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FRACTURE DISLOCATIONS OF THE ELBOW IN ATHLETES

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Acute elbow dislocations and fracture dislocations often are referred to as simple and complex elbow dislocations, respectively. Elbow dislocations represent 10% to 30% of all injuries to the elbow.[18] Among upper extremity trauma, elbow dislocations are second only to shoulder dislocations with an annual incidence of 6 cases per 100,000 people.[23, 29] The mechanism of injury is most commonly a fall on an outstretched hand with the elbow in extension and abduction. The median age for elbow dislocation in sports and other high-energy and injury mechanisms is 30 years.[12] The treatment of athletes suffering these injuries has been elucidated by new laboratory studies,[33, 28] and learning through treatment of the general population.[8]

ANATOMY

The contour of the elbow joint surfaces, combined with the capsular, ligamentous, and musculotendinous soft tissue provide significant inherent stability to the elbow. The elbow is provided further stability by virtue of the articular congruence between the ulna and trochlea (Fig. 1). The intact bony surface is the primary constraint for stability along with the anterior band of the medial collateral ligament (MCL) and the ulnar half of the lateral collateral ligament (LCL). Morrey and Ank[20] reported that the ligaments provide 50% of elbow stability in the medial and lateral plane.

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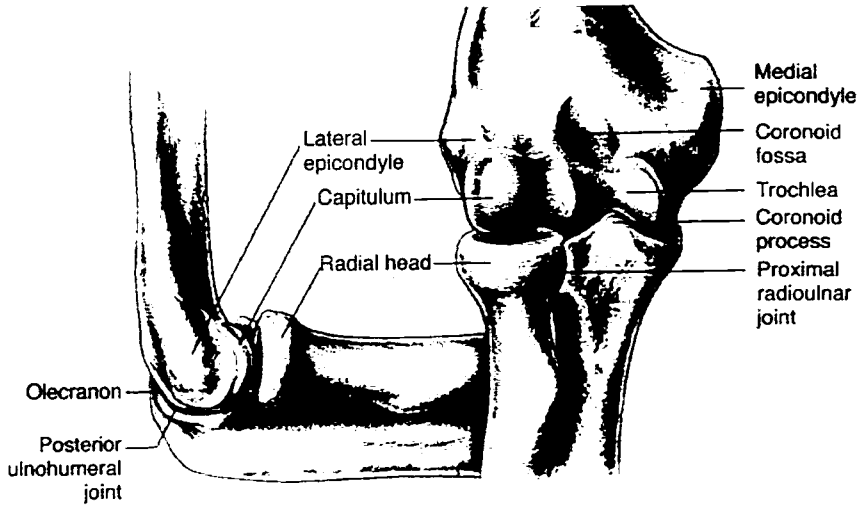

Figure 1. Bony anatomy of the elbow. Note the articular congruence between the ulna and the trochlear groove. (Courtesy of K. Plancher, MD, New York, NY.)

The radial head is believed to be a secondary stabilizer to valgus stress. When the radial head is removed or fractured, there is little effect on valgus stability if the MCL is intact. Radial head excision or incompetence will lead to significant valgus instability only if there is a complete disruption of the MCL.[15, 22] In the MCL-deficient elbow, stability in extension is determined by the radial head, along with the capsule.

Coronoid fractures (type II or type III, 50% or more of the coronoid process), when present, often lead to recurrent elbow subluxation or dislocation. These coronoid fractures must be reconstructed to return stability to the elbow and, in the authors' opinion, will help to delay arthritis due to joint incongruity.

The soft tissue stabilizers, or secondary constraints, of the elbow include the joint capsule ligaments and musculotendinous units. The anterior joint capsule provides resistance to varus and valgus stress with the elbow in full extension.[15, 22] The MCL, LCL, and the annular ligament also can provide inherent stability to the elbow. The anterior band of the MCL is the prime stabilizer to valgus stress[9, 15] (Fig. 2).

The LCL is a vital structure composed of the ulnar collateral ligament and the radial collateral ligament. The LCL provides stability against posterolateral rotatory and varus stresses.[4, 15] The annular ligament of the elbow stabilizes the proximal radial ulnar joint, and reconstruction can be required if the ligament is torn. The biceps and brachialis muscles, which cross the elbow, dynamically stabilize the elbow. All these structures contribute to the elbow's stability to avoid dislocations.

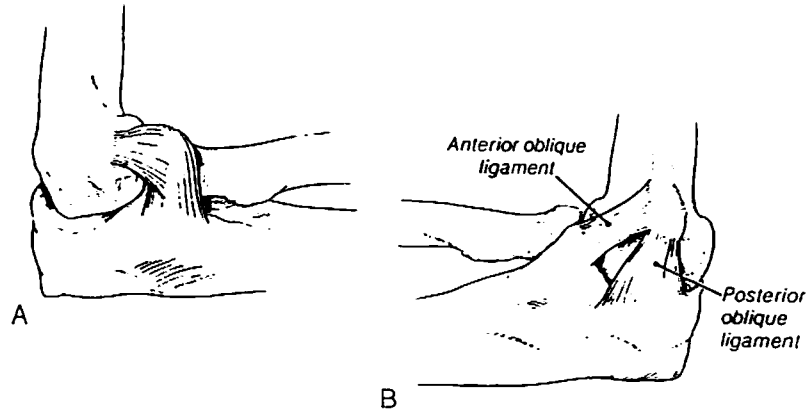

Figure 2. *A*, Lateral collateral ligament provides protection against varus stress. *B*, Medial collateral ligament as a primary stabilizer to valgus stress. (Courtesy of K. Plancher, MD, New York, NY.)

MECHANISM OF INJURY

Most elbow dislocations in sports result from a fall on an outstretched hand, leading to posterior displacement of the olecranon on the humerus (Fig. 3) from a combination of valgus, supination, and axial forces applied to the joint. The authors believe that these forces cause failure of the soft tissues, progressing from the LCL through the anterior and posterior capsule to the MCL.[25] The essential lesion for a complete dislocation of the elbow must involve the MCL. A study by Joseffsson et al showed that all complete simple elbow dislocations had evidence of valgus instability, but only 50% of the elbows had varus instability under general anesthesia before surgery.[14]

In complex dislocations, greater relative amounts of axial, valgus, and rotational forces are applied to the elbow.[1] The associated fractures about the elbow occurring with dislocations most frequently involve the radial head and coronoid process, and occasionally the humeral epicondyles (Fig. 4). Large intra-articular fractures that occur with an elbow dislocation create the complex dislocation, often with the terrible triad[22] (radial head fracture, coronoid fracture, and a MCL tear) (Fig. 5).

MANAGEMENT OF SIMPLE DISLOCATIONS

The diagnosis of an elbow dislocation is based on the history of the mechanism of injury and clinical inspection. A thorough neurovascular examination is required before and after reduction maneuvers. Particular attention should be directed to the distal radial ulnar joint and interosseous membrane to investigate for an Essex–Lopresti variant. Plain radio-

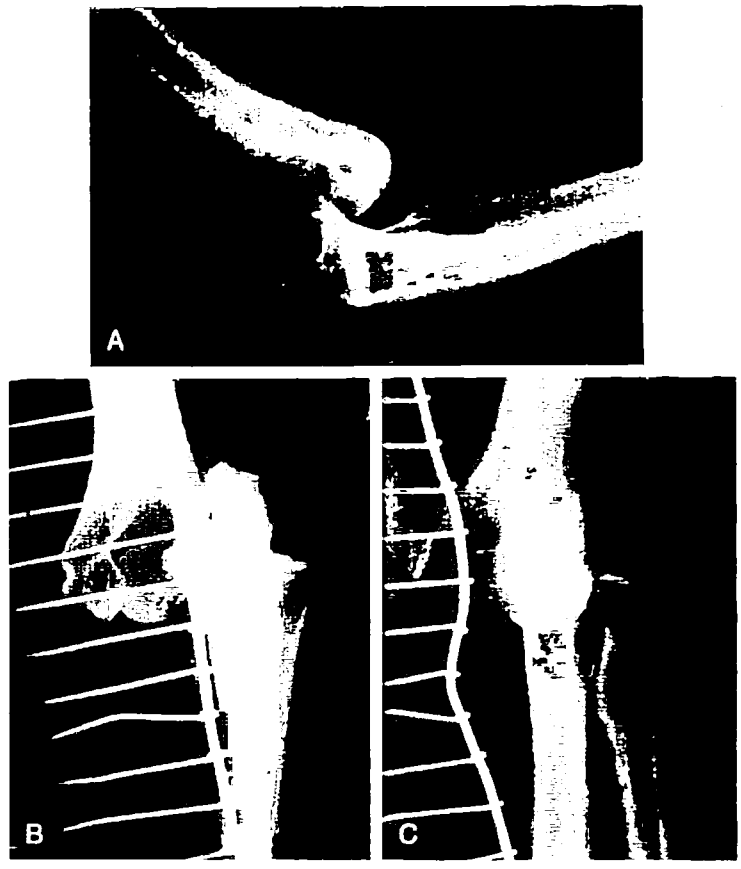

Figure 3. Posterolateral dislocation of the elbow. *A.* Lateral view. *B.* Oblique view. *C.* Anterior posterior view. (Courtesy of K. Plancher, MD, New York, NY.)

graphs are helpful in determining direction of forces and in planning for the reduction. The reduction maneuver, while necessary, is difficult to perform on most athletes because radiographs are not readily available on the field of play. A gentle examination of range of motion most often will reduce the injury. The maneuver is easiest before the initiation of swelling, and should be attempted on the field of play by an experienced sports medicine physician. Gentle longitudinal traction to the wrist with stabilization of the upper arm is performed (Fig. 6A). This will distract the elbow, and often produce a clunk as the elbow is flexed and simultaneously reduced. Concurrent pressure on the olecranon tip while traction is applied usually reduces the posterior dislocated elbow (Fig. 6B).

After reduction, the elbow is taken through range of motion of both flexion and extension and pronation and supination. The elbow can be

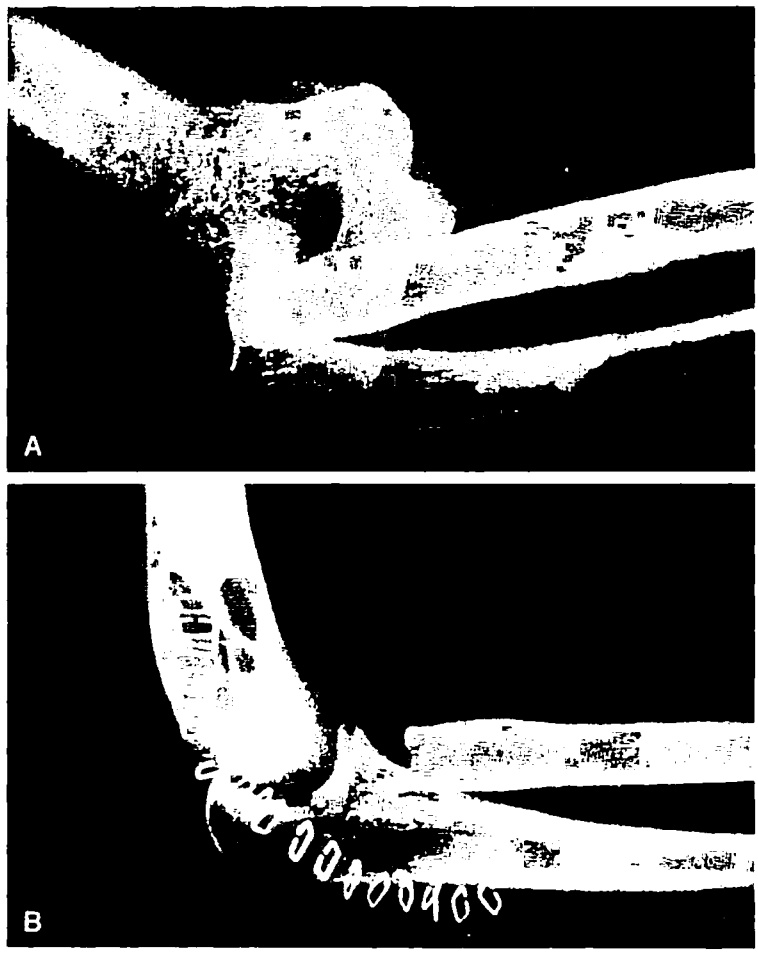

Figure 4. Complex elbow dislocation with associated radial head fracture. *A.* Preoperative. *B.* Postoperative. (Courtesy of K. Plancher, MD, New York, NY.)

splinted in 90° of flexion for 5 to 10 days, with initiation of range of motion thereafter if a stable concentric reduction is obtained. Immobilization of the elbow for more than 3 weeks has been associated with a poor ultimate range of motion.[18]

If damage is isolated to the LCL, the elbow will be more stable with the forearm pronated, whereas injury to the MCL requires supination if instability is seen. When both the MCL and LCL are disrupted, we place the arm in a neutral rotation. In the patient with instability at flexion angles less than 60°, an extension block splint can be used with active motion maintained in a stable range of motion. The extension block is progressed to 30° by 3 weeks. Healing should be complete at 6 weeks

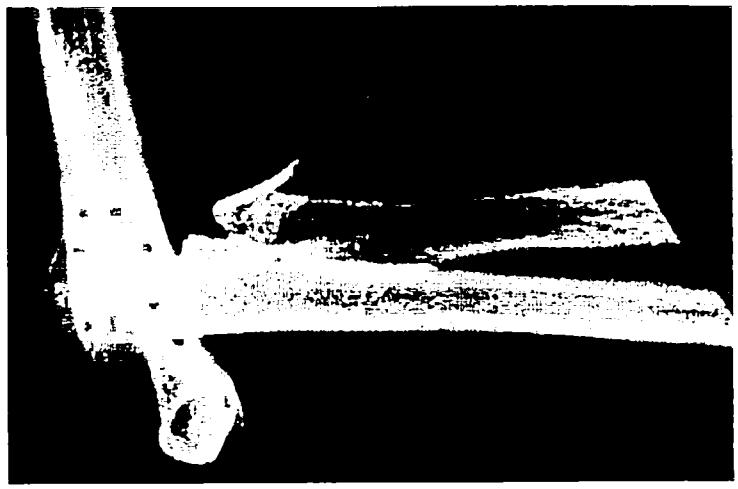

Figure 5. Terrible triad: Radial head fracture, coronoid fracture with a medial collateral ligament tear. (Courtesy of K. Plancher, MD, New York, NY.)

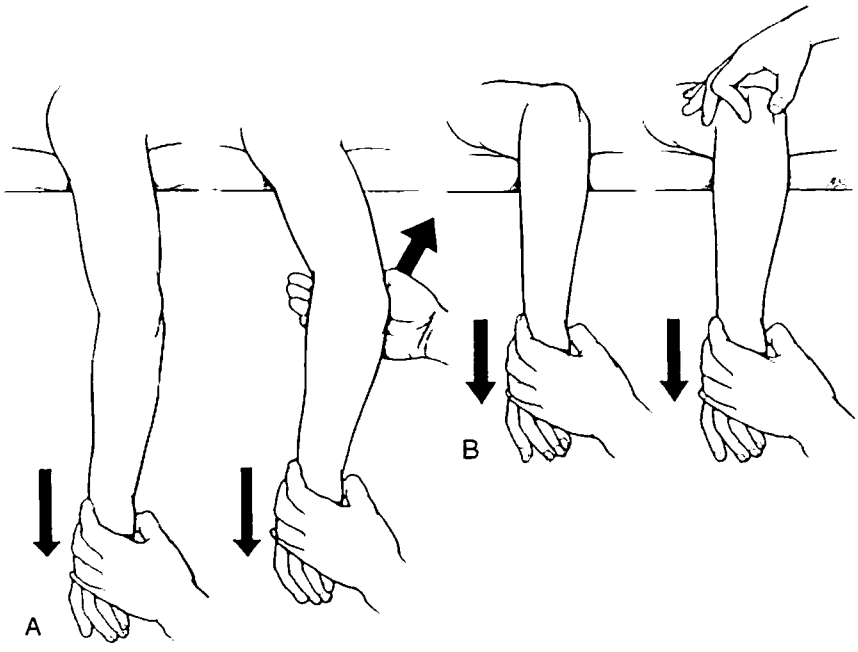

Figure 6. *A* and *B*, Maneuvers used to reduce a simple elbow dislocation. (Courtesy of K. Plancher, MD, New York, NY.)

for this injury, and therefore no extension lag nor instability should be seen. Recurrent instability with simple dislocation is rare, occurring in less than 1% to 2% of cases.[11, 18]

A prospective study[11] has shown no advantage of early collateral ligament repair versus early motion after a simple elbow dislocation. The same authors feel that nonoperative treatment yields better results, and have found that 80% of patients treated with surgical repair considered their elbow not normal, compared to less than 50% of those treated nonoperatively. We have not found this to be the case, and encourage operative treatment when indicated.[30]

An operation is indicated if the elbow remains unstable after reduction. When stability is confirmed with the necessity of flexion beyond 45° to remain reduced, or when elbow dislocations are associated with unstable fractures (e.g., type III coronoid fractures, radial head fractures) about the joint, the authors believe in the acute repair of the MCL and LCL along with all fractures noted.[5]

ACUTE LATERAL COLLATERAL LIGAMENT REPAIR

Acute collateral lateral ligament avulsions after elbow dislocations should be undertaken only by surgeons familiar and comfortable with the complex anatomy of the elbow. A modified extensile Kocher (our preference) or posterior skin incision is made. The common extensor tendon is elevated off the supracondylar ridge and epicondyles, along with the extensor carpi radialis longus, which must be released to achieve visualization distally. The interval between the anconeus and the extensor carpi ulnaris interval is released, and the torn lateral collateral ligament (radial collateral ligament) should be evident. The components of the ligament then are identified with particular emphasis on the ulnar portion. Even in the best of circumstances, this tissue is not as well defined as the anterior band of the MCL so we use multiple sutures to repair this site. First, #2 Ethibond is placed in the most proximal portion of the extensor digitorum communis and extensor carpi radialis longus at the isometric point over the lateral epicondyle. This stitch is run distally in a Krackow fashion, and brought back to exit proximally. A second stitch is placed in the anconeus flap, well posterior in the same fashion. A third stitch is placed in the lateral ulnar collateral ligament itself with a Krackow stitch. A 2.5-mm drill is used to place a hole in the isometric point of the lateral epicondyle. Two additional drill holes are made, one anterior to the flat part of the humerus and one posterior to the lateral supracondylar ridge. The two posterior sutures, and the one stitch from the proper lateral ulnar collateral ligament, are brought anterior, and the anterior stitches from the extensor carpi radialis longus and extensor carpi ulnaris complex are brought posterior, with the one suture remaining on the lateral ulnar collateral ligament. Through the lateral epicondyle, these sutures are tied with the elbow flexed 90° in neutral rotation. A polydiaxanone suture (PDS) can be placed as de-

scribed by O'Driscoll in the cristae of the ulna, with two drill holes and additional suture of #2 Ethibond connected by a Bankart awl and then brought in to reinforce the repair. Rehabilitation for this injury is begun on day 2. The modified extensile Kocher approach is perfect for rare small midsubstance partial tears, whereas the posterior approach can help when avulsions occur off the epicondyle.

ACUTE MEDIAL COLLATERAL LIGAMENT REPAIR

Repair of the medial collateral ligament after an avulsion, in an elbow dislocation, can be performed through an 8.0-cm incision centered at the medial epicondyle. The authors prefer to use a straight posterior incision, which was popularized by Morrey.[21] The incision is made no differently than for a total elbow replacement. The ulnar nerve should be dissected out of its bed and protected from injury at all times. The triceps is reflected in continuity with the periosteum. The anterior intermuscular septum is excised, and the flexor-pronator mass is incised with the brachialis left alone. With the ulnar nerve out of its groove, it is easy to dissect meticulously the flexor-pronator groove from posterior to anterior to see all the fibers of the MCL posterior band, anterior band, and transverse band. The elbow capsule is now evident and can be swept from the medial to lateral side. In an elbow dislocation, the deep soft tissues are disrupted. In the rare case when the flexor-pronator muscle mass is intact and the deep MCL is not, the authors routinely do not reflect from the origin or divide this muscle mass. This alternate technique forces the surgeon to work through a small opening in the flexor-pronator mass. We normally divide the overlying muscular fascia and fibers to visualize the underlying torn MCL (Fig. 7).

If the surgeon is not experienced in MCL repair, we recommend taking off the flexor-pronator mass before repair, for better visualization. A #2 Ethibond suture is placed with a Krackow stitch over the length of the MCL. A 2.5-mm drill bit is used to identify the isometric point of the medial epicondyle, one half the distance from the joint, to exit posterior to the intermuscular septum of the triceps. The ulnar nerve is protected and sutures are passed out the back of the elbow posteriorly and tied with the elbow held at 90° in neutral rotation and reduced. The two heads of the flexor carpi ulnaris are repaired only if they do not impinge on the ulnar nerve, which is transferred in a subcutaneous fashion. If there is a rare midsubstance tear, it is repaired and augmented with a palmaris or plantaris graft, which is beyond the scope of this article.

When tissue quality is poor or midsubstance tears are found, tendon reconstruction with autogenous tendon graft (i.e., palmaris longus, plantaris, extensor digitorum communis of the fourth toe) should be performed. The techniques are well described by others[21, 24] for the MCL and LCL, respectively. A hinged elbow orthosis, continuous passive

Figure 7. Normal anatomic relationship in radial head to the capitellum. (Courtesy of K. Plancher, MD, New York, NY.)

motion machine, and early therapy are begun 48 hours after the MCL or LCL repair. If there is continuous instability, despite ligamentous repair, due to poor tissue quality, or complex fractures/dislocations, dynamic external fixators are applied. These devices will allow motion while maintaining reduction.[3, 21]

Experience in the use of dynamic external fixation is recommended; this procedure should not be attempted by the novice. Complication rates and technical difficulties in its application can never be overstated. Nerve injury can be permanent in up to 2% of patients, and temporary in 10% to 15%. We have had pin traction infections in 15% of our patients. The infections resolved and were not deemed permanent. Dynamic fixation allows elbow motion and protects the collateral lateral ligament repair while maintaining congruent articular surfaces. Use of this device is recommended in the unstable ulnar humeral joint after acute collateral ligament disruption, with or without fractures. Complex fractures, such as coronoid type III or olecranon fractures with poor fixation, can require the dynamic hinge fixator.

Contraindications for use of dynamic fixation include proximal ulnar fractures that preclude pin placement, osteopenia, inexperience with

the device, and local infection. New devices are available, including the Compass hinge (Smith and Nephew), the dynamic joint distractor II (Mayo), and a new hinge by Howmedica. Each hinge requires identification of the axis of rotation.

COMPLEX DISLOCATIONS

Complex elbow dislocations have both ligamentous and bony injuries. These injuries are difficult to treat, but newer surgical techniques can yield satisfactory results. Few studies are available in the literature.[2, 3] Treatment for fracture dislocations consists of reduction of the elbow and treatment of the fracture, and repair of all ligaments with a test of range of motion to verify the arc of motion and stability. The most common fractures associated with elbow dislocations are fractures of the radial head, coronoid process, and olecranon. These fractures are discussed below. Reconstruction of the ligaments is beyond the scope of this article.

RADIAL HEAD FRACTURES

The radial head has a slightly oval shape, is devoid of cartilage in the anterolateral third, and articulates with the capitulum (Fig. 7). The neck shaft angle of 15° is noted anterolaterally. The radial head is an important secondary stabilizer.

The Mason classification for radial head fractures recently was modified by Hotchkiss, and is a useful and clinical guide. Type I fractures are nondisplaced or minimally displaced (less than 2.0 mm); Type II are displaced but reconstructable; Type III are severely comminuted, unreconstructable[10] fractures. Fractures that involve less than 30% of the radial head do not compromise lateral elbow support and are not associated with an unstable joint. These fractures do not require surgical intervention, unless they prevent motion, or have more than 2.0 mm of incongruity. Imaging of this fracture is accomplished with routine anteroposterior, lateral, and oblique elbow radiographs.

The type I fracture can be treated with a sling for 1 week, with early active range of motion. Extension splinting to avoid flexion contractures can be started at 4 weeks. The treatment of type III fractures, although controversial, is discussed below. We encourage early range of motion if the radial head fragment is one third the size of the radial head, with no block to forearm rotation in Hotchkiss type II fractures. Delayed fragment excision can be performed as necessary. Open reduction, internal fixation is recommended with fragments greater than one third the size of the radial head and displaced more than 2.0 mm, or with a forearm rotation block.

Reconstruction of the radial head by open reduction, internal fixa-

tion will reestablish lateral osseous support and restore the anterior buttress, resisting posterior subluxation. Reconstruction can be performed through a posterior midline incision to decrease the risk of cutaneous nerve injury. A Kocher incision, with dissection between the anconeus and extensor carpi ulnaris, is performed as for repair of the lateral collateral ligament. The exposure should be extended farther proximally when reconstructing the radial head to visualize the entire radiocapitellar joint. The radial collateral ligament is incised at the level of the midportion of the radial head. We stay anterior to the lateral ulnar collateral ligament and, if necessary, incise and repair the annular ligament to improve exposure. The radial nerve and posterior interosseous nerve are not in danger as long as the dissection is not carried out proximal to the brachioradialis or distal to the annular ligament.

Fixation of radial head fractures can be difficult. Various treatment regimens are available to the surgeon, including 2.7-mm lag screws, a 3.0 mm cannulated screw, Herbert screws, or Acutrak screws. Threaded .045 mm Kirschner wires can be used to piece together a comminuted radial head fracture (Fig. 8). The addition of a three-hole T-plate with 2.7-mm screws on the radial head connected with the shaft can allow for an anatomic reduction. The use of the low profile mini-fragment plates when the head is separated from the shaft can be technically demanding (Fig. 9). When possible, all hardware should be placed laterally, because this portion of the radius does not articulate with the ulna and will avoid impingement.

Preservation of the radial head is of prime importance to maintain valgus stability when MCL disruption exists.[9, 15, 22] Excision is contraindicated, unless replacement is considered with MCL reconstruction[10, 31] (Fig. 10). Radial head reconstruction or replacement prevents radial ulnar longitudinal disassociation. If radial ulnar longitudinal dissection is performed, attention to the distal radial ulnar joint must be considered to avoid proximal migration. Temporary pin fixation of the distal radial ulnar joint in the neutral position can prevent proximal radial migration. In the past, only Silastic radial head spacers were available. These devices lacked the needed compressive resistance.[7] Newer metallic prostheses and allografts offer the needed resistance, although routine use is not recommended.[16]

Radial head replacement with a metallic prosthesis from Avanta or Howmedica is useful when stable internal fixation cannot be achieved or fragments involve more than one third of the radial head. A metallic implant is also useful if excised fragments allow articulation with the proximal radial ulnar joint, or there is concomitant soft tissue injury with the MCL or interosseous membrane. The surgical technique for radial head implants is beyond the scope of this article.

Complications of radial head fixation include avascular necrosis, nonunion, malunion, osteoarthritis, valgus instability, and stiffness. Early results with metallic radial heads implants are encouraging. After reconstruction of the radial head, early motion always is employed.

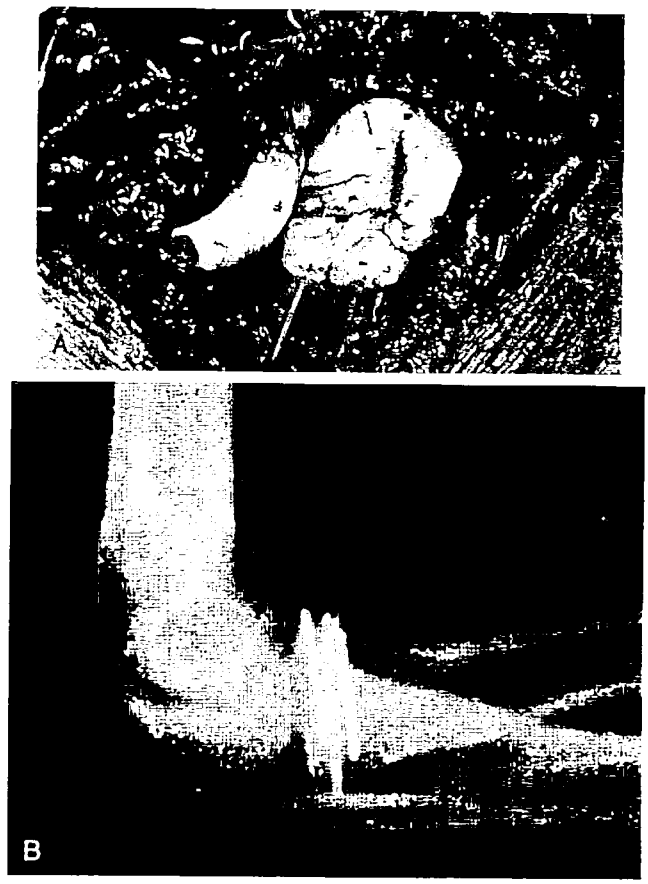

Figure 8. Radial head reconstruction (*A*) in a comminuted type II fracture (*B*). (Courtesy of K. Plancher, MD, New York, NY.)

CORONOID FRACTURE

Treatment of coronoid fracture, long suspected to be of no concern, now is realized to be of the utmost importance to regain elbow stability. Minor incongruity in the anteromedial coronoid fractures can lead to elbow arthrosis. Proper treatment of type II and III fractures will yield better outcomes to the complex unstable fracture dislocations.

Coronoid fractures are classified according to Regan and Morrey.[27] Type I fractures occur at the tip of the coronoid. Type II fractures involve less then 50% of the bone, and type III fractures involve more than 75% of the coronoid. The contour and size of the coronoid contributes to the stability of the ulnar humeral joint. Large fractures involving more than the tip of the process (types II and III) indicate an unstable joint. The

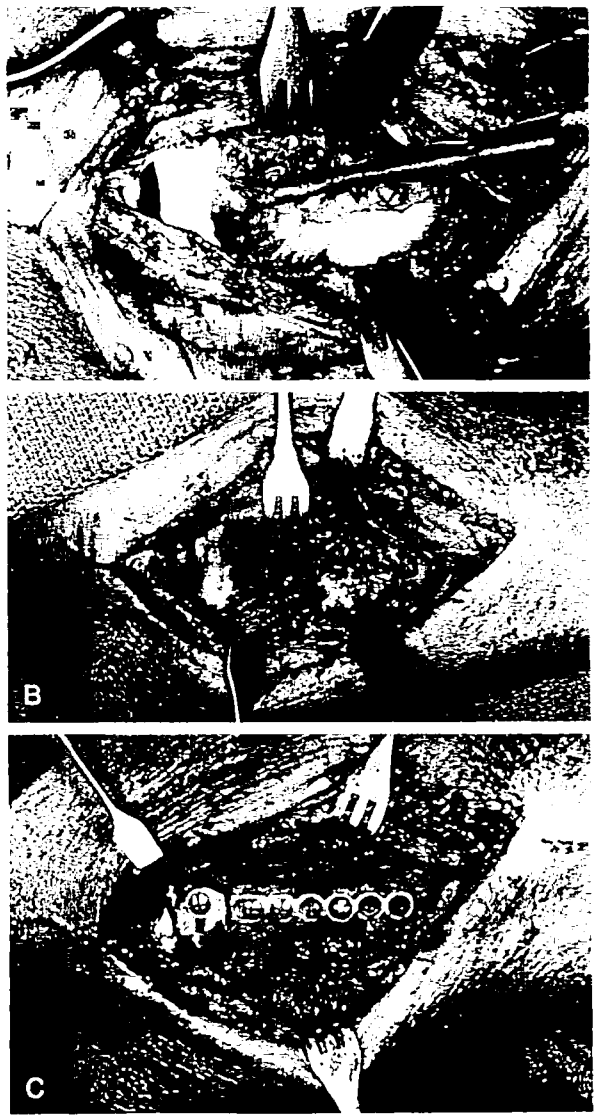

Figure 9. *A*, Failed hardware (T-plate) and nonunion of radial neck. *B*, Débridement of nonunion with hardware removed. *C*, T-plate used to attach comminuted radial head fracture after previous nonunion and hardware failure with autograft interposed between the shaft and radial head. (Courtesy of K. Plancher, MD, New York, NY.)

site of the coronoid fracture also can affect its treatment, whether at the tip, anteromedially, or at the base.

The anterior band of the MCL attaches to the medial aspect of the coronoid process. Reestablishing articular congruency and the anterior

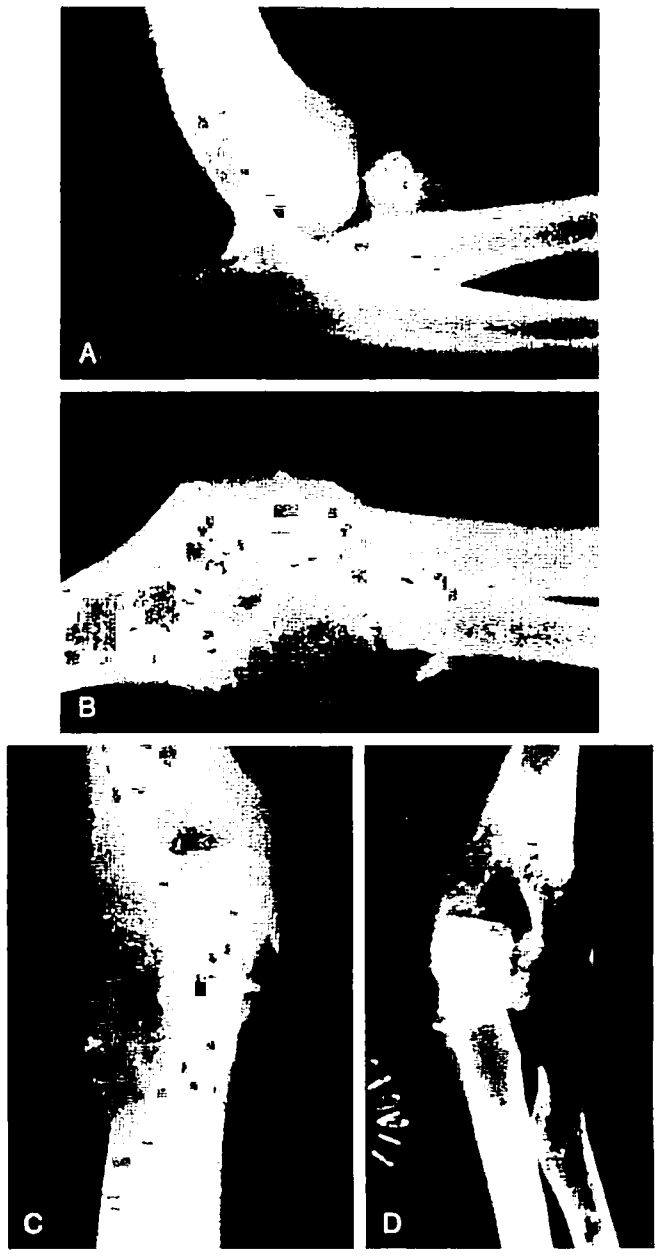

Figure 10. *A.* Lateral radiograph of an elbow with an unreconstructable radial head. *B.* Anteroposterior radiograph of a fracture dislocation of an elbow with an unreconstructable radial head. *C.* Radiograph of Silastic spacer placed after excision of radial head. *D.* Anteroposterior radiograph of an elbow with Silastic spacer removed at 10 weeks with stable forearm. (Courtesy of K. Plancher, MD, New York, NY.)

buttress of the coronoid process is particularly important when medial soft tissue or lateral bony restraints are injured (complex dislocations). When the MCL is being repaired, the coronoid fracture can be approached through the medial incision. The approach is identical to a MCL repair. Fixation of a coronoid can be performed with a #2 Panacryl or other suture, with or without .045 mm threaded pins. Recently, a three-hole pelvic reconstruction plate, as used by O'Driscoll, has been used to hold the anteromedial piece at its base in place. This technique requires two holes to be drilled from the subcutaneous part of the ulna toward the coronoid. The first hole must exit right at the junction of the articular and nonarticular area. The other drill hole must exit at the midsection of the fracture fragment. The sutures then are passed through the drill holes and tied down over the subcutaneous border. A plate is added, depending on the fracture pattern. A threaded wire is placed between the sutures to help fixation. If the fracture can be reduced easily, a lag screw is placed from a posterior to anterior direction and no plate is placed. The authors have found that this last technique does not allow for immediate range of motion, and favor use of a plate to help stabilize the fracture.[19]

OLECRANON FRACTURES

Olecranon fractures can be treated with either tension band wiring or a neutralization plate. Newer plates by Acumed could make fixation easier with increased stability to allow for early and immediate range of motion. These fractures normally are approached through a direct posterior incision. In the case of a fracture dislocation, however, they can be repaired using an extended medial or lateral incision during ligamentous repair. When these fractures are associated with a coronoid fracture, fixation and stability are often difficult to obtain.[32]

RESULTS

Most patients who sustain simple elbow dislocations regain preinjury functional status. Good results have been reported in 75% to 100% of studies.[14, 17] Satisfactory results are reported as an arc of motion of 100°. Flexion can return first, with maximal improvement taking from 6 to 12 weeks. Extension returns more slowly, and can require the use of extension splinting at night. Pronosupination returns now, with little difficulty in most patients. Mechanical testing has confirmed 15% average loss of elbow strength in many patients.[2] These results can be satisfactory for the general population where activities of daily living are performed adequately with 100° of elbow range of motion. For the athlete, however, this result would be a devastating injury. A result with 100° of range of motion most likely would end the career of most

overhead athletes (e.g., thrower, swimmer, racquet sports). For this reason, the use of aggressive splinting is encouraged in all athletes.

The results of treatment in complex elbow dislocations are less favorable.[2, 3, 13] The potential magnitude of a flexion contracture is greater and pain is more frequent. Ulnar humeral arthritis is common, especially after radial head excision. Recurrent dislocations are reported in up to 17% of cases.[13, 26] Poor results are associated with longer periods of immobilization needed for the more unstable joints.[2] Broberg and Morrey report a satisfactory outcome in 80% of 24 patients with dislocations associated with radial head fractures. No patient with a satisfactory result has been immobilized for more than 4 weeks. Regan and Morrey reported satisfactory results in 75% of patients in which the coronoid fracture was a type I, and in only 50% of cases of type II fractures. Patients with type III coronoid fractures have more discouraging results, with only 20% reporting a satisfactory outcome.

REHABILITATION

An accelerated rehabilitation program of any complex fracture or fracture dislocation is possible if stability has been achieved in treatment of the injury. We employ a program that elevates the arm for 24 to 48 hours with the elbow extended to control edema. In the operating room, stability of the elbow must be confirmed under fluoroscopic guidance. Early digital motion is begun, and indomethacin is used as prophylaxis to avoid heterotopic ossification in Mayo type III fracture dislocations of the elbow, except in elderly patients. At 48 hours, the initial dressing is removed and range of motion of the elbow is commenced. A resting splint at 90° and a custom fabricated nighttime extension splint are used (Fig. 11). Full, active-assisted flexion and gravity-assisted extension are begun. No strengthening is started until all fractures have healed. We employ nighttime splints for up to 16 weeks. A Cryo/Cuff is applied, and a continuous passive motion machine is used as necessary at 48 hours.

SUMMARY

Elbow dislocations can result in extensive injury to the supporting structures of the elbow joint. Principles of treatment include prompt reduction of the dislocation and treatment of associated fractures. The goal is to restore joint stability and to allow for early mobility. Most simple dislocations are stable after closed reduction with early mobility that can lead to anatomic and functional restoration. When stability is compromised, as with many complex dislocations, further stabilization with ligament repair, reconstruction, and fracture fixation also can lead to satisfactory results. The prognosis following complex dislocations is

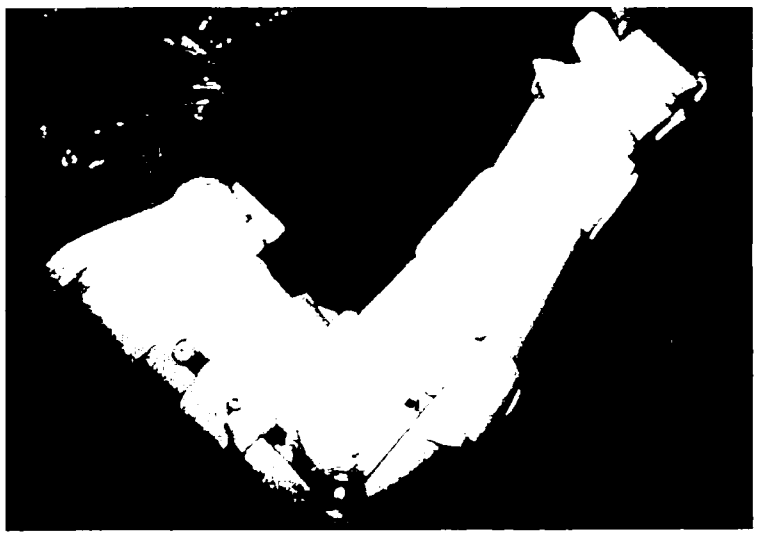

Figure 11. Custom fabricated resting splint with a hinge. (Courtesy of K. Plancher, MD, New York, NY.)

more guarded in the athlete, and depends on anatomic restoration and initiation of early motion.

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