Fractures About the Elbow

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Fracture Separation of the Distal Humeral Physis

In children younger than 2 or 3 years of age, an apparent dislocation of the elbow frequently is a fracture-separation of the distal humeral physis (Fig. 1). This injury is difficult to diagnose, because the only ossified structure about the elbow in children of this age is the ossification center of the lateral humeral condyle. In addition, the radius, proximal olecranon, and lateral condyle move medially or laterally as a single unit, giving the appearance of an elbow dislocation.[1-6] When this entity was first recognized, it occasionally was diagnosed by arthrography or magnetic resonance imaging; however, an increased awareness of the injury has made it easier to recognize on plain radiographs.[5,6]

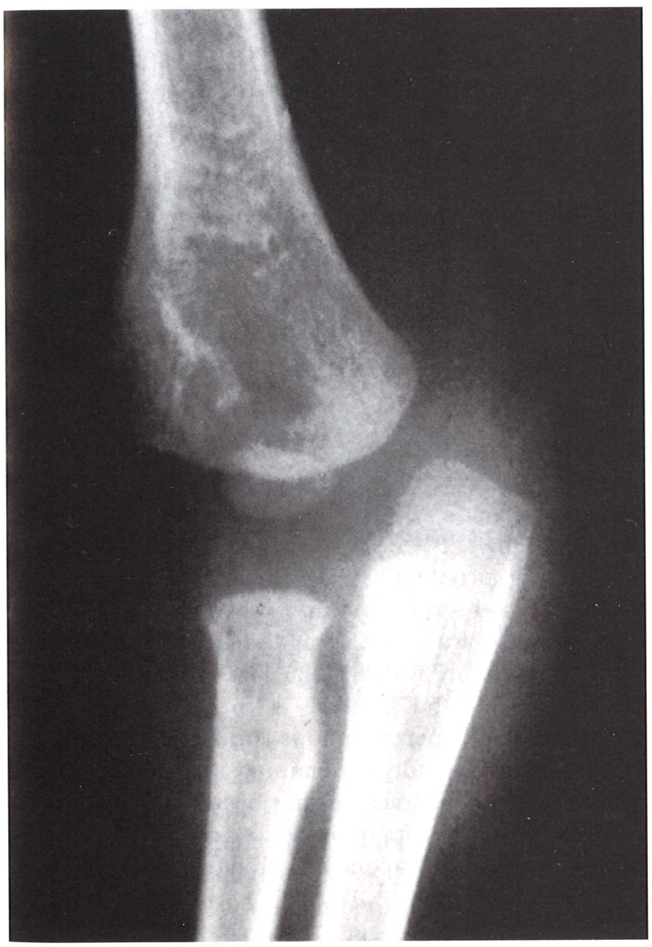

Fig. 1 Transepiphyseal fracture-separation of the distal humeral physis in a 2-year-old child. Ulna, radius, and lateral condyle are displaced medially as a single unit.

At one time, closed reduction and splinting were recommended for this injury,[3,7,8] but, more recently, closed or open reduction and percutaneous pinning have become the treatment of choice to avoid the possibility of instability and loss of reduction.

T-Condylar-Supracondylar Fracture

This rare fracture is difficult to diagnose and treat in young children (Fig. 2).[9] If the T-condylar component of the injury is not displaced, the supracondylar fracture can be treated either by splinting or by closed reduction and percutaneous pinning, but displacement of more than 2 to 3 mm requires open reduction and pinning (Fig. 3).[9-11] The fixation used depends on the age of the child. In very young children, pins can be used to fix the two condylar fragments and crossed Kirschner wires (K-wires) can be used for fixation of both condyles to the humeral shaft. In adolescents approaching skeletal maturity, fixation should be the same as in adults, with acetabular reconstruction plates

Fig. 2 T-condylar supracondylar fracture in a 4-year-old girl that was initially diagnosed as a supracondylar fracture only. After percutaneous pinning, malunion of the medial condyle and nonunion of the laterally displaced lateral condyle are present.

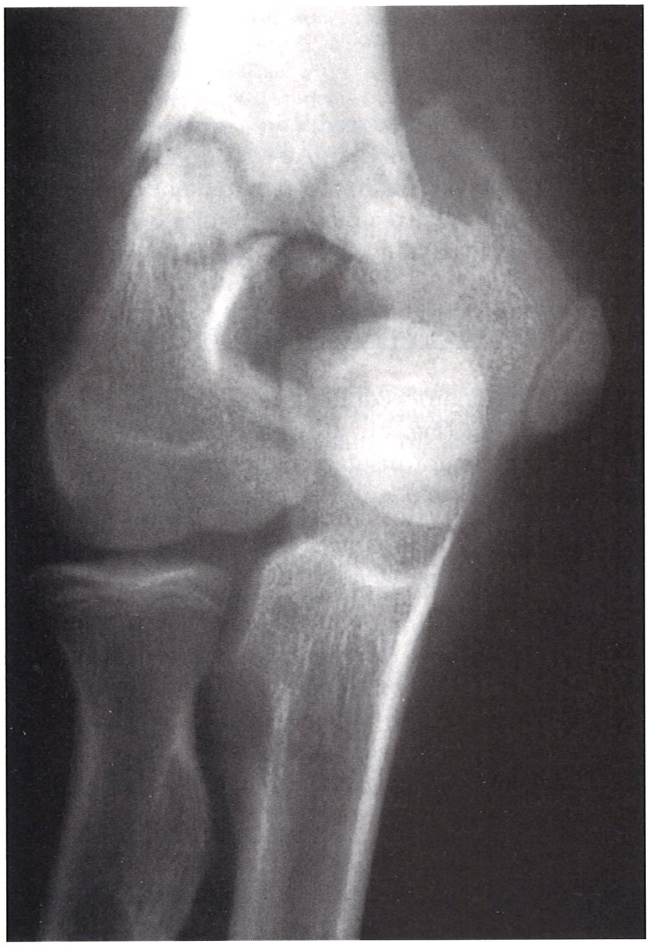

Fig. 3 T-condylar fracture in a 14-year-old boy with mild comminution at the supracondylar level, displacement and rotation of the medial condyle, and 1-cm displacement of the articular surface.

and screw fixation as needed. The triceps-splitting approach may be used, or olecranon osteotomy can be performed for severe comminution or additional exposure. The "pearl" is fixation and early motion to make rehabilitation more effective.[10]

Supracondylar Fracture

Incompletely displaced supracondylar fractures may have the same clinical appearance as fractures of the lateral condylar physis or avulsion of the medial epicondyle. Careful palpation of the bony landmarks about the elbow will pinpoint the area of maximum tenderness and will help in making the diagnosis.

Minimally displaced supracondylar fractures may be difficult to diagnose on plain anteroposterior and lateral radiographs. Signs of a supracondylar fracture on a true lateral view include displacement of the anterior fat pad and posterior displacement of the capitellum relative to the anterior humeral line.[2,7,12] If a supracondylar fracture is suspected but is not visible on routine views, oblique views may be helpful.[7]

Treatment

Generally accepted treatment guidelines are based on the classification of Gartland:[13] type I, nondisplaced; type II, displaced with some cortical contact; and type III, completely displaced. Type I (nondisplaced) fractures are treated with posterior plaster splinting with a collar and a cuff for 2 to 3 weeks. Type II fractures must be evaluated carefully to determine the position of the fracture fragments. If the fragments are in an acceptable alignment on anteroposterior and lateral radiographs, posterior splint immobilization may be appropriate. Excessive angulation, especially in "medial impacted" type II varus injuries, is an indication for closed reduction and percutaneous pinning (Fig. 4). Treatment options for type III injuries include reduction and splinting, skin or skeletal traction, closed reduction and percutaneous pinning, and open reduction. Although each of these options has advantages and disadvantages, the currently recommended treatment for type III injuries is closed reduction and percutaneous pinning, if acceptable closed reduction can be obtained with the patient anesthesized.[14-20] Skeletal traction is used rarely, but it may be helpful in certain situations, for example, when comminution is significant or when reduction and percutaneous pinning are not technically possible.[7,21-23]

Open reduction is indicated for open fractures that require irrigation and debridement and for fractures that cannot be adequately reduced by closed methods. Most fractures with posteromedial or posterolateral displacement of the distal fragment can be reduced through an anterior incision because the soft-tissue dissection has been completed by the fracture itself. After open reduction, fixation can be accomplished with percutaneous medial and lateral crossed K-wires or two lateral wires.

A special problem is the "flexion" supracondylar fracture, which accounts for approximately 2% of all supracondylar fractures.[7,16] If the fracture is in good position, splinting with a collar and cuff for 3 weeks is appropriate. If the fracture is in excessive flexion, reduction and percutaneous pinning are recommended. The difficulty of obtaining a satisfactory closed reduction of these fractures has been noted by several authors,[7,24-26] and open reduction of completely displaced flexion supracondylar fractures frequently is required (Fig. 5).

Pearls

Techniques for closed reduction and percutaneous pinning have been well-described in the literature, but some technical points should be considered.

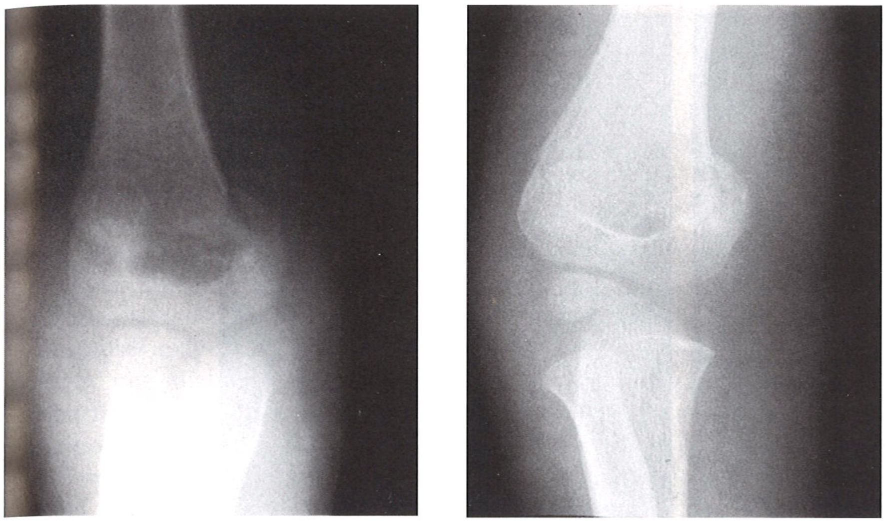

Fig. 4 **Left,** Type II "medially-impacted" supracondylar fracture of the right elbow in a 6-year-old child. **Right,** Three days after injury, medial collapse into varus alignment required manipulation and pinning.

Fig. 5 Flexion supracondylar fracture in a 9-year-old boy. Note anterior displacement and rotation of the distal fragment on the lateral radiograph. Open reduction and internal fixation was required because closed reduction was not acceptable.

General anesthesia should be used, and reduction is done as an emergency procedure, to delay continued edema about the elbow.

Image intensification can be used to evaluate reduction and assist in placement of the pins.[27]

Pin size should be selected carefully. For children younger than 5 or 6 years of age, a 0.062-in smooth K-wire usually is used; for children older than 6 years of age, a 5⁄64-in wire is appropriate.

The elbow is reduced by longitudinal traction with counter-traction, correction of the medial and lateral displacement, and flexion of the elbow to reduce the extension injury.

After the fracture is reduced, fixation can be obtained with either crossed K-wires (Fig. 6, *left*) or two lateral pins (Fig. 6, *right*). Although crossed wires are more stable mechanically, either technique is acceptable. What is important is that the fracture reduction is stable and in acceptable position before fixation. The more stable the reduction, the more likely two lateral pins will be acceptable. For unstable fractures, crossed medial and lateral K-wires are preferred.

Leaving the wires or pins protruding from the skin and bending them 90° makes removal easier. Removal usually is done as an outpatient procedure approximately 3 weeks after injury. Postoperative immobilization should include a well-padded posterior plaster splint and a collar-and-cuff sling.

Complications

Ulnar Nerve Injury When medial and lateral crossed K-wires are used for fixation, special care must be taken to avoid injury to the ulnar nerve when the medial pin is inserted.[28,29] If necessary, a small 1- to 2-cm incision can be made medially to allow palpation of the medial epicondyle to insure that the medial pin enters at this point. If the pin is distal to the medial epicondyle on image intensification or radiograph, it may pierce the ulnar nerve. For this reason, the ulnar groove should be avoided when the medial wire is inserted.

Brachial Artery Injury Injuries to the brachial artery, although rare, are the most serious complication of supracondylar fractures.[30,31] In a child with a supracondylar humeral fracture, a pink, viable hand with no radial or ulnar pulses must be distinguished from a

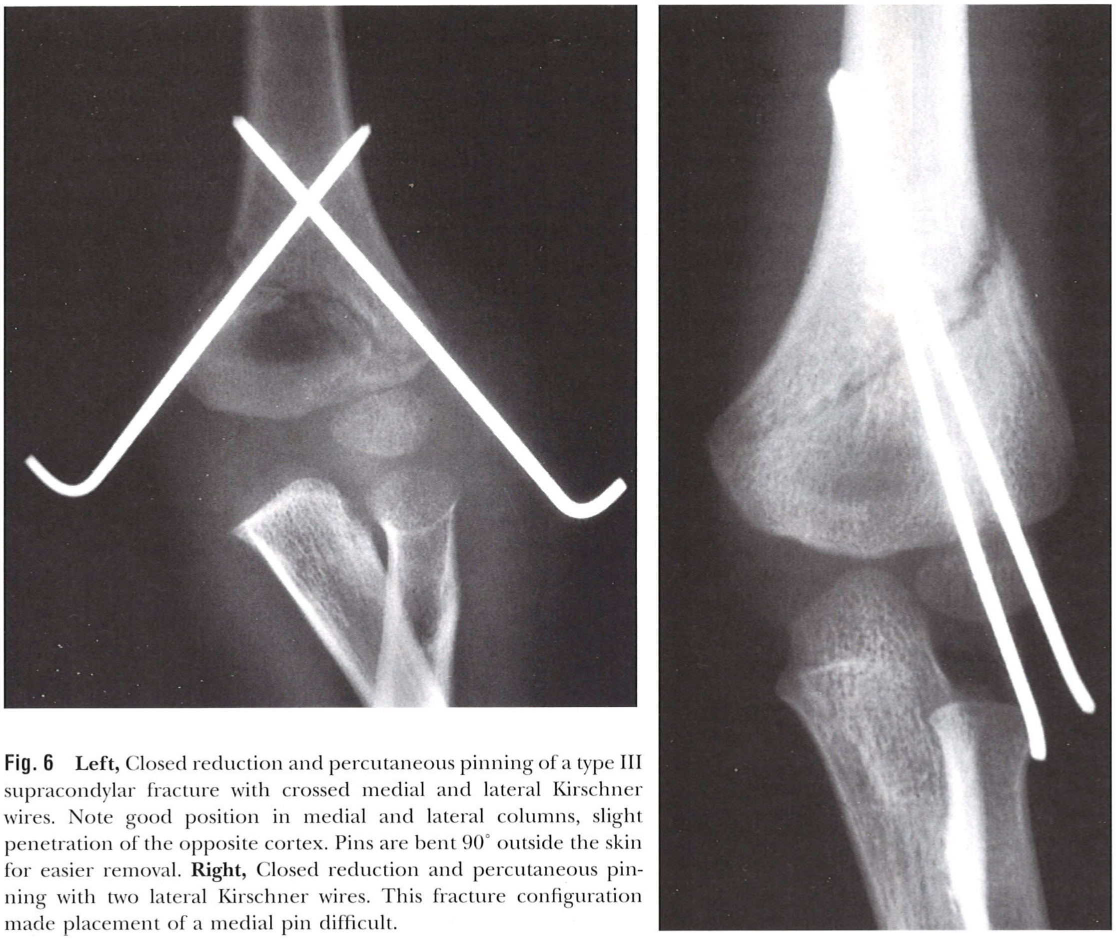

Fig. 6 **Left,** Closed reduction and percutaneous pinning of a type III supracondylar fracture with crossed medial and lateral Kirschner wires. Note good position in medial and lateral columns, slight penetration of the opposite cortex. Pins are bent 90° outside the skin for easier removal. **Right,** Closed reduction and percutaneous pinning with two lateral Kirschner wires. This fracture configuration made placement of a medial pin difficult.

pale, nonviable hand, which is an orthopaedic emergency. Reported injuries to the brachial artery include arterial spasm, laceration, "kinking" by soft tissues, and intimal tear with thrombus formation.

After closed reduction, if pulses are not palpable but the child has a pink, apparently viable hand with good capillary refill and pulses that can be detected by Doppler evaluation, observation is appropriate. If pulses cannot be detected by physical examination or Doppler evaluation, and if the hand appears pale and nonviable, brachial artery exploration is recommended (Fig. 7). In isolated elbow injuries, an arteriogram is not absolutely necessary because the site of the injury is known. If an arteriogram is requested it should be obtained in the operating room rather than in the radiology department to avoid delay in treatment of the arterial injury. Recently, the necessity of obtaining an arteriogram has been questioned when exploration is already planned for a suspected arterial injury.[31]

Findings at arterial exploration include laceration, thrombus formation, and spasm. The pathology dictates treatment, which may range from incision and removal of a thrombus to segmental removal of a portion of the artery and vein grafting. In type III fractures with arterial injuries, the fracture should be reduced and percutaneously pinned as quickly as pos-

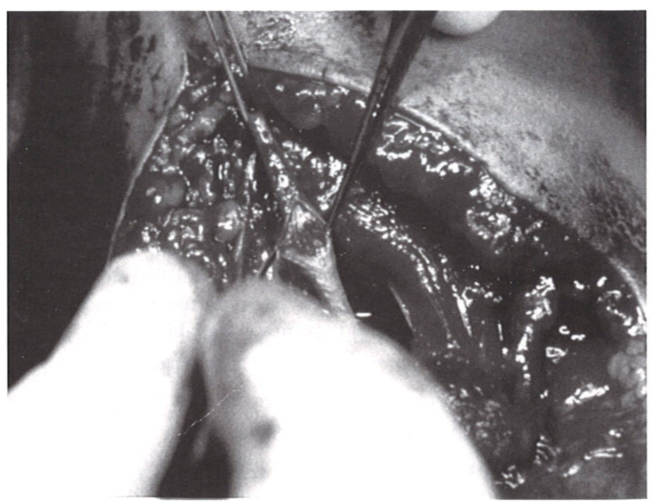

Fig. 7 Arterial exploration identified an intimal tear with thrombus formation in this child with a supracondylar fracture and a nonviable hand (no palpable or Doppler pulse).

sible to allow extension of the elbow for anterior arterial exploration without fear of instability of the fracture.

Volkmann's Ischemic Contracture and Compartment Syndrome Because of an increasing awareness of the association of compartment syndrome with supracondylar humeral fractures, the incidence of this complication is decreasing. Close observation is recommended for at least 24 hours after treatment of acute fractures. The most important clinical finding is pain with passive motion of the digits, because good capillary refill and even palpable pulses may be present in a child with ischemic forearm musculature or compartment syndrome. If compartment syndrome is suspected, the splint should be removed to allow careful inspection of the elbow and forearm. If the forearm compartment appears normal and pain is immediately relieved, continued observation may be appropriate; however, if compartment syndrome is suspected, compartment pressures may be measured. If pressures are more than 30 mm/Hg, or, more important, if clinical examination suggests compartment syndrome, elbow and forearm fasciotomies are indicated.

Cubitus Varus Cubitus varus has been estimated to occur after approximately 10% of supracondylar humeral fractures.[7,32-34] Although osteonecrosis of the trochlea and growth arrest of the medial aspect of the distal humeral physis rarely have been reported as causes of cubitus varus deformities, most such deformities are caused by malunion of the fracture. Cubitus varus deformities are most frequent after type II impacted varus fractures that heal in varus alignment and after type II or III injuries treated with closed reduction and splinting that displace into a varus position (Fig.

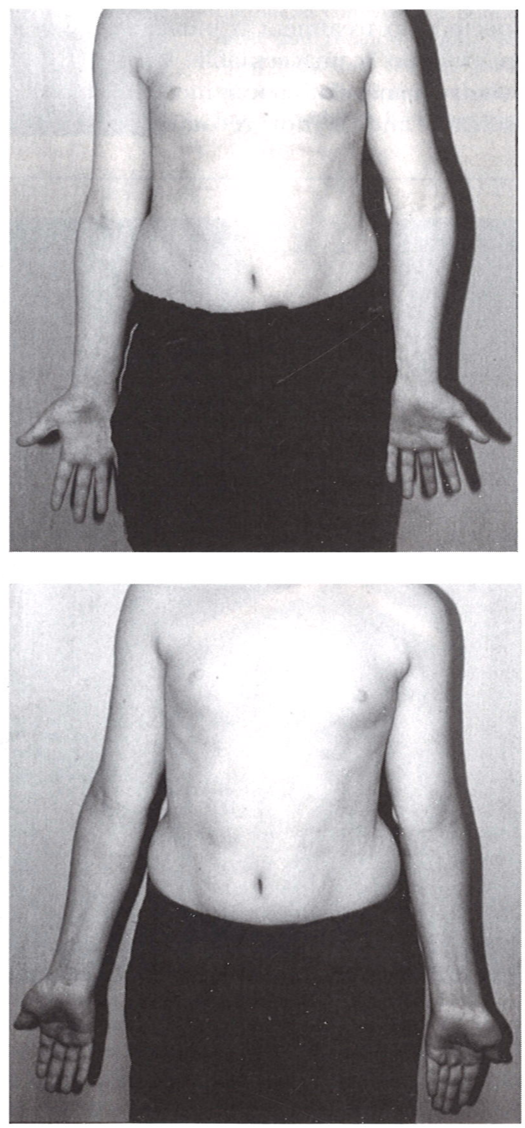

Fig. 8 **Top left and right,** Type III supracondylar fracture in a 9-year-old boy was treated with closed reduction and immobilization in a long-arm splint for 3 weeks. Note cubitus varus and changes in Baumann's angle and humeral-ulnar angle on radiograph. **Bottom left and right,** After lateral closing wedge supracondylar osteotomy and oblique screw fixation.

8). Finally, cubitus varus can occur in fractures that are pinned in varus after closed or open reduction.[26]

Most children with cubitus varus deformities have little functional impairment, but the cosmetic appearance may be unacceptable to the patient or parents. Correction can be obtained with humeral osteotomy, preferably a lateral closing wedge osteotomy of the supracondylar region (Fig. 8, *bottom left*).[32,33,35-37] Care must be taken not to make the osteotomy too far proximally in the diaphyseal bone rather than in the metaphyseal region. As noted by Wilkins,[7] if pins are used for fixation of the osteotomy, the position of the ulnar nerve should be checked with the elbow flexed as well as extended after the pins are inserted. Rigid screw fixation may be used to allow early motion and insure stability of the osteotomy (Fig. 8, *bottom right*).

Late Displacement Occasionally, after closed reduction and splinting or pinning, displacement may occur 7 to 21 days after injury (Fig. 9).[2,7,26,38] If the fracture is in acceptable position, and adequate remodeling can be expected, no treatment is indicated. Even if the fracture position is unacceptable, late open reduction or excessive manipulation may increase the risk of myositis ossificans and is not recommended. Humeral osteotomy can be performed for correction of severe cubitus varus deformity.[31]

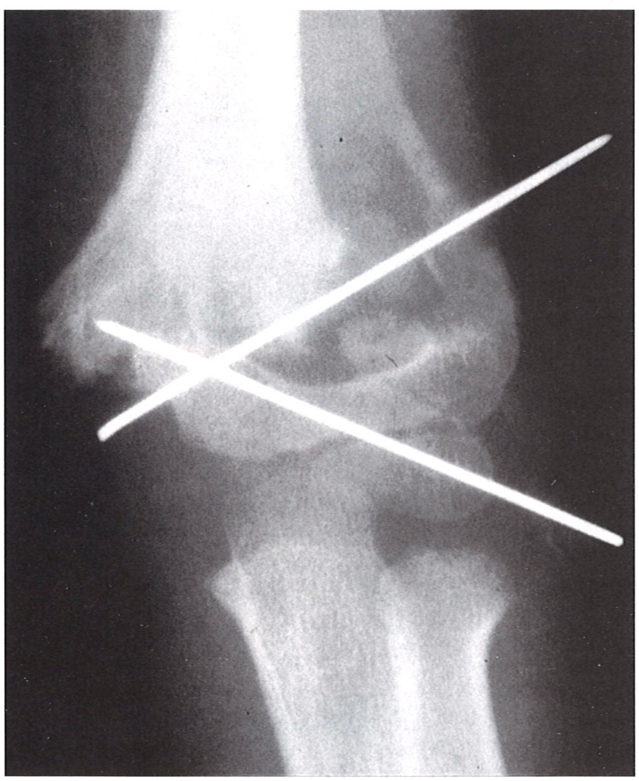

Fig. 9 Late displacement of a type III supracondylar fracture in a 10-year-old girl 2 weeks after closed reduction and percutaneous pinning. Note that the medial pin passes through the fracture site, but the lateral pin is too distal. The fracture displaced laterally 30%, but the carrying angle is acceptable and fracture was allowed to heal in this position.

Myositis Ossificans Myositis ossificans has been reported occasionally in children who have severe soft-tissue injuries or who have participated in an aggressive passive range-of-motion exercise program after fracture treatment. In most children, the bone formation resolves spontaneously over 12 to 24 months. If it impairs function, the heterotopic bone can be excised after it has matured.

Fractures of the Lateral Humeral Condyle

Approximately 15% of fractures about the elbow are fractures of the lateral humeral condyle.[7,39] These fractures may appear to be Salter-Harris type II injuries of the distal humeral physis with lateral metaphyseal fragments. Because the trochlea is not ossified in children younger than 8 years of age, it is also difficult to differentiate this injury from a lateral condylar fracture with extension into the joint.[40-42] Lateral humeral condylar fractures are classified as type I, nondisplaced or displaced less than 2 mm; type II, moderately (2 to 4 mm) displaced; or type III, completely displaced.[41]

The standard treatment of types II and III fractures is open reduction and internal fixation (Fig. 10).[39,43-47] The treatment of type I fractures is more controversial. Several authors have reported late displacement of approximately 10% of type I fractures, with an increased risk of nonunion. Splinting generally is recommended for type I fractures, with close follow-up until union occurs, but some authors recommend percutaneous pinning of nondisplaced or minimally displaced (type I or type II) lateral humeral condylar fractures.[45] If splinting is used, weekly follow-up until radiographic union is essential. Late displacement can be treated as an early nonunion.

Pearls

Open reduction may be performed through a lateral incision, with dissection through the interval between the brachioradialis and triceps muscles.

The soft tissue attached to the posterior aspect of the lateral condyle should be left intact because it is the primary source of blood supply to the condyle.

Clots in the joint should be gently suctioned out and removed with a hemostat, without aggressive debridement of the metaphyseal fragment.

Fracture reduction can be held with a towel clip or bone clamp while the pins are inserted.

In children younger than 5 or 6 years of age, two 0.062-in K-wires are inserted from lateral to medial to penetrate the medial cortex. In children older than 6 years of age, two 5/64-in K-wires are used.

The wound is closed in layers and a suction drain is left in place for 24 hours.

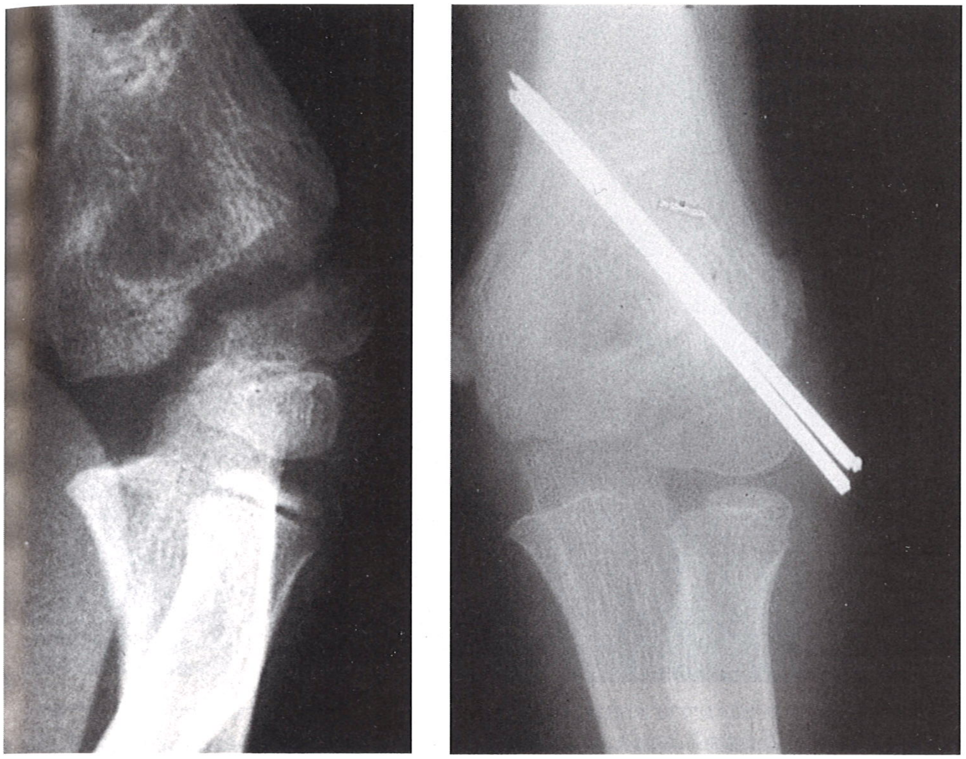

Fig. 10 **Left,** Type III fracture of the lateral condyle with displacement and rotation. **Right,** After open reduction through lateral brachioradialis-triceps interval and fixation with two Kirschner wires.

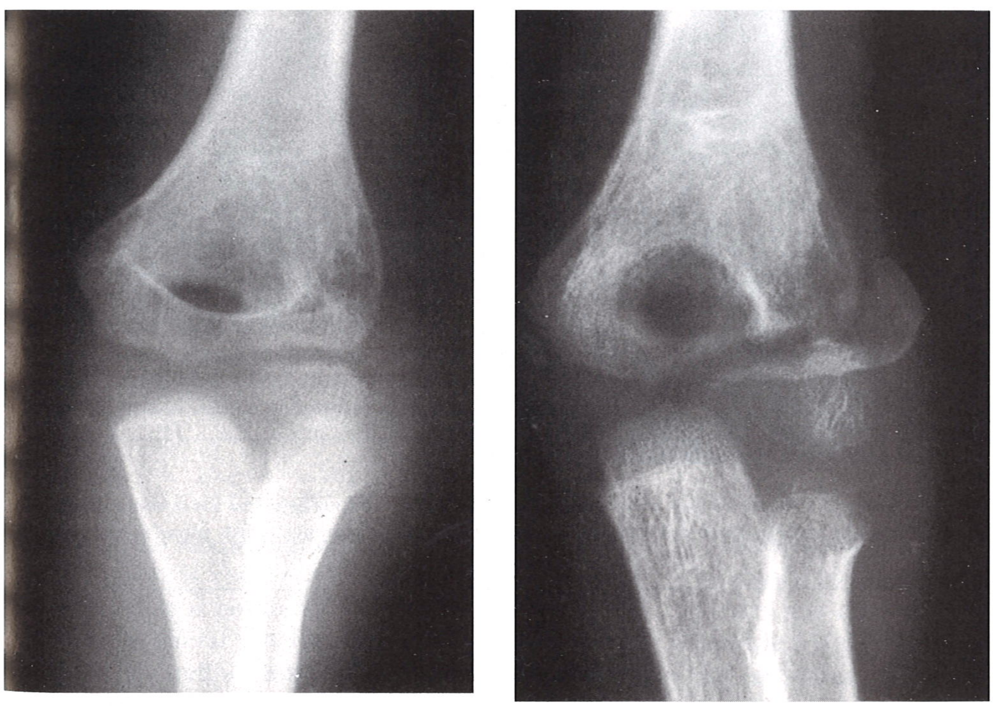

Fig. 11 **Left,** Nondisplaced type I fracture of the lateral condyle in a 6-year-old boy treated with immobilization in a long-arm cast. **Right,** Four weeks after injury, lateral displacement and nonunion of the lateral humeral condyle.

Children with lateral humeral condylar fractures should begin motion early, especially after open reduction and internal fixation, approximately 2 weeks after surgery.

Pins are left buried beneath the skin. They may be removed with the use of local or general anesthesia approximately 3 to 5 weeks after injury when radiographic union is certain.

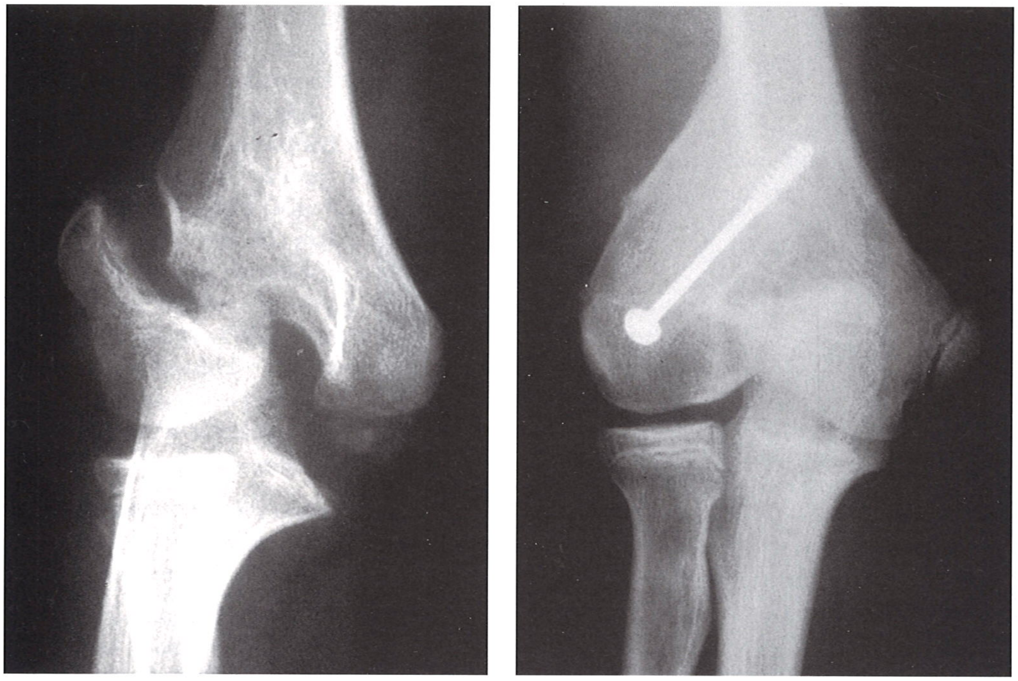

Fig. 12 **Left,** Nonunion of the lateral condyle in a 7-year-old boy. At 5 years of age, he was treated with a sling for what was believed to be an "elbow sprain". Note the large metaphyseal fragment, open physis, and 1-cm joint displacement. **Right,** Postoperative radiograph showing late reconstruction, screw fixation, bone grafting.

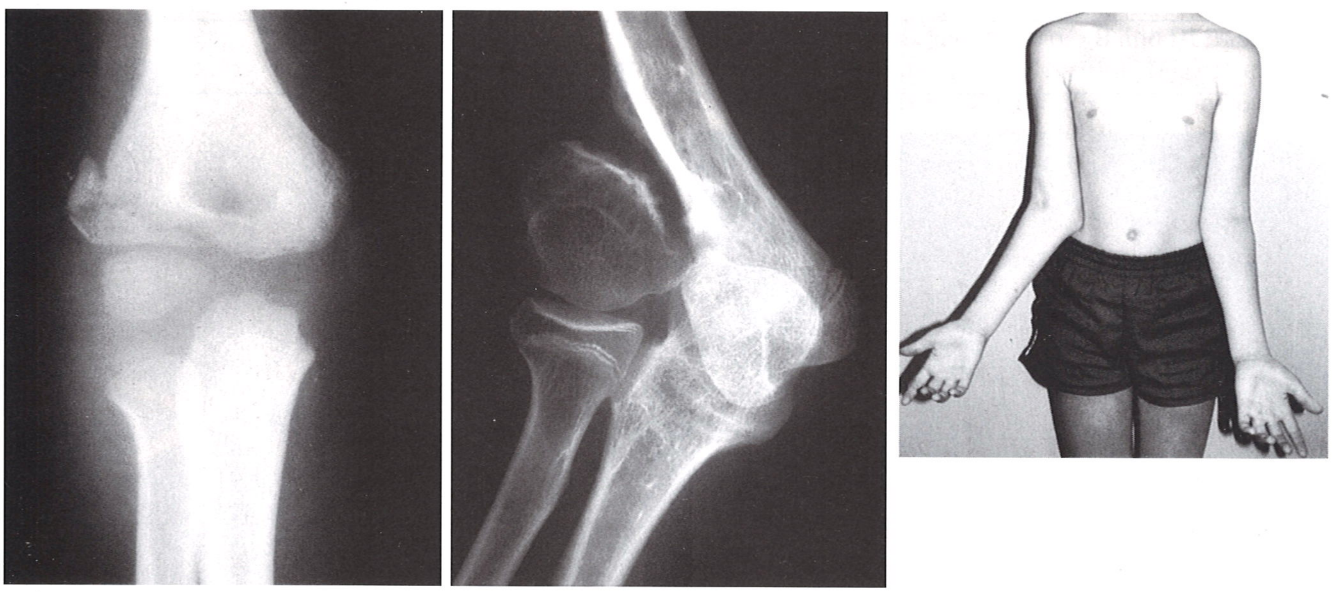

Fig. 13 **Left,** Type II fracture of the lateral condyle in a 6-year-old boy treated with immobilization in a long-arm cast for 3 weeks. **Center,** At age 13 years, lateral condylar fracture is ununited and cubitus varus deformity is 45°. **Right,** Clinical appearance. Tardy ulnar nerve palsy was treated by anterior transposition of the ulnar nerve.

Complications

Nonunion and Cubitus Valgus Deformity Nonunion can occur in fractures with late displacement and in unrecognized, untreated fractures (Fig. 11).[48-51] Treatment of nonunions of lateral condylar fractures depends on the position of the nonunion. Nonunions in good position (within 1 cm of the joint and with a large metaphyseal fragment), in a child with a viable, growing lateral condylar physis, may be treated with late reconstruction, but attention to detail is mandatory. The reconstructive technique is considerably different from that used for open reduction and intra-articular alignment of an acute fracture. A lateral incision is used, but no dissection is made into the articular

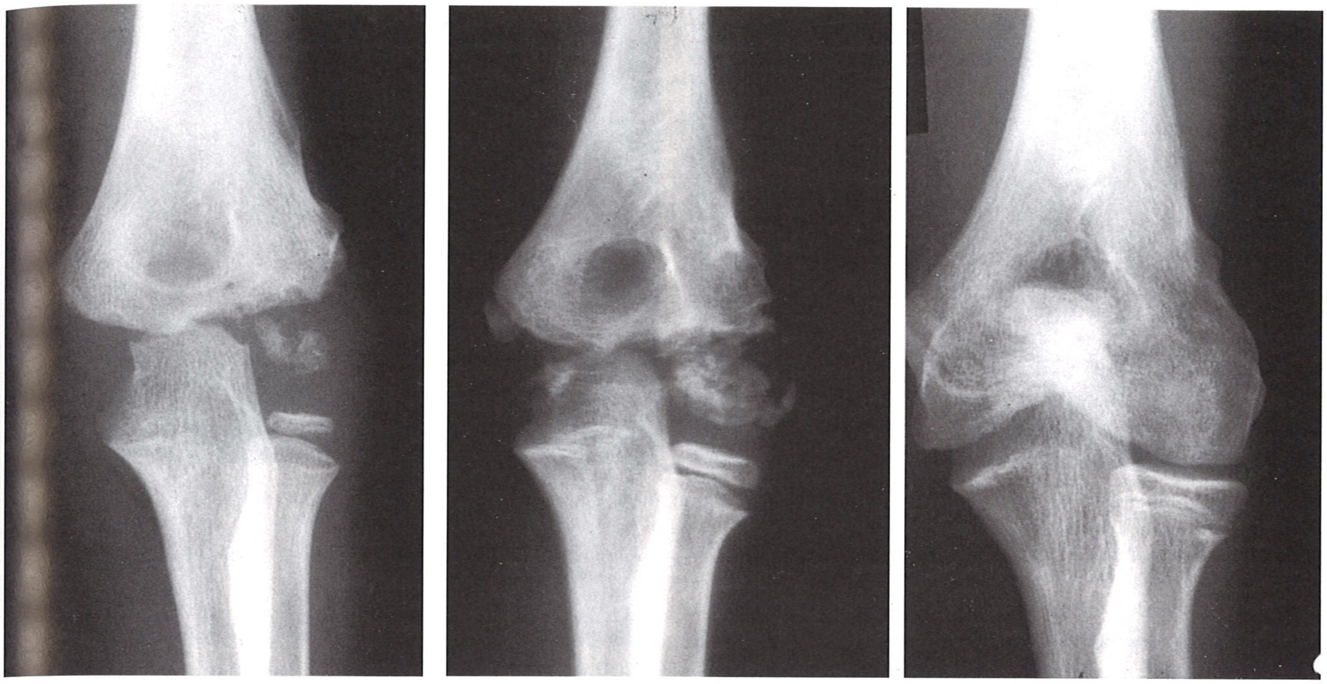

Fig. 14 **Left,** Six months after open reduction and internal fixation of fracture of the lateral condyle in a 7-year-old boy. Note osteonecrosis of the lateral condyle and the irregular metaphysis and physeal region. **Center,** At age 9 years, lateral condyle is beginning to remodel and trochlea is beginning to ossify medially. **Right,** At age 15 years, lateral condyle has reossified and remodeled. "Fishtail" appearance of the distal humerus is caused by central growth arrest. Patient had a good functional result with satisfactory range of motion.

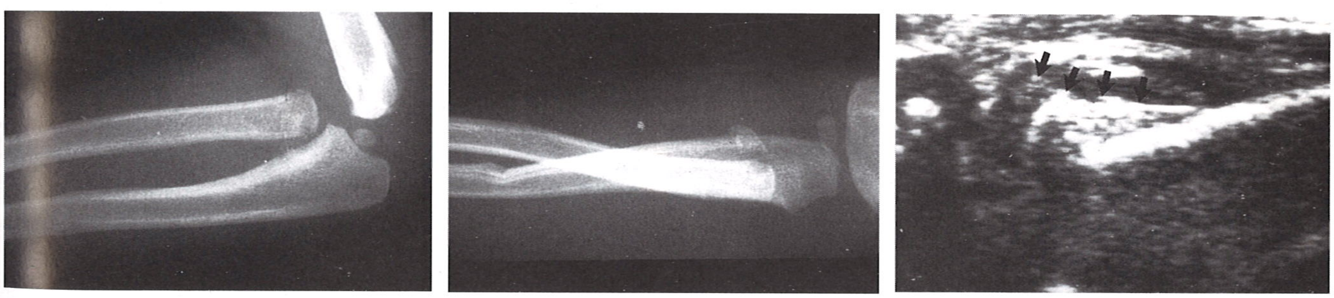

Fig. 15 **Left** and **center,** On plain radiographs, this fracture in an 18-month-old child could be confused with a Monteggia lesion. **Right,** Ultrasound demonstrates normal articulation of the radial head with the capitellum, confirming the diagnosis of radial head fracture without dislocation. Arrows outline periosteum and radial head.

surface of the elbow joint or beyond the fracture. The fibrous tissue is resected at the nonunion, and the lateral condyle is positioned against fresh metaphyseal bone of the lateral distal humerus. A screw is inserted for fixation, and a bone graft is placed along the posterolateral aspect of the fracture (Fig. 12). For nonunions not in good position, or nonunions of long duration, observation is the appropriate treatment. Anterior transposition of the ulnar nerve should be performed if early symptoms of tardy ulnar nerve palsy appear (Fig. 13).

Osteonecrosis Osteonecrosis of the lateral condyle may be caused by the injury itself or by excessive dissection of the soft tissues along the posterior aspect of the condyle.[7] If the fracture unites, the osteonecrosis usually reossifies with time, much like the process in Legg-Perthes disease about the hip (Fig. 14).

Physeal Growth Arrest Growth arrest in the area where the fracture crosses the distal humeral physis is a common radiographic finding after lateral humeral condylar fractures. The "fish-tail" appearance of the

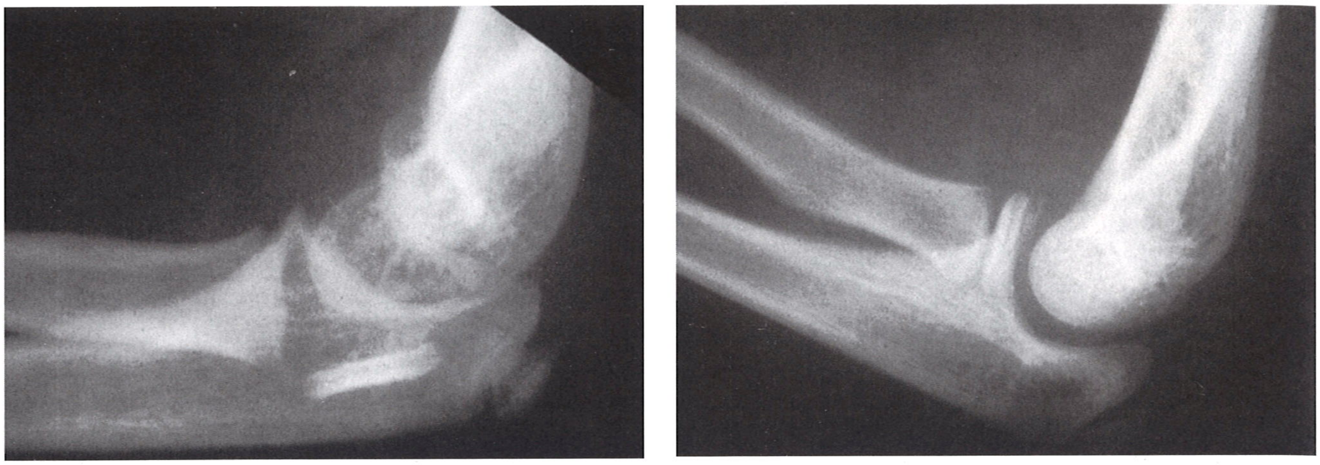

Fig. 16 **Left,** After closed reduction of this posterior elbow dislocation, the radial head was completely displaced. **Right,** After attempted closed reduction, the radial head was inverted 180°, and open reduction was required.

distal humerus on radiographs is interesting, but rarely is it of any clinical consequence.[2,7]

Fractures of the Radial Head

Fractures of the radial head usually occur in the radial neck or metaphysis, at the insertion of the annular ligament. Most frequently, these are Salter-Harris types I and II fractures.

Especially in young children, injuries around the radial head may be difficult to diagnose. Fractures of the cartilaginous epiphysis in young children may mimic Monteggia fracture-dislocations (Fig. 15).[52,53] The radial diaphysis and metaphysis are displaced so that the longitudinal axis of the bone does not cross the capitellum, while the cartilaginous radial head remains located relative to the capitellum. After closed reduction of an elbow dislocation with an associated radial head fracture, ultrasound or MRI may be necessary to determine the location of the radial head. An inverted Salter-Harris type I fracture of the radial head may appear as a subtle malposition after closed reduction (Fig. 16). The diagnosis of this injury is based on apparent physeal widening, an abnormal joint space, and irregular ossification. It is an absolute indication for open reduction and internal fixation.

Most radial head and neck fractures can be treated with closed reduction and, depending on the patient's age, a less-than-perfect reduction (less than 4 mm of translation and 30° to 60° of angulation) is acceptable.[2,7,54,55] Closed reduction of displaced fractures may be attempted by applying direct thumb pressure over the radial head with the forearm in supination. Varying the position of forearm rotation, especially into supination, will make reduction easier, and position should be confirmed by radiographs. Closed reduction of impacted or totally displaced fractures may be impossible because there is no "handle" on the small radial head. A K-wire can be used as a lever for percutaneously manipulating the fracture fragments.

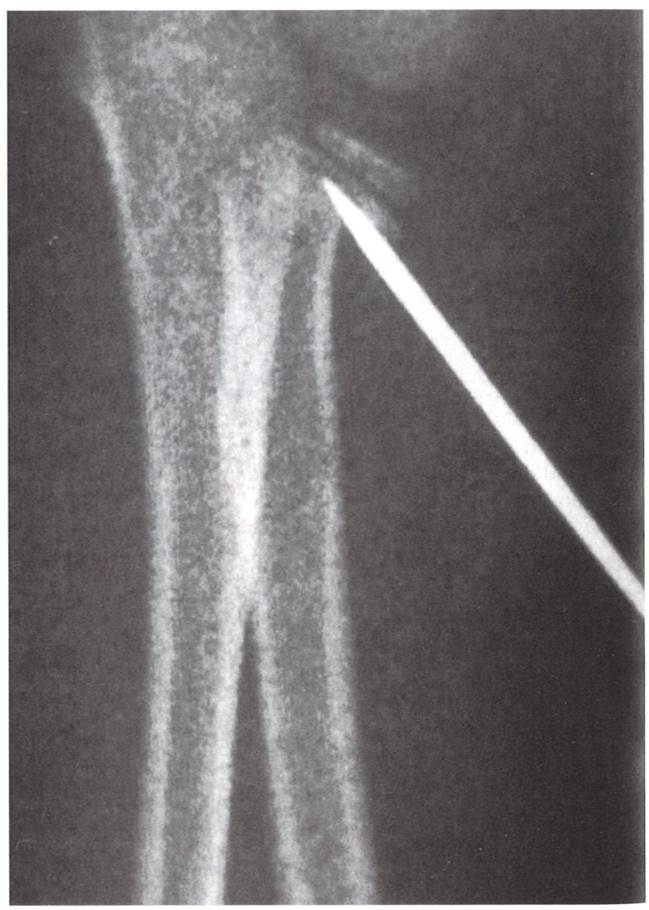

Fig. 17 A K-wire is inserted percutaneously and is used as a "lever" for reduction of the radial head fracture.

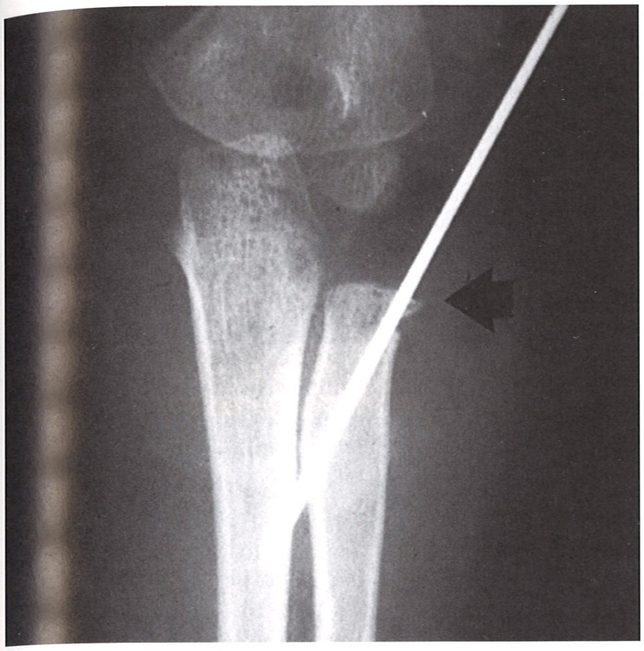

Fig. 18 After open reduction, a single oblique K-wire is sufficient for fixation.

The wire is inserted percutaneously, from distal to proximal (Fig. 17) and is used to gently push the proximal radial fragment under image intensifier control. This may allow acceptable reduction of the radial head without open reduction. Percutaneous internal fixation of the radial head fragment rarely is necessary if this maneuver is successful.

If the displaced radial head fracture cannot be reduced closed or with the percutaneous K-wire technique, open reduction is indicated.[52,56-59] As much of the annular ligament as possible and all of the soft-tissue attachments to the radial head should be preserved. These fractures usually are unstable after reduction and require internal fixation. A single 0.062-in or 5/64-in K-wire may be inserted obliquely across the fracture site, beginning at the articular margin of the radial head and crossing through the opposite cortex (Fig. 18); a long-arm cast is used postoperatively. Transcapitellar fixation is unnecessary and is contraindicated because of the risk of pin breakage (Fig. 19). Whether osteonecrosis and loss of motion after severe radial fractures are caused by the extent of the injury or by the open reduction remains controversial. With the lever technique of reduction, we have found that open reduction is rarely necessary. If open reduction is performed, minimal dissection of soft tissues and the use of a single oblique K-wire for fixation keep operative trauma to a minimum. We encourage early pin removal and early motion, by 2 weeks after surgery.

If the radial head is totally displaced from the joint and all soft tissues are detached (Fig. 20), the avascular radial head should be replaced and fixed with an oblique K-wire. Key,[60] in 1946, reported normal growth after replacement of the radial head in one child, but

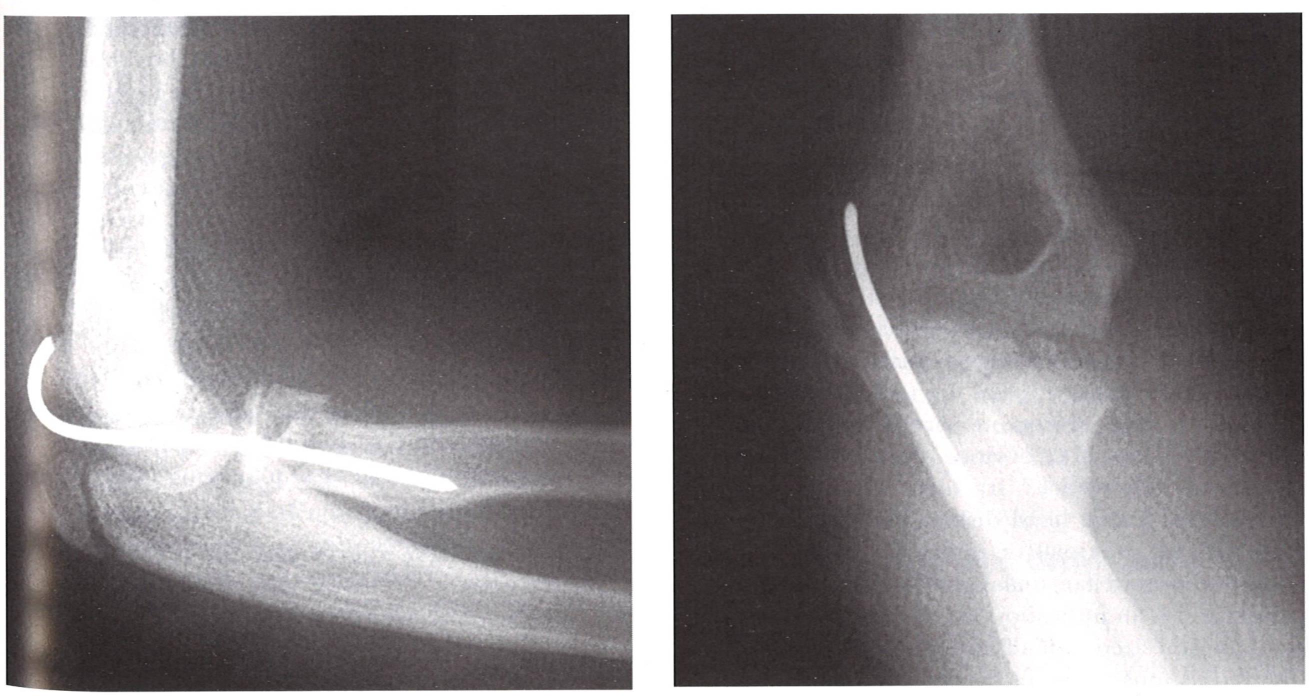

Fig. 19 A transcapitellar wire should be avoided. Note the bent pin in this patient.

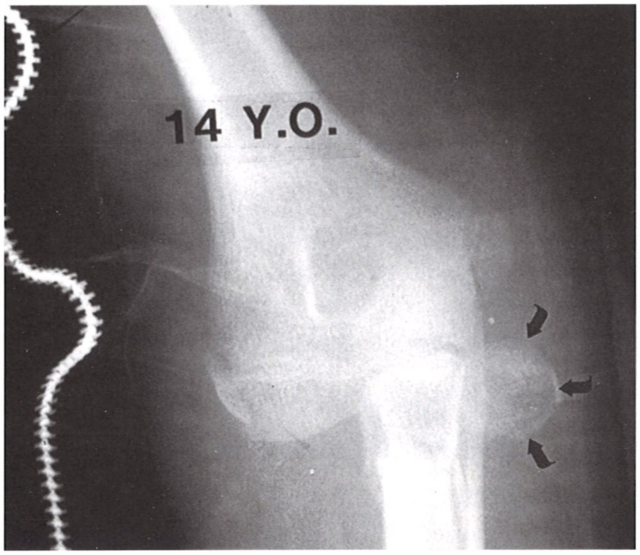

Fig. 20 A radial head that is totally displaced from the radiocapitellar articulation (arrow) should be replaced and internally fixed rather than removed.

this has not been noted by other authors. Posttraumatic resection of the radial head in children has unacceptably high risks of progressive elbow valgus deformity, proximal migration of the radius, and wrist pain. Even if osteonecrosis and growth arrest occur after replacement of the radial head, excision is not indicated. The totally detached radial head is an ideal biologic spacer, with articular cartilage and some potential for healing. Pain caused by radial head deformity may require surgical excision of the radial head, but this should be delayed until skeletal maturity.

Monteggia Fracture-Dislocations

A Monteggia[61] fracture is a combination of radial head dislocation and ulnar fracture.[62,63] These injuries are classified as type 1, extension type with anterior radial head dislocation; type 2, flexion type with posterior radial head dislocation; type 3, with lateral head dislocation; and type 4, with an associated fracture of the radial shaft. Most Monteggia fractures in children are type 1. Missed diagnosis of the radial head dislocation is the most frequent problem with these injuries.[64-66] Often the obvious fracture leads to a diagnosis of "night-stick" fracture or isolated ulnar shaft fracture. Radial head dislocation should be suspected with all proximal or midshaft ulnar fractures. "Mild" radiocapitellar malalignment should not be accepted and is an indication for examination with the patient anesthesized. On all radiographs, the long axis of the radius must transect the capitellum. The radiocapitellar articulation should be carefully scrutinized on anteroposterior, lateral, and oblique views before the diagnosis of isolated ulnar fracture is made.

Treatment

The key to treatment of Monteggia injuries is maintenance of ulnar length and alignment. The radial head usually can be reduced easily if the ulna is aligned and "out to length." Closed reduction of the ulnar fracture may be sufficient if the fracture configuration is stable and anatomically aligned.[67] After reduction of the type 1 Monteggia fracture, the arm is immobilized with the elbow in 110° of flexion and 120° of supination.

If the ulnar fracture is unstable, with shortening and angulation, closed reduction is never satisfactory, and fixation with an intramedullary rod or a plate-and-screw device is mandatory. Because of the remodeling potential of children, acceptance of "reasonable" ulnar alignment may be tempting. However, progressive ulnar shortening and angulation can occur insidiously, followed by radial head dislocation (Fig. 21). Intramedullary fixation of the ulna is simple and can be done with closed technique by inserting a single appropriately sized K-wire through the olecranon apophysis under fluoroscopic guidance. Intramedullary fixation of very oblique unstable ulnar fractures may not prevent shortening and radial head dislocation (Fig. 22), and use of a four-hole 3.5 mm AO plate with interfragmentary screw fixation (Fig. 23) is preferable.

Complications

Compartment Syndrome Although not as frequent as after supracondylar fractures, compartment syndrome may rarely occur after Monteggia fractures. If compartment syndrome or vascular compromise is questionable, internal fixation of the ulnar fracture makes management easier. If the cast must be bivalved or removed, internal fixation decreases the need for tight external support. Although the elbow is immobilized in 120° of flexion after most type 1 Monteggia fractures, if impending compartment syndrome or vascular insufficiency is suspected, the elbow should be extended less than 90°. Management of the compartment syndrome or vascular compromise obviously takes priority over management of the radial head dislocation. A second closed manipulation of the radial head may be necessary after the vascular problems are resolved. Determining the range of stability of the radial head at the time of closed reduction is helpful in determining the length of immobilization or in managing postoperative complications.

Nerve injuries Nerve injuries also may occur with Monteggia fractures.[2,7,68,69] Most commonly, the posterior interosseous nerve, which crosses anterior to the radial head, is injured. If the nerve is not functioning at initial examination, but anatomic reduction can be obtained, exploration of the nerve is not indicated. If closed reduction cannot be obtained, the radial head probably has button-holed through the anterior capsule and

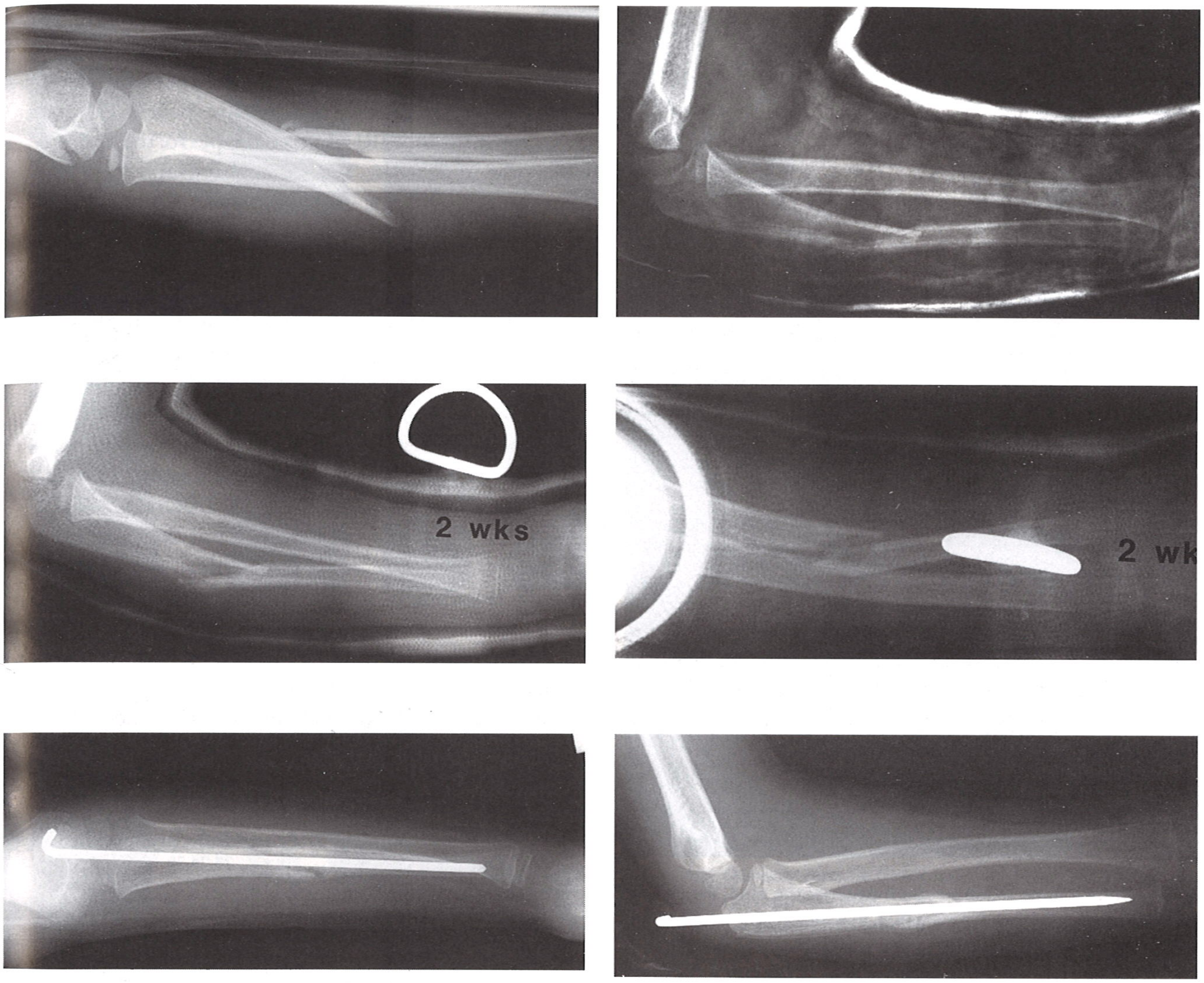

Fig. 21 **Top,** In this Monteggia injury, closed reduction obtained good radial head alignment, but marginal alignment of the ulna. **Center,** At 2 weeks, the ulna has shortened and angulated further and the radial head has subluxed. **Bottom,** After open reduction and internal fixation of the ulnar and a second closed reduction of the radial head.

torn the annular ligament; the posterior interosseous nerve may be trapped under the radial head. If open reduction is required, the posterior interosseous nerve should be carefully identified and relocated to its normal anatomic position.

Untreated Dislocations The annular ligament usually can be repaired primarily, but untreated radial dislocations often require reconstruction of the annular ligament, using a portion of the triceps (Bell-Tawse[70] procedure).

Late reconstruction of untreated radial head dislocations is somewhat controversial.[64,65,71,72] Kasser and associates have attempted reconstruction in seven patients over the past 15 years, some of whom were totally asymptomatic. Reconstruction usually consisted of ulnar osteotomy and lengthening, open reduction of the radial head, and reconstruction of the annular ligament. Results with this protocol have been mixed: two excellent results with near normal motion but diminished strength, three good results with persistent lack of motion, and two poor results with nerve injuries at the time of surgery. Although late reconstruction seems appropriate for symptomatic chronic Monteggia injuries, its usefulness for asymptomatic patients with almost full motion is questionable because of the frequency of nerve injuries and loss of motion after reconstruction.

Fractures of the Medial Condyle

Fractures of the medial condyle are rare in children.[7,73,74] Because the trochlea does not begin to ossify until about the age of 8 years, this injury may be missed in young children, or it may be confused with an isolated fracture of the medial epicondyle (Fig. 24).[75]

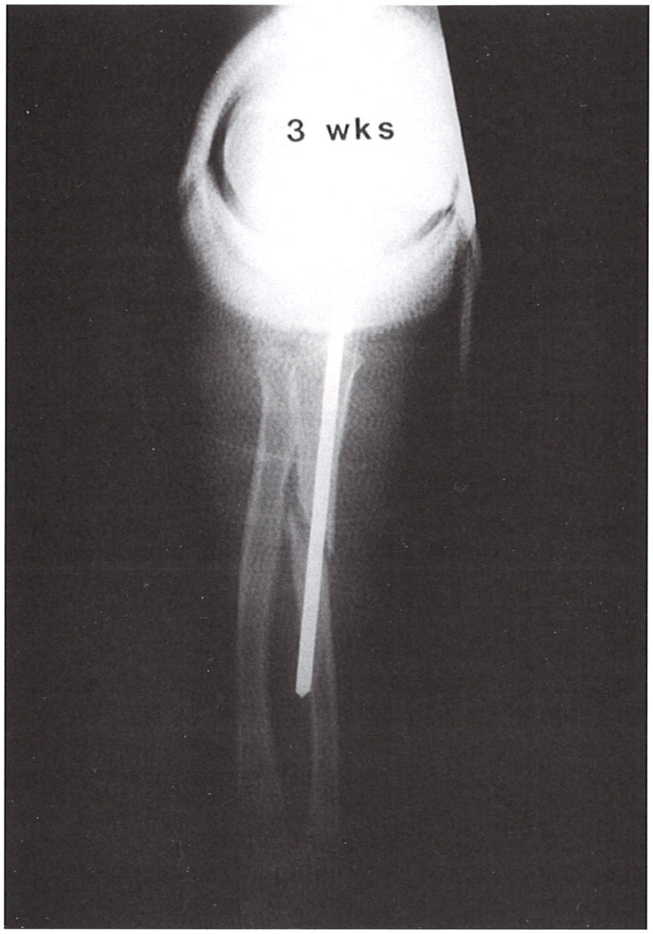

Fig. 22 Despite intramedullary rod fixation of the ulna, shortening and recurrent radial head dislocation may occur in very unstable oblique ulnar fractures.

Medial epicondyle avulsions usually are mild injuries with minimal elbow instability, unless they are associated with an elbow dislocation. If a child has marked medial swelling, ecchymosis, and instability, isolated fracture of the medial epicondyle is less likely, and arthrography or MRI should be performed to determine the diagnosis. Use of arthrography or MRI is especially important in very young children with a suspected intra-articular injury but no radiographic evidence of fracture.

Treatment of medial condylar fractures follows the general principles of treatment of all intra-articular fractures in children. For displaced fractures in young children, open reduction and internal fixation of the fragment are indicated. A medial approach is used, with protection of the ulnar and median nerves and the brachial artery. Care must be taken not to injure the physis or the blood supply to the trochlea. Aggressive dissection should be avoided around the perichondral ring and posterior to the trochlea. K-wire fixation usually is sufficient in the young child.

In adolescents, what appears to be an isolated medial or lateral condylar fracture may be a T-condylar injury that requires open reduction through a posterior approach and rigid internal fixation (Fig. 25). Because 80% of the growth of the humerus occurs proximally, transepiphyseal screws cause little growth inhibition in older children and adolescents.

A long-term problem after medial condylar fractures is osteonecrosis of the trochlea.[73,74,76] Malunion may occur, but accurate diagnosis and treatment minimize the risk of this complication.

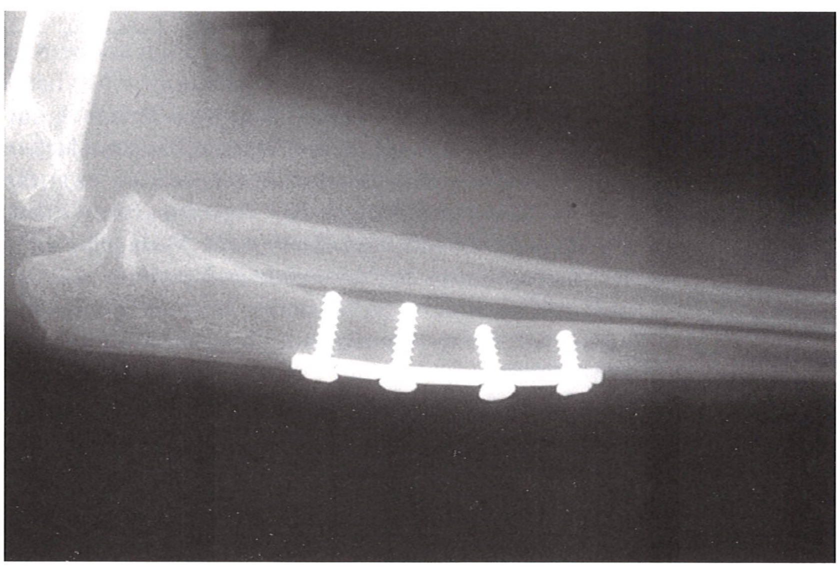

Fig. 23 A small 3.5-mm AO plate with four screws can be used for unstable Monteggia fractures.

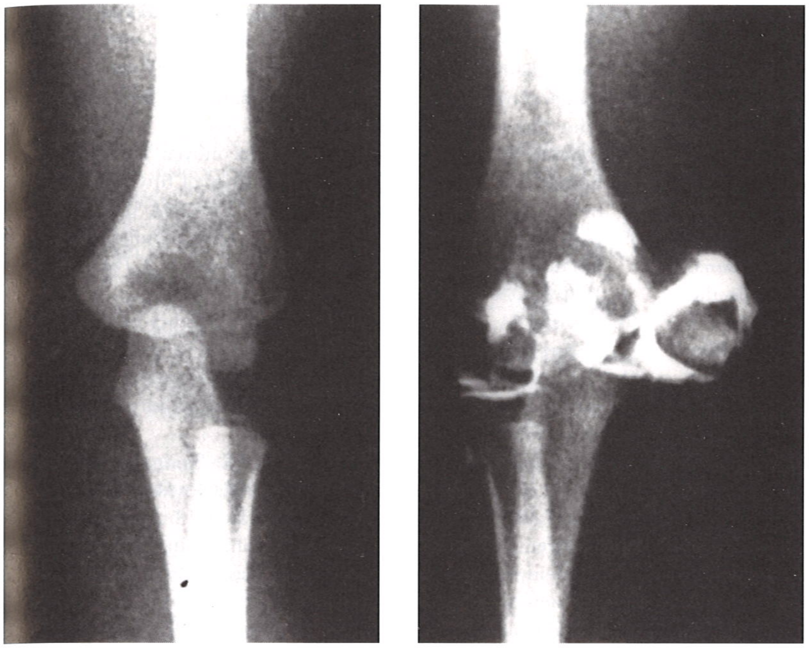

Fig. 24 **Left,** On radiograph this fracture appears to be a small displaced fracture of the medial epicondyle. **Right,** Arthrogram shows fracture of the medial condyle.

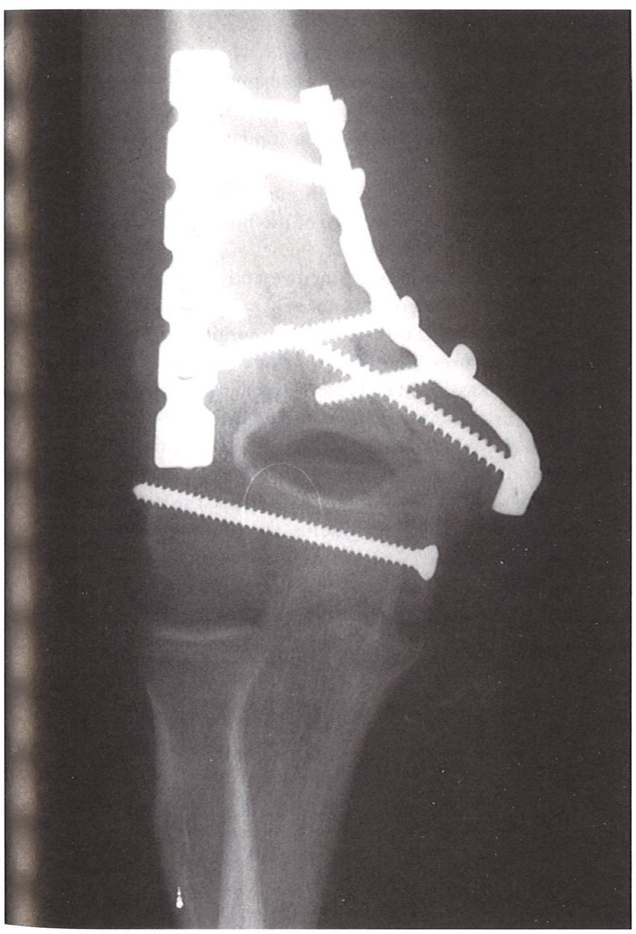

Fig. 25 An intercondylar lag screw and a neutralization plate can be used on fractures of the medial and lateral columns for rigid fixation.

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