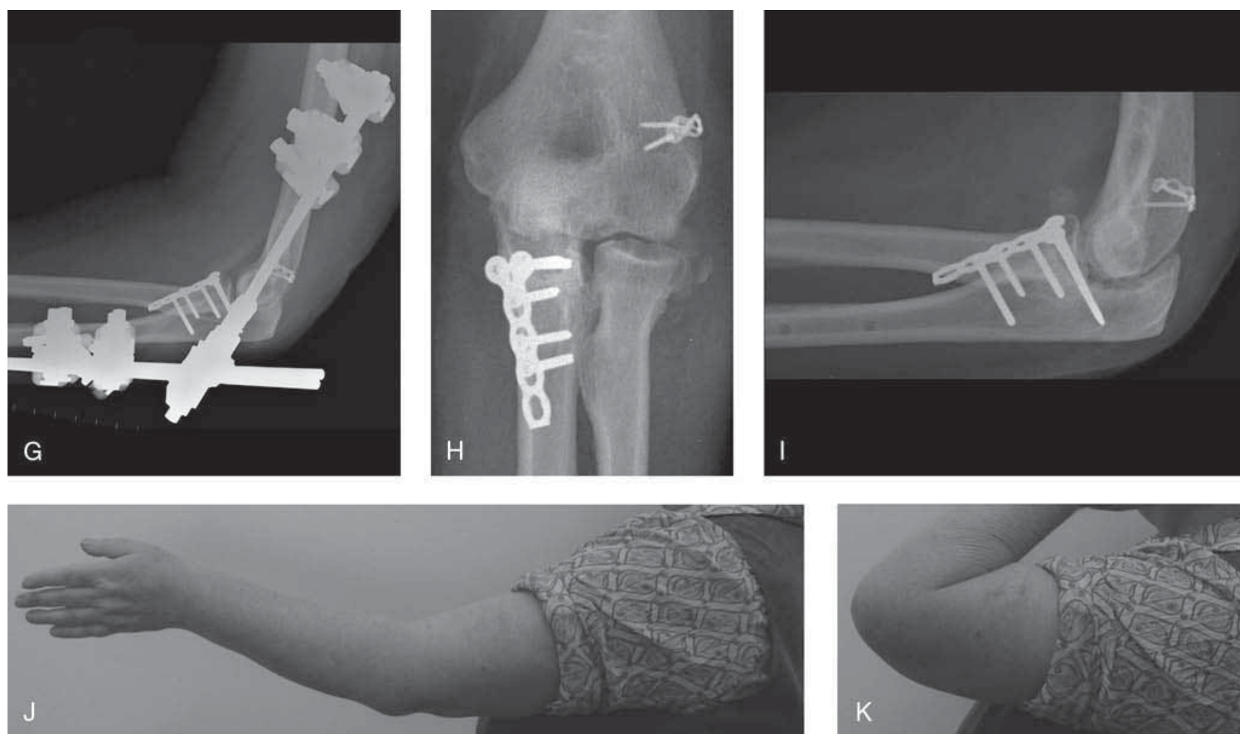

Figure 6 (cont'd) **G,** Postoperative lateral radiograph showing the reduced elbow joint with hinged external fixator. AP **(H)** and lateral **(I)** 6-month postoperative radiographs demonstrating a congruous elbow. The patient had no pain and a functional arc of motion. **J** and **K,** The elbow at 1 year after surgery.

radial head excision and significantly contributes to posterior stability of the elbow when there is coronoid deficiency.[26-28]

Classification

Numerous classification systems have been used for fractures of the proximal radius, but it is difficult to distinguish among subtypes on plain radiographs. The modified Mason classification includes type I, a nondisplaced fracture; type II, a fracture with displaced wedge fragments; and type III, a comminuted fracture.[29] A type IV fracture is any radial head fracture associated with an elbow dislocation.[30]

Imaging

Imaging is essential to fully understand a radial head injury with chronic elbow subluxation and develop a treatment plan. AP, lateral, and oblique radiographic views are useful. If the patient has wrist pain or a comminuted radial head fracture, bilateral PA radiographs of the wrists are used to evaluate for an Essex-Lopresti injury. Axial, sagittal, and coronal CT scans, as well as three-dimensional reconstructions, are mandatory.

Reconstruction

Reconstruction using a displaced native fragment can be considered for a partial defect of the radial head. There may be a significant risk of fragment nonunion or osteonecrosis when performing an osteotomy of a healed displaced fracture, particularly if an intact periosteum cannot be maintained. The radial head is approached through a lateral Kocher or extensor digitorum communis–splitting approach. The suitability of the displaced fragment for osteotomy is evaluated. If significant degenerative changes of the radial head are present, radial head arthroplasty is preferred. Isolated excision is contraindicated if the elbow is unstable. Fibrocartilage is removed from the fracture site, and osteotomes are placed through the articular surface with an attempt to maintain the attachment of the periosteum to the displaced segment. Kirschner wires are used as joysticks to elevate and temporarily stabilize the fragment. Definitive fixation is achieved with countersunk compression screws (Figure 7). If bone graft is needed, cancellous bone can be harvested from the proximal ulna or lateral condyle of the distal hu-

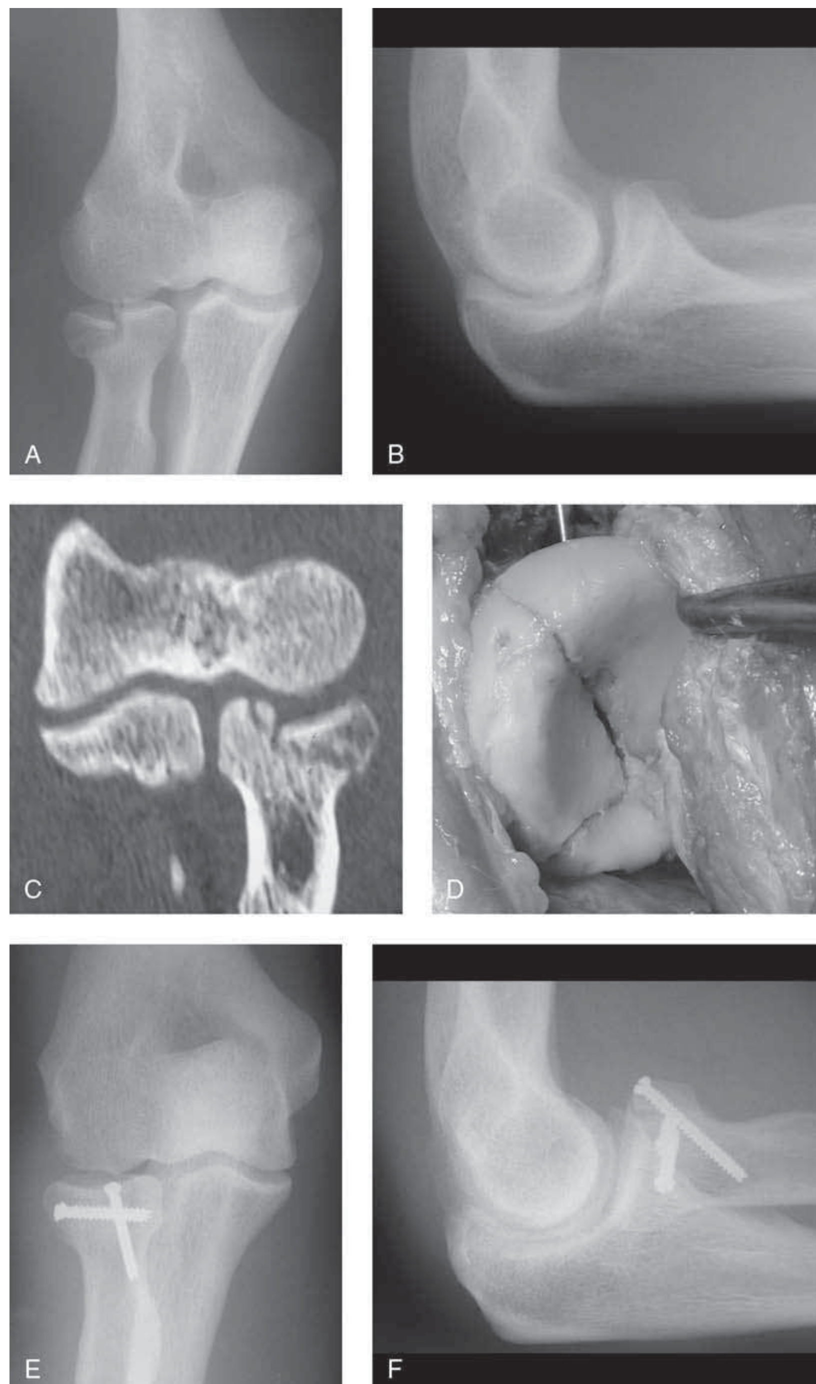

Figure 7 Radial head reconstruction with intra-articular osteotomy. AP **(A)** and lateral **(B)** radiographs of the elbow of a 44-year-old man with pain and persistent clicking 8 weeks after nonsurgical treatment of a radial head fracture. **C,** CT scan showing a healed displaced partial articular radial head fracture. **D,** Articular congruity after fixation of the osteotomy. AP **(E)** and lateral **(F)** radiographs showing healed osteotomy without evidence of osteonecrosis 1 year after surgery. The patient had no pain or crepitus and full range of motion.

merus. A lateral surgical approach is used for an intra-articular radial head osteotomy, and compression screws are used for fixation, with or without a plate. There is only one published report of a successful outcome using this method of radial head reconstruction.[31]

A radial head fragment can be left displaced in the joint or soft tissues of the elbow. Open reduction and fixation on a delayed basis can be considered if the quality and size of the fragment allow a congruous reduction with stable internal fixation, but nonunion and osteonecrosis are likely more frequent than with primary treatment.

Osteochondral allograft reconstruction can be considered for a partial articular fracture of the radial head, but the outcome of this method is unknown. Nonunion and collapse of the allograft segment may occur. Whole-head allograft reconstruction of the radial head was reported to be unsuccessful at medium- or long-term follow-up, and it should not be used.[32,33]

Radial head arthroplasty typically is done if the radial head is not salvageable and the capitellum is not excessively damaged (Figure 8). Metallic radial head implants have been successfully used for many years, and many different designs, materials, shapes, and types of stem fixation are available. A fixed head-stem construct may be superior to a bipolar implant for a patient with residual elbow subluxation. A biomechanical study found that a fixed head-stem construct is superior to a bipolar implant for a patient with residual posterolateral rotatory instability.[12]

The surgical technique varies with the type of implant system used. An elbow with subacute or chronic instability and an intact lat-

eral collateral ligament may have decreased mobility of the proximal radius, and scarring may prevent the insertion of a monoblock prosthesis. A modular implant system is preferred. A lateral surgical approach is used for excision of the damaged radial head at the head-neck junction. The diameter and thickness are carefully measured to determine implant size. The diameter of the articular dish is measured, rather than the outer diameter of the head, which typically is at least 2 mm larger. If the radial head was excised earlier and is not available, radiographic templates of the contralateral elbow are used for implant sizing. The implant must not be too thick because overlengthening of the radius may cause elbow stiffness as well as capitellar wear and pain. The lateral ligaments may be deficient, so the thickness of the radial head prosthesis is most correctly determined based on the size of the resected radial head, if it is available, rather than the gap between the radial head and capitellum.

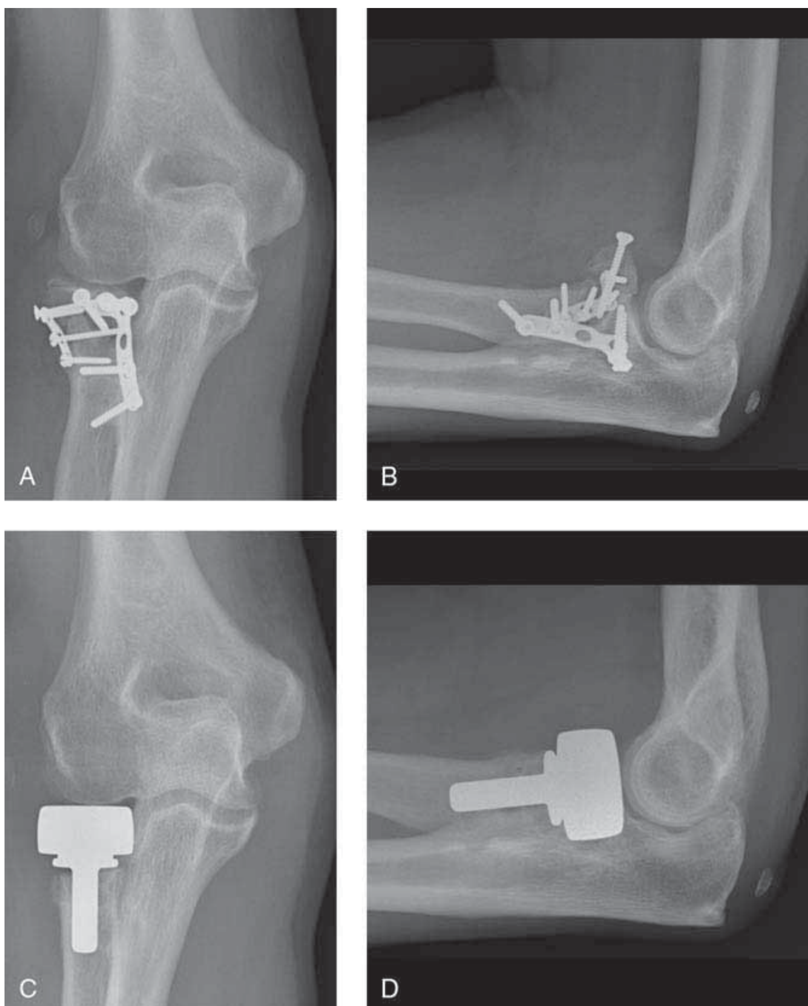

Figure 8 Radial head reconstruction with replacement arthroplasty. AP **(A)** and lateral **(B)** radiographs of the elbow of a 48-year-old man with pain, stiffness, and persistent clicking 6 months after open reduction and internal fixation of an elbow fracture-dislocation. The hardware had failed. AP **(C)** and lateral **(D)** radiographs 6 months after open capsular release and radial head replacement with a modular implant. The patient had no pain and nearly full range of motion.

Broaches are used to prepare the medullary canal of the radial neck. If a press fit is selected, an implant with the same diameter as the broach is inserted. If a smooth stem-spacer implant is selected, the stem should be one size smaller to ensure congruous tracking of the implant on the capitellum. The trial implant and tracking are carefully evaluated clinically and radiographically before the definitive radial head and stem are inserted into the elbow. The implant should articulate at the level of the proximal radioulnar joint, approximately 1 to 2 mm distal to the coronoid process. Modular radial head components are coupled ex vivo or in situ, depending on the status of the collateral ligaments. If needed, a careful lateral ligament repair or reconstruction is done. Metallic radial head arthroplasty for chronic elbow reconstruction has achieved good to excellent results in most patients.[34]

Radial head excision is contraindicated in the setting of persistent elbow instability. If the capitellum is deficient because of damage from persistent elbow subluxation, a radiocapitellar replacement should be considered (Figure 9). Although only the use of custom-made radiocapitellar implants has been reported, commercial prostheses are now available. Little is known about the outcome of using radiocapitellar implants for lateral column reconstruction.[35] Because these implants contain polyethylene, probably they

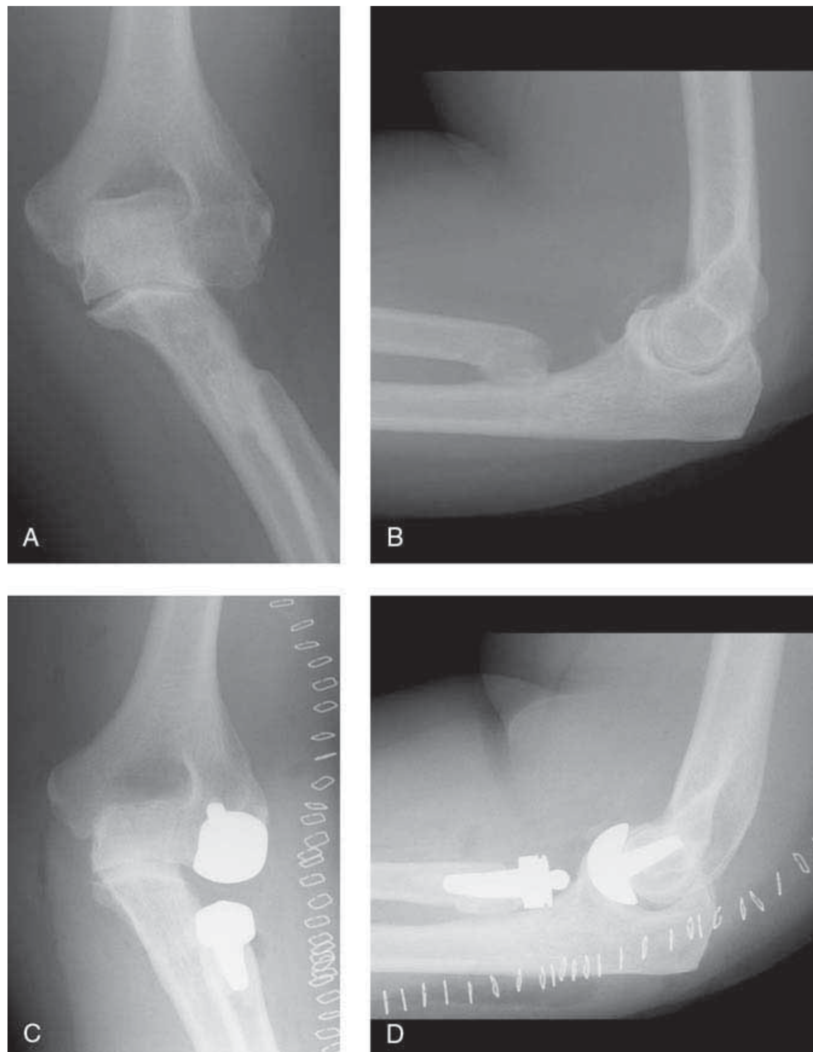

Figure 9 Radial head and capitellar reconstruction with a unicompartmental arthroplasty. AP **(A)** and lateral **(B)** radiographs of the elbow of a 38-year-old man with pain and valgus instability after a radial head excision. AP **(C)** and lateral **(D)** radiographs after radial head replacement with a lateral unicompartmental arthroplasty. (Courtesy of Bernard Morrey, MD, Rochester, MN.)

should be used only in older, lower demand patients. The precise surgical technique varies with the implant. Like coronoid reconstruction, radial head reconstruction requires that associated osseous and ligamentous injuries of the elbow receive careful attention.

Salvage Procedures for Persistent Subluxation

Interposition arthroplasty, total elbow arthroplasty, or elbow arthrodesis should be considered if chronic subluxation persists after reconstruction or cannot be appropriately treated with reconstruction. Although there is only limited published information on the use of interposition arthroplasty for chronic or persistent elbow subluxation, deepening of the olecranon to compensate for a deficient coronoid may improve the stability of the elbow.[8] Interposition arthroplasty has been most successful in elbows with stiffness and a competent radial head. It includes dislocation or subluxation of the elbow, with roughening of the distal humerus to promote adhesion of the interposition material. To avoid resorption of the distal humerus, minimal bone should be removed. The materials used for interposition have included autogenous and allograft fascia lata and dermis as well as Achilles tendon allograft; none has been found superior. Achilles tendon allograft is particularly useful because a portion of the graft can be used to reconstruct or augment deficient collateral ligaments. An articulated external fixator with joint distraction can be used during the early postoperative period to maintain elbow stability and allow early motion while offloading the interposition material during healing.[36]

Total elbow arthroplasty using a linked implant has an important role in the reconstruction of persistent elbow instability, particularly in lower demand patients (Figure 10). These devices restore stability and effectively treat the concomitant posttraumatic arthritis that often develops quickly in patients with persistent elbow subluxation. Caution is required in considering elbow arthroplasty for younger, higher demand patients because the longevity of these implants is less than ideal. The surgical technique varies with the choice of implant. The ulnar nerve is routinely transposed. If bony deficiency is present, a triceps-

on approach should be considered because the triceps often fails to heal after detachment and repair. After elbow arthroplasty, patients must comply with a permanent restriction on lifting more than 5 kg. Loosening and bearing wear are more frequent in patients with posttraumatic instability and arthritis.[37,38]

Elbow arthrodesis can be considered for posttraumatic elbow reconstruction.[39] There is no optimal angle of flexion in which to fuse the elbow, however, and most patients will not accept this treatment option. The rate of union is much higher with plate fixation than with earlier methods of elbow arthrodesis, but patient satisfaction remains suboptimal. Elbow arthrodesis should be used only in young, higher demand patients, for whom other reconstruction options are unreliable. To ensure the patient can accept the treatment and agrees to the position of fusion, a cast or splint should be used before surgery to immobilize the elbow in the desired position (typically 60° of flexion). The elbow is approached through a posterior elbow incision, and the triceps is split and elevated medially and laterally. The ulnar nerve should be transposed if this was not done earlier. The radial head typically is excised, and the articular surfaces of the proximal ulna and distal humerus are denuded to bleeding bone. A long 4.5-mm dynamic compression plate is contoured to the position of fusion using a goniometer, and the plate is fixed to the ulna and humerus while the ulna and humerus are compressed together. Autogenous cancellous bone graft should be used to improve the likelihood of union. The triceps is carefully closed over the plate and reattached to the olecranon to facilitate possible future conversion to total elbow arthroplasty. The elbow is immobilized in a cast until union is achieved.

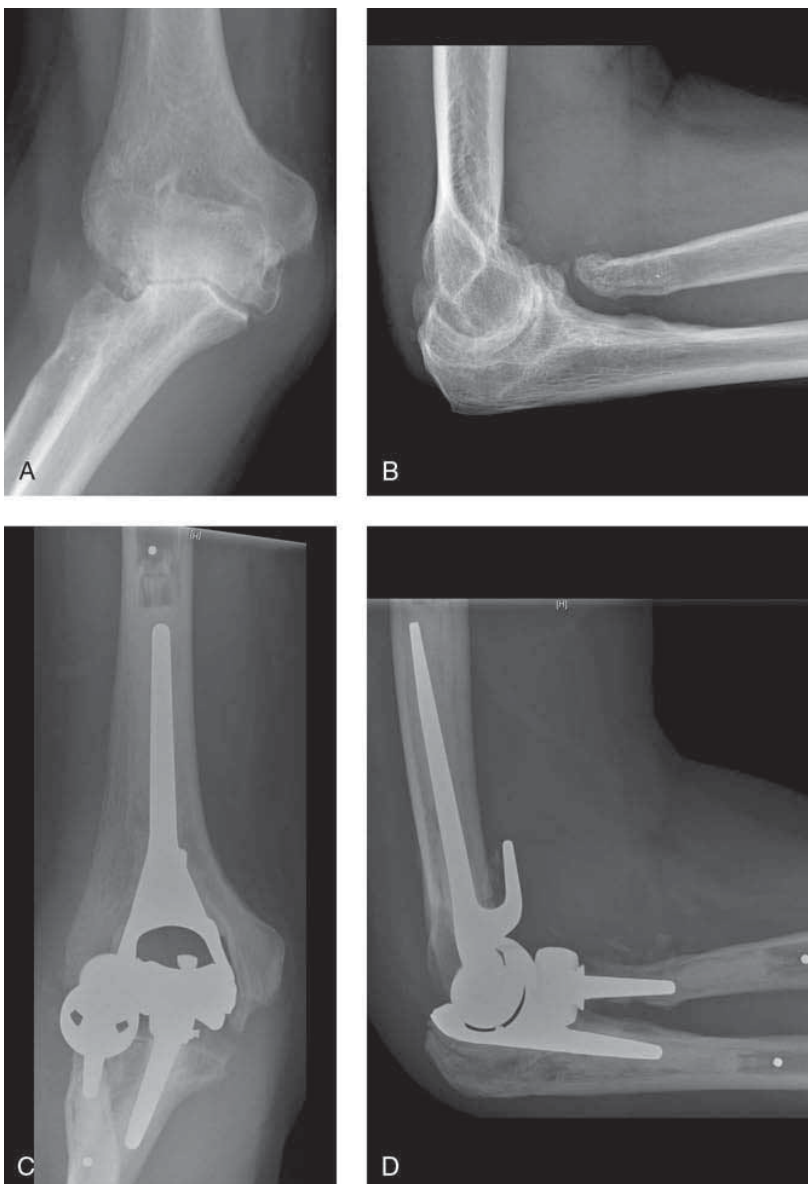

Figure 10 Total elbow arthroplasty for salvage of persistent elbow instability. AP **(A)** and lateral **(B)** radiographs of a 48-year-old man with pain, stiffness, and valgus instability after remote radial head excision and failed radial head reconstruction with an osteoarticular allograft. AP **(C)** and lateral **(D)** radiographs 1 year after an unlinked total elbow arthroplasty. The patient's pain and motion improved; however, a contracture release was required at 5 months because heterotopic ossification developed after the index procedure.

Summary

The surgical treatment of coronoid and radial head deficiencies associat-

ed with chronic elbow subluxation is challenging. Successful reconstruction requires recognizing and treating concomitant soft-tissue deficiencies. Sound knowledge of the anatomy and biomechanics of the normal elbow is necessary, with an understanding of the required imaging and the options for reconstruction. Anatomic reconstruction generally is recommended, although appropriate prosthetic reconstruction can achieve a satisfactory result, especially with a radial head deficiency. Further studies are needed to evaluate the outcomes of the reconstruction techniques used for these uncommon injuries.

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