Injuries in Baseball, edited by James R. Andrews,
Bertram Zarins, and Kevin E. Wilk,
Lippincott–Raven Publishers, Philadelphia © 1998.

CHAPTER 26

Elbow Injuries

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INTRODUCTION

In the pediatric throwing athlete, elbow injuries are common and can end participation in baseball and alter career plans. Because of the wide range of normal developmental and radiographic variants, to arrive at a diagnosis can be challenging. This chapter will elucidate and clarify the unique aspects of the skeletally immature elbow, its biomechanics, development, radiographic evaluation, and injury patterns.

Biomechanics

The phases of throwing are similar in the mature and immature athlete. The differences in the immature are growth plates, articular surfaces, and lack of muscular development in the upper extremity. During the cocking phase, compressive forces occur in the lateral compartment. The medial humeral epicondyle apophysis can be avulsed by extreme tensile forces. Lateral compressive forces in the growing child can lead to deformities of the radial head and capitellum, which are due to pressure on the articular surfaces and physeal plates and possibly result in a vascular insult to the bone (1,2). Articular surface incongruity, loss of motion, loose fragments of cartilage and bone, and pain can result. Sequential elbow examinations should be performed in order to demonstrate the subtle loss of motion or tenderness. Early diagnosis and treatment usually can prevent permanent impairment of elbow function.

In the immature athlete, the stresses placed on the elbow when throwing a curve ball have been of particularly concern. Side-arm motion pitching has been reported to be three times more likely to develop problems about the elbow than using a more overhand technique (3,4). A study comparing fastball pitching in Little League and at the professional level was performed (5). The results reveal that the Little League athlete had greater forces at the elbow in extension torque, follow through, and a prolonged elbow valgus moment. Repetitive microtraumatic forces are of concern to produce potentially permanent problems as a result of articular surface changes, motion loss, or growth imbalance.

During the acceleration phase, medial ligamentous tension and lateral compressive forces are reduced. Yet as these forces decrease, the extreme pronation of the forearm places the lateral ligaments and their connection to the lateral humeral epicondyle under tension (6). During the follow-through phase, the elbow is in full extension, which produces large stresses on the posterior joint to resist hyperextension. Posteriorly, impingement can occur as the olecranon is forced into its fossa. Fractures of the olecranon do occur in throwing. In the older throwing athlete, the repetitive stress posteriorly may lead to spurring, synovitis, tendonitis, and impingement. Anteriorly, in the follow-through phase, traction spurs and capsular tightness can occur. By understanding the forces that develop in each phase of throwing, injury patterns are more predictable.

GROWTH AND DEVELOPMENT

Understanding the anatomy and the sequence of development in the elbow of the immature athlete is essential to determine the proper diagnoses and treatment of injuries. Just like the area around the elbow in the adult, the young athlete can have injury to the muscles, tendons, ligaments, neurovascular structures, or bones.

In the skeletally immature, the important ulnar collateral ligament (UCL) attaches on the sublime tubercle of the medial ulna, inferiorly and distally to the medial humeral epicondyle (7–9) (Figs. 1A and 1B). Originating proximal

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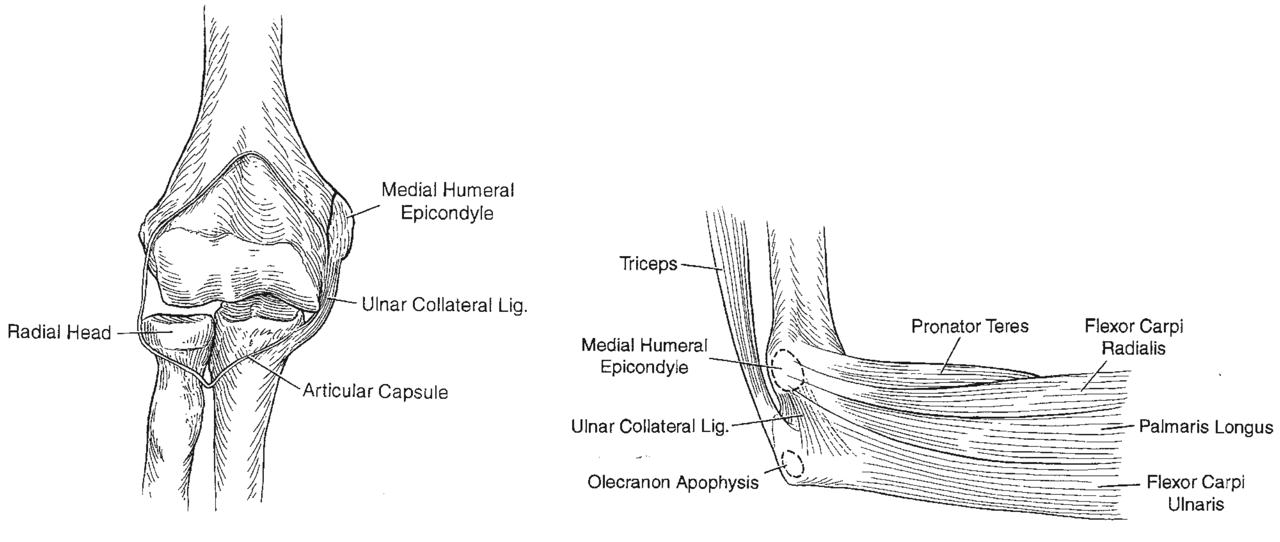
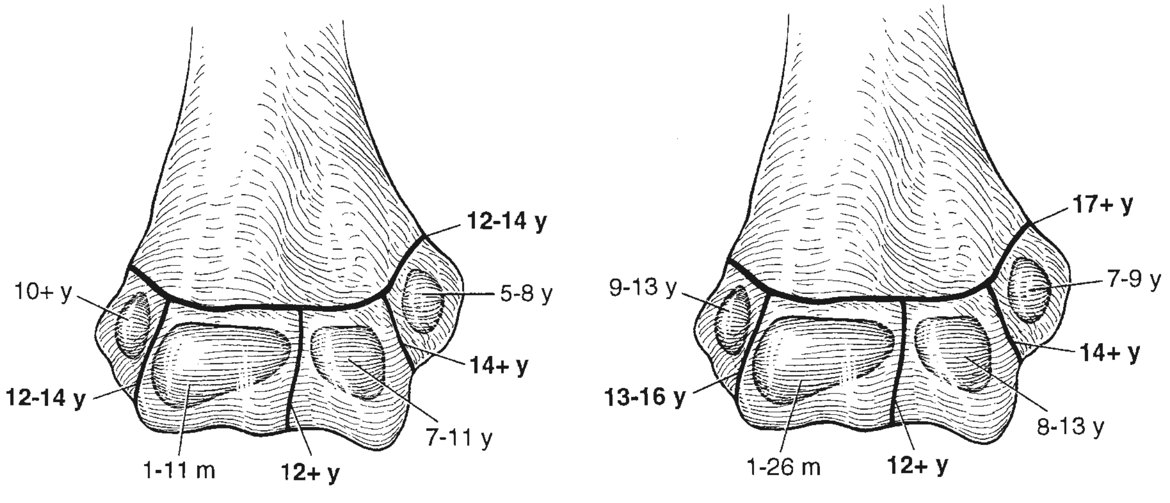


A **Anterior Elbow** **Medial Elbow** B

FIG. 1. (A) The attachment of the capsule and ulnar collateral ligament (UCL) is shown. The UCL attaches in the area just distal and medial to the medial humeral epicondyle. The flexor pronator musculature originates on the medial humeral epicondyle (pronator teres, flexor carpi radialis, longus flexor carpi ulnaris, and deep flexor digitorum superficialis, and deep to that flexor digitorum profundus). **(B)** The coronoid fossa and the insertion of the triceps onto the olecranon apophysis. Posteriorly, a very shallow olecranon fossa is seen, and there should be no fat seen on lateral plain radiographs.

to the UCL on the medial epicondyle, the flexor pronator muscle group that includes the pronator teres, flexor carpi radialis, flexor carpi ulnaris superficially and the flexor digitorum superficialis and flexor digitorum profundus. Posteriorly, the triceps inserts on the olecranon apophysis. Unlike in the adult elbow, the unfused physis and multiple ossification centers in the immature athlete create a myriad of normal variants and possible abnormal findings. The key is to be able to distinguish normal from abnormal.

Elbow development of the appearance, development, and fusion of ossification centers about the elbow and measurement of angles should be evaluated. The bones about the elbow have six separate ossification centers, five of which participate in elbow articulation. The appearance of the ossification centers and their maturation varies between girls (Fig. 2A) and boys (Fig. 2B) (10–15). The best assessment of the symmetry of maturation is to obtain comparison AP view radiographs.



A **Girls** **Boys** B

FIG. 2. The appearance and fusion of the secondary ossification centers of the elbow in **(A)** girls and in **(B)** boys are shown. The arrows point to the four secondary ossification centers. The age of fusion of the centers is shown with the darker line.

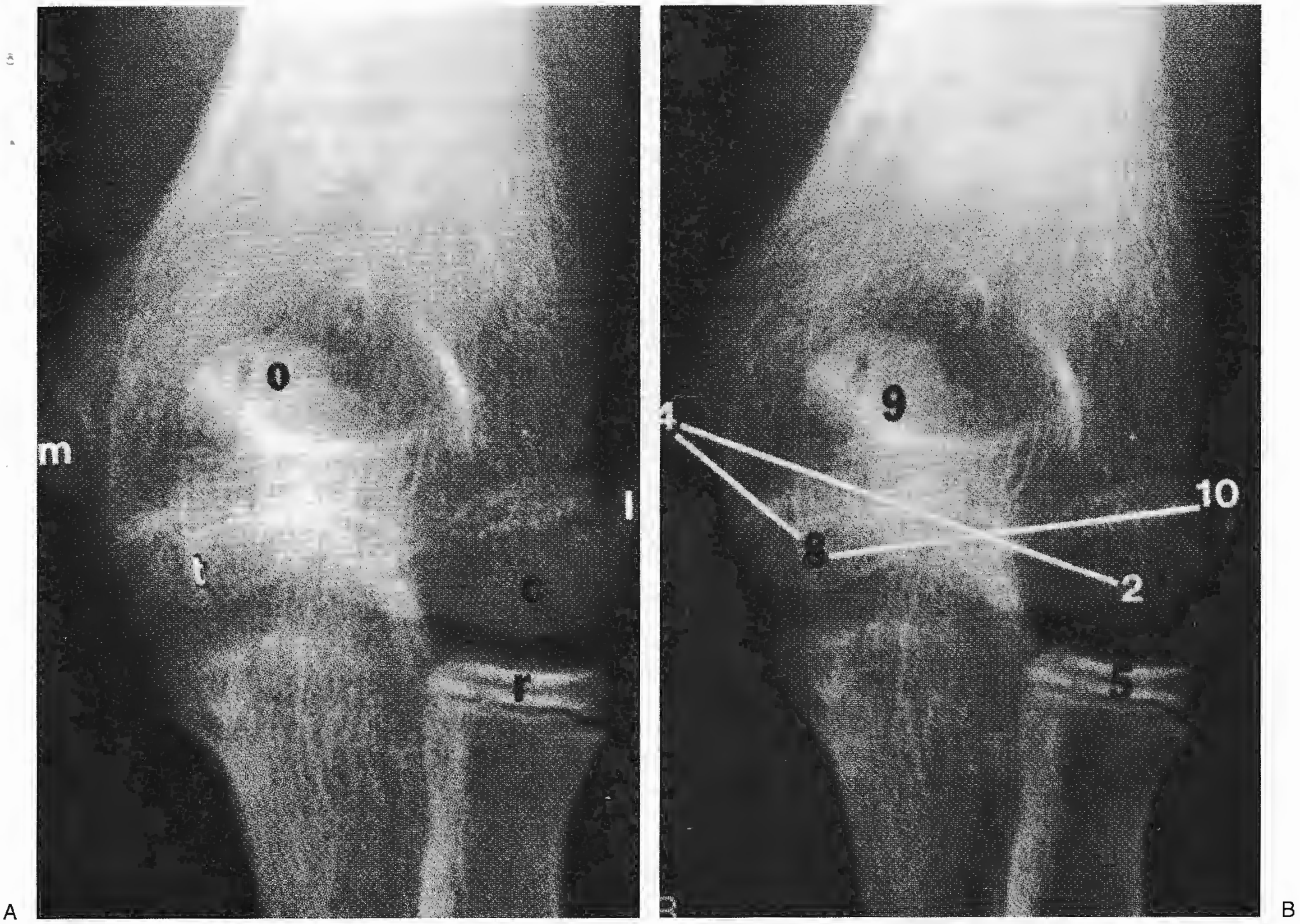


FIG. 3. (A,B) secondary ossification centers in normal elbows are depicted. The capitellum (C), medial humeral epicondyle (M), radial head (R), trochlea (T), olecranon (O), and lateral humeral epicondyle (L) are depicted. The age of the appearance of the secondary ossification centers is indicated in years with cross connection to secondary ossification centers as a reminder of the order of appearance C, M, R, T, O, L.

In order to remember the age of appearance of ossification centers, an acronym is helpful. The order of progression of appearance of ossification about the elbow can be remembered as CRITOE (16). The "C" (capitellum) 1 to 2 years, "R" (radial epiphysis) 3 to 4 years, "I" (inner [medial] epicondyle) 5 to 6 years, "T" (trochlea) 9 to 10 years, "O" (outer or lateral) epicondyle) >10 years, and "E" (epiphyses) 14 to 16 years (Figs. 3A and 3B).

PHYSICAL EXAMINATION

In the 3- to 11-year age group, the mean carrying angle is considered to be 5.4° in boys and 6.1° in girls. A carrying angle up to 15° is normal in the female adolescent, with a range of 11° to 14°, and in the male the normal range is 13° to 16°. During physical screenings, a right-hand–dominant pitcher was noted to have a 20° carrying angle (Fig. 4). He had no elbow complaints. The elbow is at a greater risk for injury when the carrying angle is increased, and there is excessive laxity and hypertension.

Another athlete was noted during physicals to have an 18° cubitus varus angle of his dominant arm. He had sustained a supracondylar humeral fracture of his dominant arm at age 6. Cubitus varus malunion position resulted (Fig. 5A). This athlete had clinically and radiographically 18° varus carrying angle on the left and a 10° valgus alignment on the right. AP radiographs of the left elbow revealed the cubitus varus and a relatively lengthened lateral column (Fig. 5B). There was limitation of flexion range to 125°. Lateral radiographs revealed the 20° anterior angulation seen on the lateral view and the 30° limited true elbow extension range (Fig. 5C). A maximal flexion view exhibited 120° of

FIG. 4. This right-hand–dominant pitcher during physicals was noted to have a 20° carrying angle of the throwing elbow. With underdeveloped musculature, generalized, excessive joint laxity and increased carrying angle, increased forces occur on the medial aspect of the elbow. The pitcher should be completely asymptomatic.

flexion with impingement of the anterior compartment (Fig. C:5D). Repetitive microtraumatic forces applied to the elbow in varus in this left-handed baseball athlete is of major concern. Since the player had no complaints, he was cleared to play baseball. It was suggested, however, that he not pitch or catch in order to decrease the chances of sustaining permanent degenerative changes in the malaligned elbow.

Adolescent pitchers may have a mildly increased carrying angle in the pitching arm compared to the nondominant arm (17,18). The physical exam should document the carrying angle, range of motion, (flexion and extension, supination, and pronation) medial and lateral stability, and radial head motion. Palpation of secondary ossification centers to correlate with areas of tenderness and to identify anatomic landmarks and biomechanical stress areas should be performed.

Radiographic Evaluation

Routine radiographs of AP and lateral views need to be obtained. If secondary ossification centers are in question, comparison views of the opposite elbow or standards are helpful (19). Oblique and axial views are obtained in the throwers. The AP view assesses the carrying angle and the degree of development of ossification centers.

On the lateral view, an anterior fat-pad shadow is seen normally as a very thin linear radiolucency. With a joint effusion, the fat pad is displaced superiorly and appears tented like the shape of a ship's sail (19). An 8-year-old fell onto the outstretched arm running for a base. A Salter III fracture was determined after noting tenderness on supination over the radial head and asymmetrical lucency in the diaphysis (Fig. 6A). A lateral view reveals a positive fat-pad sign and a normal variant of ossification centers (Fig. 6B). In the normal elbow, the posterior fat pad is not seen because of the depth of the olecranon fossa.

A systematic evaluation of the radiographs always should be performed. Emphasis is placed on measurement of angles, appearance of the ossification centers, fat-pad sign, and viewing of the opposite elbow for comparison.

RADIOGRAPHIC VAGARIES

Normal variants or vagaries have been reported in areas capitellum, medial, and lateral humeral epicondyles, and olecranon of the elbow (17,19–22). Medial and lateral humeral secondary ossification irregularities are seen in this normal elbow (Fig. 7). Note the open olecranon apophysis.

In some athletes, a supracondylar process from the anterior distal humerus also may be present. Nerve compression or local irritation because of the size of the process can be seen.

The radiographic appearance of the olecranon apophysis may differ depending upon the phase of growth and triceps insertion tightness. The olecranon secondary ossification center appears at age 9 and fuses at age 14 in males. The round or ovoid ossific nuclei will develop smooth or slightly wavy edges as they mature, but may be confused for a fracture line (22). These multiple separate ossification centers may fuse into a single ossification center prior to complete union with the proximal ulna. If

FIG. 5. (A) This left-hand–dominant baseball athlete during physicals was noted to have a cubitus varus deformity of 18° in his left elbow, compared to 10° of valgus on the opposite side. Past history is significant in that he had sustained a supracondylar humeral fracture at age 6. **(B)** AP radiograph of the left elbow revealed the cubitus varus alignment due to malunion and lengthened lateral column of the elbow. **(C)** Maximal extension and **(D)** flexion and **(D)** a lateral radiograph document the true range of motion of the elbow, which was limited to 30° to 120°. There was anterior angulation of 20° at the fracture site **(C)**. Anterior impingement is noted in maximal flexion **(D)**.

A B C D

A B

FIG. 6. (A) Salter III fracture proximal radius occurred in this 8-year-old who fell on the outstretched arm running toward a base. The arrow indicates the fracture through the epiphysis. **(B)** The lateral view reveals a positive fat-pad sign. (Elevation of the fat pad anteriorly out of the coronoid fossa.)

there is tenderness over any portion of the olecranon, clinically the diagnosis of tension apophysitis, which is similar to Osgood-Schlatter's disease of the knee, should be considered. Relative rest, stretching, assessment of biomechanics is recommended.

The capitellum is the first epiphyseal center of the elbow to ossify. The normal position is slightly anterior and tilted downward relative to the humeral shaft. Only the lateral view, the humeral shaft line passes through the posterior half of the developing capitellum. The curved coronoid line just touches or lies anterior to the developing capitellum. Both should be measured. Vagaries of the capitellum have been described (23).

Ossification of the medial epicondyle begins at age 4 as a central, single ovoid body of cartilage anlage. This nucleus may be eccentric or multicenter and appear as a separation from the humeral shaft or as a fracture. Vagaries also have been described in the medial epicondyle (24).

The lateral humeral epicondyle ossification center develops at age 10 in boys and earlier in girls. The lateral ossification center is a smooth thin sliver of bone unlike the other ossification centers about the elbow (20). It can be confused with an avulsion or periosteal reaction. Lateral humeral epicondylar injuries are rare (11,25).

Radiographic Studies

Plain radiographs are most helpful in assessment of the pediatric elbow. Multiple views, including comparison views to help elucidate subtle irregularity in the ossification centers, may show loose bodies, minimally displaced fractures, and normal vagaries. Gravity or stress, valgus views will reveal widening of the medial joint space if there is a UCL injury. In the skeletally immature age group, medial humeral epicondyle injuries are more common than UCL sprains. Radiographs are assessed for medial humeral epiphyseal plate widening and increased size of the secondary ossification center. A Little League pitcher complained of left-hand–dominant, medial elbow pain. His UCL was stable. The medial humeral epicondylar size was greater on the involved left elbow with the height measuring 2 cm (Fig. 8A, arrow) when compared with the right (Fig. 8B, arrow), which measured 1.2 cm. The axial view can be helpful to assess the medial humeral epicondyle, which in this instance is shown to be still open (Fig. 8C, arrow). Also the widening of medial humeral epicondyle and some apparent fragmentation, which is actually the undulation of the plate (Fig. 8A, arrow) should be noted. The axial view can be helpful to

FIG. 7. Anatomic vagaries are seen in this normal elbow radiograph. The closed arrow points to an open olecranon apophysis. Vagaries are seen on the medial humeral epicondyle (*open arrow*) irregularity of the lateral humeral epicondyle (*open arrow*).

identify the separation of the inferior and widened medial humeral epicondyle (Fig. 8C) (Fig. 8A, arrow).

Arthrography and ultrasound have been shown to be helpful to document physeal injuries in younger children (15). The low yield from these procedures and the lack of cooperation in the pediatric age group make the plain radiographs the most helpful. In older children, arthrography and CT can be helpful. MRI may be helpful to stage vascularity, and bony changes of the capitellum in osteochondritis dissecans. MRI with contrast is of limited value in this age group.

INJURIES

Classically, Little Leaguer's elbow occurs in the 9- to 14-year-old whose athletic enthusiasm surpasses skillful, throwing mechanics (26–28). This age group presents with elbow pain, limited motion, locking, clicking, or inability to throw (1,27,28). The pain, which may be nonspecific, often increases with activity and improves with rest. In studies of adolescent pitchers, approximately 20% had some elbow complaints, but most had no time loss from sport (18,29). Grana noted that 58% of older adolescent pitchers had pain, and he felt that this was related to age (30). Abnormalities in the radiographs of these young athletes has been reported to vary from 28% to 100% (18,29–31). Fortunately, the incidence of long-term significant pathology, such as degenerative changes of the lateral compartment of the elbow in athletes who pitched as children, is rare (26,30). Nonetheless, if the pediatric athlete continues to pitch, problems may develop (32).

The Little Leaguer's Elbow

The sore elbow is very common in baseball. In a Little League survey, elbow complaints were usual, but only a small number of pitchers have injuries sufficiently severe to keep them from continued participation in sport (33). The term *Little Leaguer's elbow* has been used for a variety of pathologic lesions (20,28). In 1965, Adams described Little Leaguer's elbow (27). Nonetheless, Little Leaguer's elbow is nonspecific, includes many diagnoses, and only defines an age group, a joint, and an activity. The catch-all term of Little Leaguer's elbow should not be used. A specific diagnosis should be made.

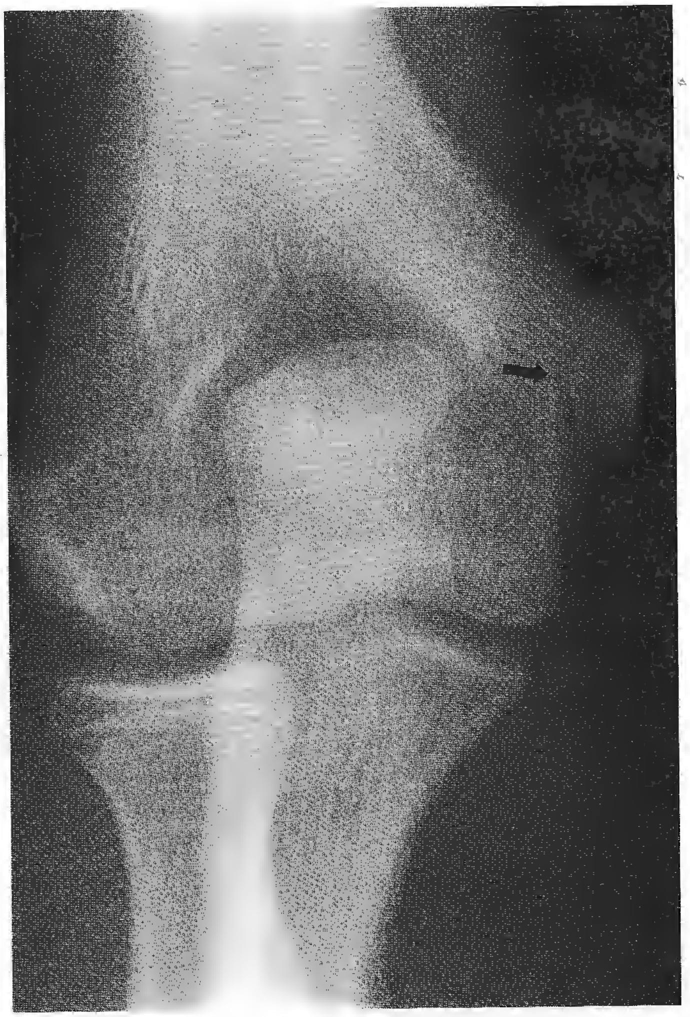
Panner's disease is an osteochondrosis of the capitellum that may be confused with Little Leaguer's elbow (34). Radiographically it is similar to the capitellar stress lesion, osteochondritis dissecans, as seen in pediatric throwers. However, Panner's disease is a separate entity. It is more common in a younger population and occurs at an average age of 8 years (with range of 5–10 years) (26). Panner's appears to be self-limited. It is not associated with stresses and progressively reconstitutes over 1 to 3 years without intervention. Loose bodies are not formed in Panner's disease (34,35).

Classification

A helpful classification of injury is to delineate by anatomic compartment and the biomechanical forces (Table 1). The compartments are medial, lateral, posterior, and anterior. Most injuries involving the lateral compartment result from valgus compression forces. Medial stresses are usually tensile. Posteromedial forces in the adult produce spurs and loss of extension range of motion (36).

Injuries can further be subdivided into acute or chronic in nature. Acute injuries are associated with one specific event, or with increased time or intensity of training. An exact diagnosis should be made. Specific fracture types and Salter physeal fracture descriptions should be stated.

A



B

C

FIG. 8. Greater medial humeral epicondyle size is noted in this Little League pitcher where secondary overgrowth occurred on his dominant side. **(A)** The height of the medial epicondyle on the involved left side measured 2 cm, compared to 1.2 cm. on the nonthrowing side (*arrow*). **(B)** Left comparison view shows normal size of medial humeral epicondyle (*arrow*). **(C)** Axial view on the involved side reveals the medial humeral epicondyle (*arrow*). The axial view can be helpful to identify inferior and widened separation of the medial humeral epicondyle.

Repetitive microtrauma causes chronic injuries. These injuries include epicondylitis (medial or lateral), osteochondritis of the capitellum or radial head, overdevelopment of the radial head, olecranon traction apophysitis, and the development of loose bodies in the joint. A progressive spectrum of severity exists from the acute into chronic categories. Clinically an attempt should be made to correlate the location of pain and phase of throw with the anatomy. An example would be physeal plate involvement of the olecranon apophysis that results in posterior pain and triceps weakness. A vigorous attempt to place these repetitive microtraumatic injuries into these categories will help to standardize diagnosis in order that injury patterns can be studied.

MEDIAL COMPARTMENT INJURIES

Medial elbow pain originates from the flexor muscle origin at the medial epicondyle, the UCL, and the ulnar nerve. Medial microtraumatic forces can create stress reaction or avulsion of the medial humeral apophysis (36). Repetitive valgus stress on the medial epicondyle can lead to fragmentation, irregularity, and enlargement. These findings may not be related to complaints of pain (37,38). Mild widening of the physis may be due to traction alone and, in the absence of clinical signs, is not considered a fracture (6,28). This right-hand–dominant pitcher complained of pain for 3 months in the medial aspect of his elbow. The medial humeral epiphyseal plate is widened, and there is some fragmentation of the secondary ossification center inferiorly. (Fig. 9A, arrow). There is no widening on the opposite, normal side (Fig. 9B). Three months with no pitching resulted in clinical and radiographic healing with closure of the medial humeral epicondylar apophysis. A rehabilitation program and assessment of throwing resulted in return to painless pitching. In the adult with a fully ossified physis, the medial stress of throwing leads to musculotendinous injury at the flexor pronator origin or a UCL sprain. In children, first consider physeal involvement.

Medial Epicondyle Fractures

In the adolescent or preadolescent throwing athlete, avulsion of the medial epicondyle should be considered (8). Medial stability is dependent on the UCL and medial humeral epicondyle. The UCL attaches distally on the medial epicondyle (Fig. 1A, and Fig. 1B) (8,18). The valgus overload during the acceleration phase of the pitching motion creates the excessive forces that cause the fracture (19).

An isolated medial epicondyle fracture is usually not associated with UCL instability. During a throw, this right-handed pitcher felt a pop. Plain x rays revealed a displaced medial humeral epicondyle fracture (Fig. 10A). The normal left epiphysis appears almost fused. The UCL was stable when stressed (Fig. 10B). Open reduction, internal fixation was performed. Postoperative radiographs are shown. (Fig. 10C). There were no previous elbow complaints.

Stress views to assess UCL integrity are helpful. For 3 months, this right-hand–dominant pitcher complained

TABLE 1. *Differential diagnosis elbow injuries of the immature skeleton*

Medial	
Acute	Avulsion Fracture Medial Humeral Epicondyle (Apophysis)
	Flexor/Pronator Strain
	Fracture Trochlea/Distal Humerus
	Ulnar Collateral Ligament Sprain
	Ulnar Nerve Subluxation (Neuritis)
Chronic	Fracture Medial Epicondyle
	Ulnar Neuropathy
	Ulnar Nerve Subluxation
	Medial Humeral Epicondylitis
	Traction Spurs Coronoid Process
Lateral	
Acute	Osteochondritis Dissecans Capitellum
	Osteochondral Fracture Capitellum
	Avulsion Fracture Lateral Humeral Epicondyle (Apophysis)
	Fracture Capitellum/Distal Humerus
	Anterior Subluxation Radial Head
	Fracture Proximal Radius
	Fracture Radial Head—Dislocation Radial Head
Chronic	Lateral Humeral Epicondylitis
	Radial Head Hypertrophy/Overdevelopment
	Loose Bodies
	Osteochondritis Dissecans Capitellum
	Osteochondritis Radial Head
Posterior	
Acute	Olecranon Fracture
	Olecranon Apophysitis
	Olecranon Spur with Fracture
	Triceps Strain
	Olecranon Bursitis
	Dislocation
Chronic	Olecranon Traction Apophysitis
	Olecranon Spurs
	Loose Bodies
	Synovitis
	Posteromedial Spurs
	Valgus Extension Overload
Anterior	
Acute	Biceps Strain
	Distal Physeal Humerus Fracture
Chronic	Loose Bodies
	Adhesions
	Synovitis
	Capsular Sprain

FIG. 9. This right-hand–dominant pitcher complained of pain for three months on the medial aspect of his elbow. **(A)** Medial humeral epiphyseal plate appears widened with fragmentation of the secondary ossification center inferiorly (*arrow*). **(B)** There is no widening on the opposite non-throwing side. After 3 months of not pitching, clinical and radiographic healing and closure of the medial humeral epicondyle apophysis resulted.

of medial pain just before ball release. Stress views of the elbows demonstrated no instability. Measurement of the space between the humerus and ulna of both elbows were equal. There was increased size of the medial humeral epicondyle and greater physeal lucency (Fig. 11A). An unexpected variation can be seen in the trochlea medially (Fig. 11B). The athlete stopped pitching for 6 months, then returned to full activities without recurrent symptoms.

A physeal injury of the medial epicondyle apophysis may occur without roentgenographic separation. If there is displacement, closed reduction treatment commonly allows the injury to heal by fibrous union. Roentgenographically callus, therefore, may not be seen (39). Micheli feels that prolonged cast immobilization can lead to permanent loss of motion and result in fibrous union and continued pain. If there is associated medial instability, open reduction and fixation of the fracture and UCL exploration is necessary. Others agree that displaced, unstable injuries are best treated with open reduction and fixation (30,39,40). If there is any displacement on plain radiographs or recurrent pain in an athlete who desires to return to the sport of baseball, internal fixation should be performed.

ULNAR COLLATERAL LIGAMENT SPRAIN

Isolated UCL injuries in the skeletally immature are rare. Stress views of both elbows by gravity or manual testing are helpful. A left-hand—dominant pitcher complained of medial elbow pain for over a year. There was a stable ligamentous examination and very mild pain was reported over the UCL. The irregularity at the ulnar col-

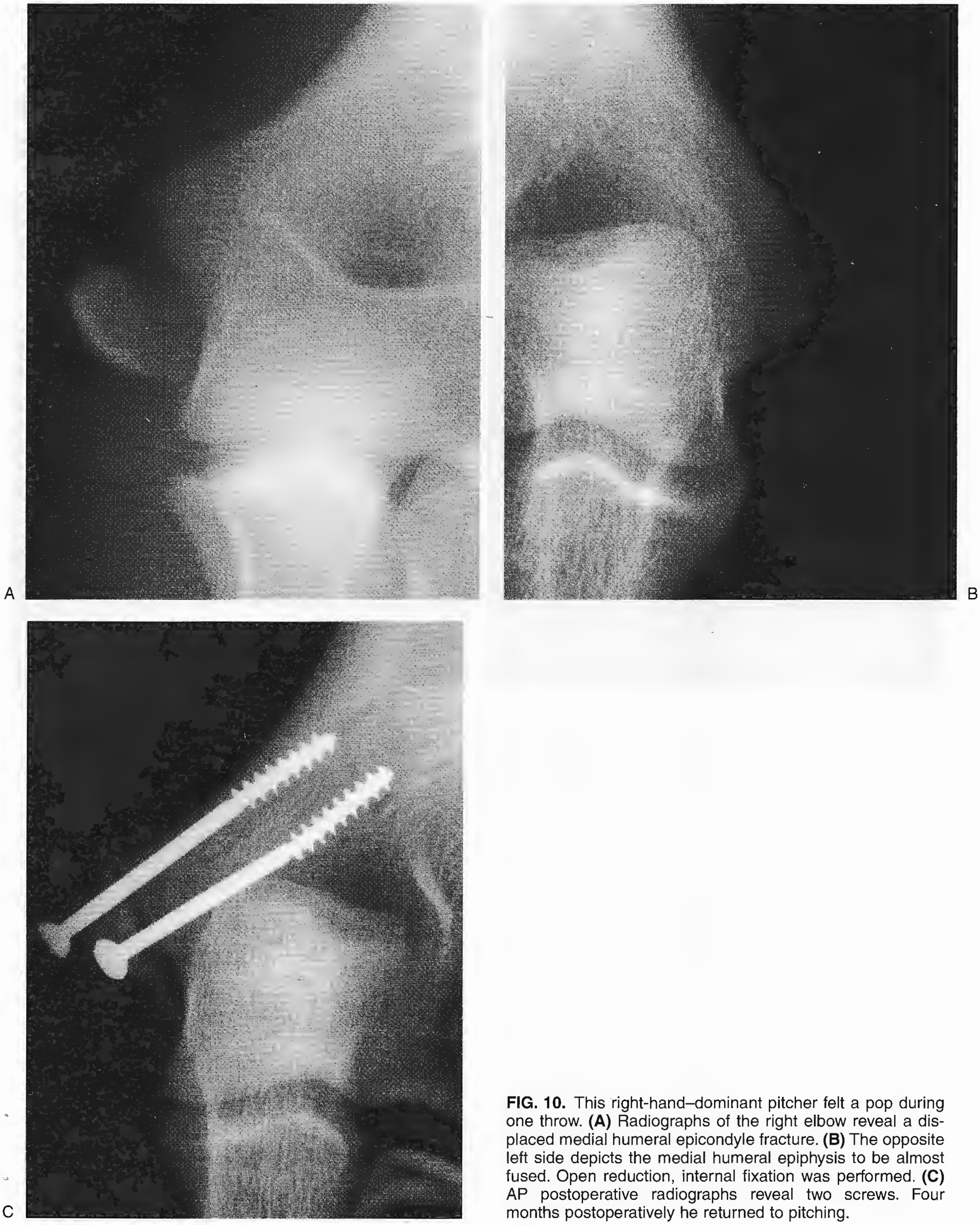


FIG. 10. This right-hand–dominant pitcher felt a pop during one throw. **(A)** Radiographs of the right elbow reveal a displaced medial humeral epicondyle fracture. **(B)** The opposite left side depicts the medial humeral epiphysis to be almost fused. Open reduction, internal fixation was performed. **(C)** AP postoperative radiographs reveal two screws. Four months postoperatively he returned to pitching.

A B

FIG. 11. (**A**) and (**B**) Vagaries and stress views of the immature elbow. Stress views of both elbows reveal no significant difference in the distance from the distal humerus to the proximal ulna as a result of applying a valgus force at 30° of flexion. The open arrow reveals an increased lucency over the medial humeral epicondyle (**A**). A vagary is seen on the normal left side of (**B**), as shown with the open arrow. The distances on stress views are similar on the involved, abnormal elbow. This athlete demonstrates a stress reaction of the medial humeral epicondyle without involvement of the ulnar collateral ligament.

lateral ligament attachment to the medial humeral epicondyle is shown (Fig. 12). When the patient was evaluated radiographically, the ligamentous examination was stable. Clinically, the ligamentous examination was stable. Changing the pitching style and a specific rehabilitation program allowed return to painless throwing.

Chronic Overuse

Long-term traction forces and stresses on the skeletally immature elbow may result in elbow enlargement, hypertrophy of the medial humeral condyle, microtears of the flexor-pronator muscle group, fragmentation of the epicondylar apophysis, and breaking of the medial humeral condyle (35,41). Medial humeral epicondyle increases in size and depth of the epiphyseal plate, indicating involvement of the physis and bone as shown in Figures 8 and 9. Successful treatment occurred with relative rest and reduced pitching until there was no pain over the medial epicondyle. The potential for an acute avulsion of the medial epicondyle exists if throwing is started while pain is still present and if there is generalized muscular fatigue. Since this epicondyle is extra-articular, no articular surface incongruity will result. In general, such physeal plate problems do not have long-term implications, and usually need only to be treated symptomatically (41).

Elbow Dislocation

Macrotraumatic mechanisms can result in elbow dislocation. Careful examination and classification of the mechanism of injury and documentation with stress views should be performed (8,40,41). The capsular sign is usually significant. The UCL, if torn, fails proximally in most

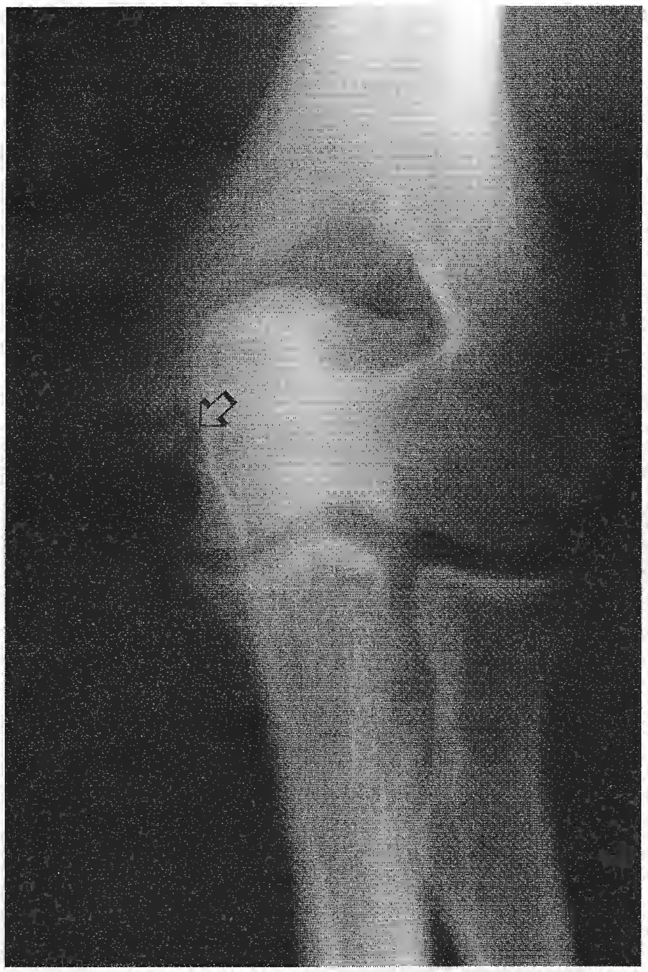


FIG. 12. Ulnar collateral ligament avulsion occurred in this Little League pitcher. The open arrow reveals the irregularity just distal to the medial humeral epicondyle. The ligamentous examination was stable.

cases. Careful surgical exploration of the anteromedial elbow and repair is necessary if postdislocation is unstable.

A catcher fell into the dugout when attempting to catch a foul ball. A posterior elbow dislocation resulted as shown on the lateral radiograph (Fig. 13A). The medial humeral epicondyle could not be seen. Stress AP views (Fig. 13B) reveal the displaced medial humeral epicondyle and severe medial laxity. A normal stress view (Fig. 13C) is shown. Open repair of the capsule, UCL, and internal fixation of the fracture of the medial epicondyle was performed (Fig. 13D). The capsule is held in forceps. The medial humeral epicondyle has been fixed with two screws. Postoperative radiographs reveal good anatomic reduction (Fig. 13E, Fig. 13F).

Ulnar Neuritis

Repetitive valgus stress can cause traction, stretching, and inflammation of the ulnar nerve at the elbow. Muscular hypertrophy, fibrous bands and scarring, or bony hypertrophy and irregularity can further impinge and irritate the nerve. More commonly, friction on the nerve occurs when forcefully going from extension to flexion, which results in recurrent subluxation or infrequent dislocation of the nerve out of the ulnar groove (34). Subluxaton/dislocation happens more frequently in congenitally lax throwing athletes (1,7). If conservative treatment does not alleviate the symptoms, nerve conduction and electromyographic studies are performed. Surgical exploration with transposition of the nerve is rarely performed in the skeletally immature athlete.

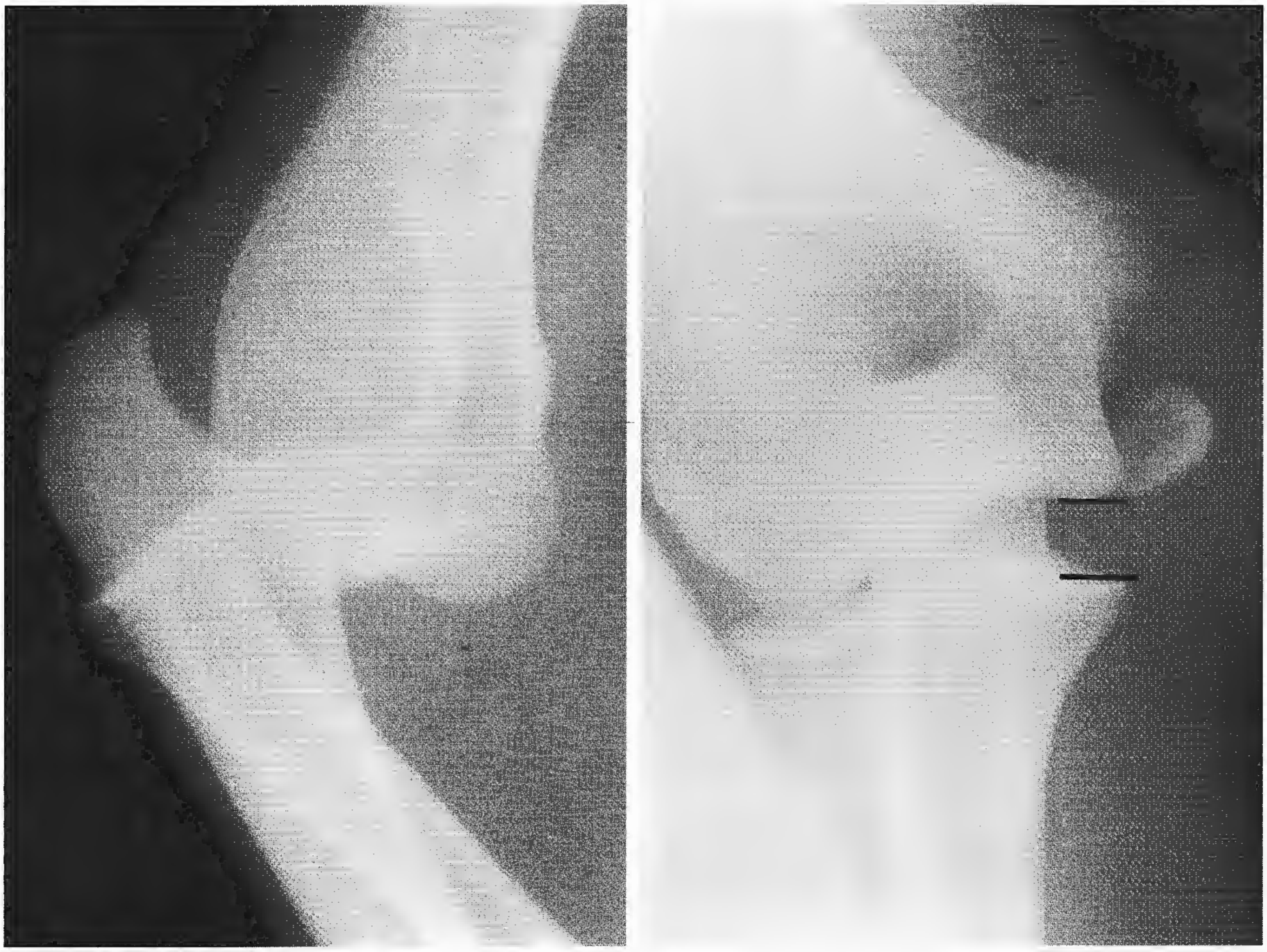
LATERAL COMPARTMENT INJURIES

Osteochondritis Dissecans of the Capitellum

The compressive and rotatory forces occurring between the radial head and the capitellum during the acceleration phase of pitching can cause significant and permanent injury to the lateral compartment (15,37). Lateral compression injuries seem to occur in the youngest and least experienced pitchers (37). Pappas (1) has noted that athletes prone to other osteochondroses, e.g., Köhlers, Legg-Perthes, or Osgood-Schlatters, may be at an increased risk with pitching of developing osteochondritis dissecans (OCD) of the elbow (37). A 14-year-old pitcher had pain laterally, and radiographs confirmed osteochondritis dissecans of the capitellum (Fig. 14A).

Throwing was not allowed for 1 year. Follow-up radiographs reveal the lesion healed (Fig. 14B). The repetitive forces from throwing can injure both the articular cartilage and underlying subchondral bone of the capitellum and radial head. It is thought that a vascular insult with repetitive loading can lead to osteochondrosis or osteochondritis dissecans of the capitellum or overgrowth and irregularity of the radial head. The etiology is probably vascular insufficiency that is magnified by the compressive forces (10). If the underlying bone dies, the overlying cartilage can become loose like a flap or become a loose body. The defect left by the osteochondrosis can lead to long-term joint irregularity and arthrosis (20,41). Although the lesion is relatively rare (16), osteochondrosis dissecans is the leading cause of permanent disability in pitching athletes (41,43). In a series of 29 patients with OCD of the capitellum, 10 gave up sports due to elbow complaints (44). The destructive process of capitellum OCD was emphasized in a series of 183 patients by Volk et al. (5). Of the 92 severe cases treated surgically, degenerative changes were noted posteriorly or laterally in 84%.

There are three stages of OCD (45). These are (a) intact cartilage, (b) partially detached cartilage, and (c) fragmented with loose bodies. Treatment of these osteo-



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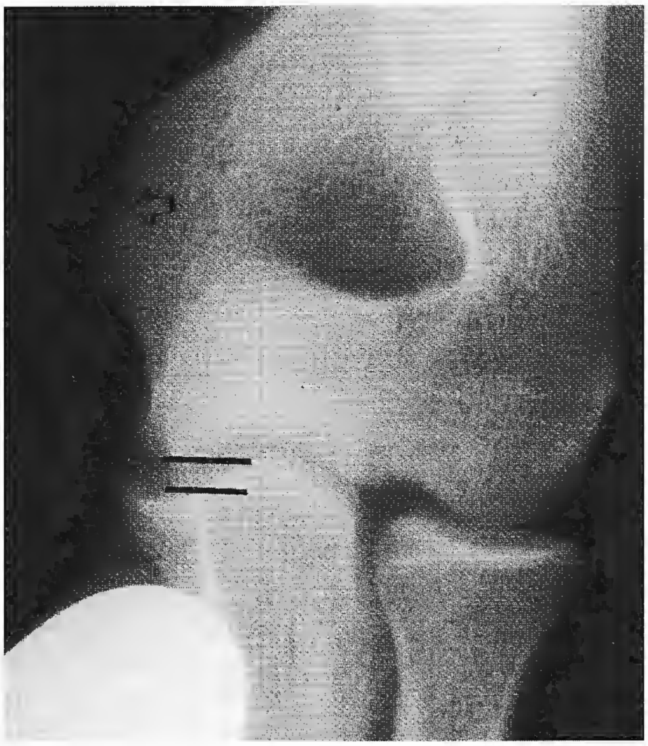
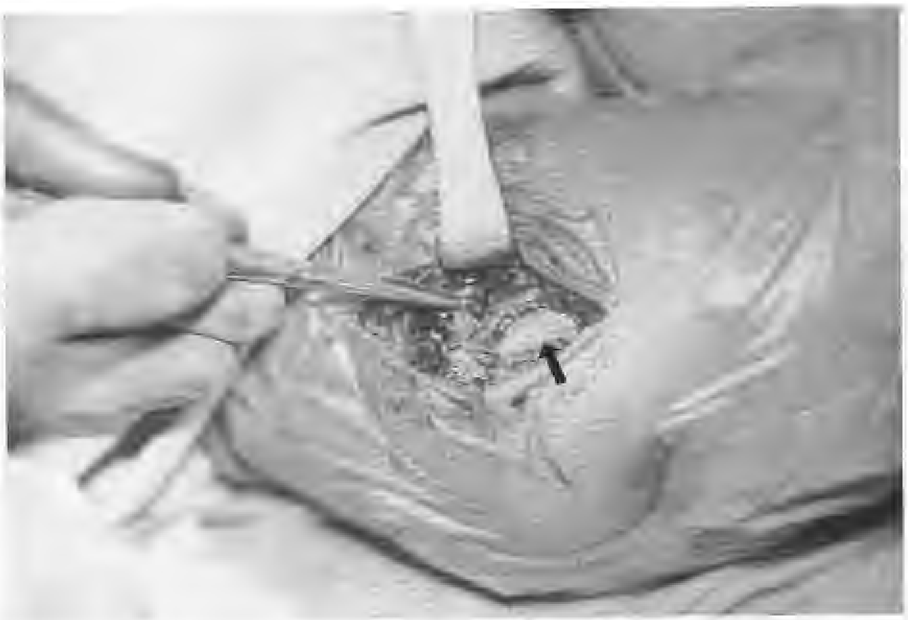


C

FIG. 13. A posterior elbow dislocation occurred when this catcher fell in the dugout going for a foul ball. On initial films a displaced avulsion fracture of the medial humeral epicondyle could not be seen. (**A**) A lateral radiograph revealed only a posterior dislocation. (**B**) The epicondylar fracture was seen after reduction on an AP stress view. Following closed reduction of the elbow dislocation, stress views reveal a 10-mm increased opening of the medial joint and a significantly displaced medial humeral epicondyle. (**C**) A comparison stress view of the opposite side revealed a 5-mm opening (*lines*) while the involved side revealed a 15-mm opening (**B**, *lines*). Note the almost closed physeal plate of the medial humeral epicondyle opophysis (**C**, *open arrow*). Open reduction, internal fixation, two 3.5 cancellous screws, and medial exploration was performed.



D

FIG. 13. *(Continued)* **(D)** An operative radiograph. Forceps are noted on the capsule that had received excessive damage and was avulsed distally. **(E)** AP and **(F)** Lateral postoperative radiographs are shown.

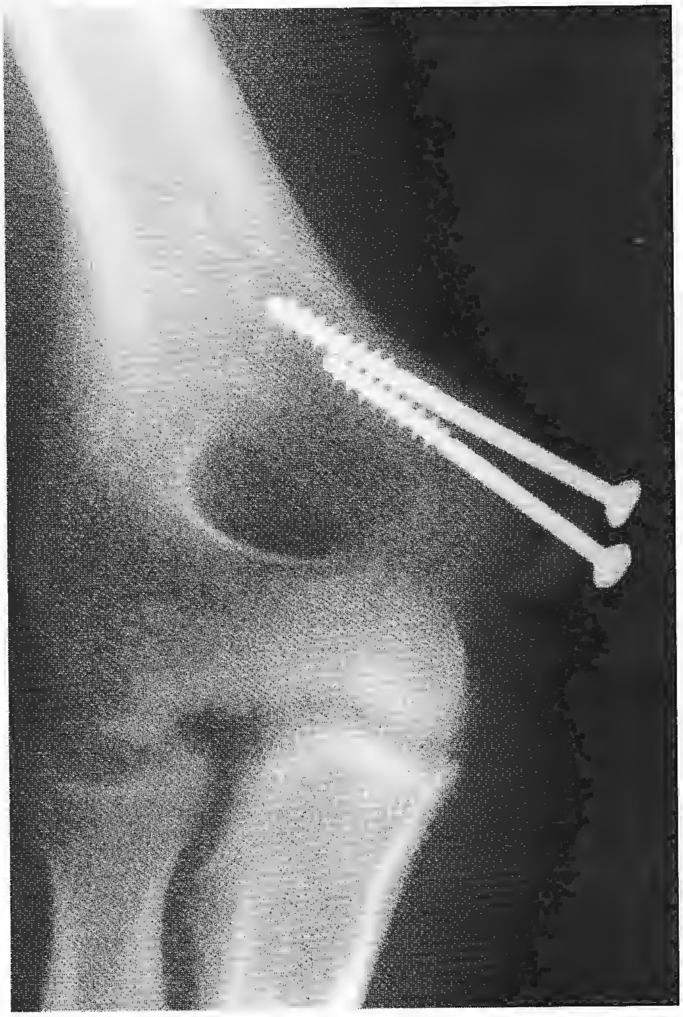


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FIG. 14. A 14-year-old with lateral elbow pain was found to present with increased radiolucency of the capitellum consistent with osteochondritis dissecans. (**A**) There were no loose fragments (*arrow*). (**B**) After limited in throwing for 1 year, a follow-up radiograph revealed the lesion to be healing.

chondral lesions is based on the stability of the fragments (46,47). Arthrograms and CT scans may help to determine if an osteochondritic lesion is loose (19). If the fragments are stable and not loose, an attempt at immobilization and reduction of activity can be made. Range of motion should be instituted early, but resistive weight training should be withheld for at least 6 to 12 weeks until bony healing can occur and the pain has resolved. By 6 to 12 months, most athletes can return to full activities.

If the OCD fragments are loose, the best result can be obtained with excision of the osteochondral loose body. (48) A right-hand–dominant pitcher complained of locking of his right elbow. Arthroscopic removal of a loose body improved his range of motion but grade III and IV changes of his capitellum existed. Loose body removal arthroscopically (Fig. 15A) improved the symptoms of locking. Debridement of the capitellum improved but did not cure the disorders (Fig. 15B). In addition, drilling or curettage of the subchondral bone may stimulate active repair (1).

This 14-year-old right-hand–dominant athlete had limited range of motion and pain in the right elbow. Radiographs revealed an osteochondritis dissecans lesion with a large loose body. He underwent arthroscopic removal of the fragment and drilling of the extensive defect. Postoperatively, the range of motion was 35° to 135°. Pain and locking symptoms improved for a year (Fig. 16A). When seen in follow-up 3 years later at age 17, repeat radiographs (Fig. 16B) reveal abnormal bone formation of the capitellum in the anterior posterior view. Range of motion was 40° to 120°. Pronation was limited to 45° with full supination. The athlete continues to have pain and is not active in any sports. Further surgical intervention was not suggested (Fig. 16C, 16D).

Poor results can be expected in patients with loose fragments who are treated nonsurgically or surgically after a long delay. This athlete had several loose frag-

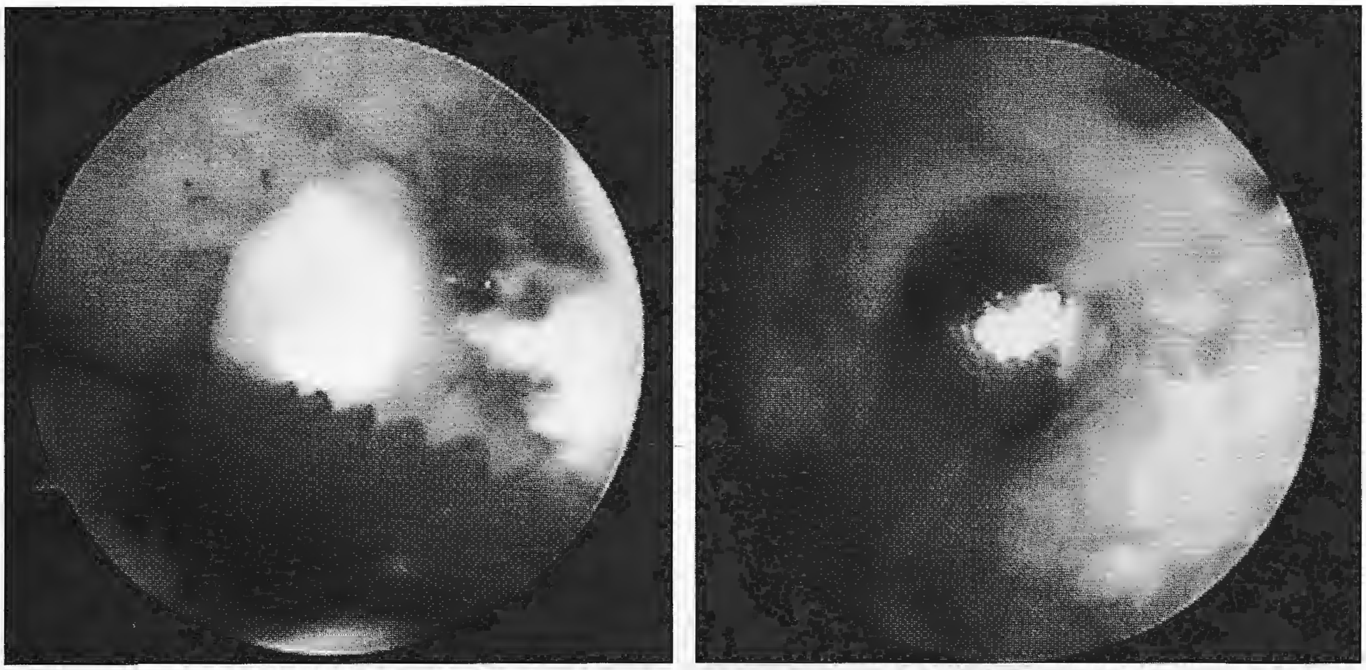
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FIG. 15. (A) Diagnostic arthroscopy reveals a large loose body in a clamp and irregularity of the adjacent capitellum. **(B)** Debridement of the capitellum with a motorized resector.

ments from a chronic OCD, which required arthrotomy and capitellar debridement, drilling, and removal of multiple loose fragments (Fig. 17). Bone grafting or pinning of loose fragments is not recommended (35).

Overdevelopment and Osteochondritis of the Radial Head

Abnormalities of the radial head can be associated with the lateral compression lesions from valgus stress. Radial head hypertrophy is a frequent finding and may be related to repeated microtrauma and microfractures of the articular cartilage and subchondral bone of the radial head (40). Hughston believes that the presence of radial head hypertrophy with a flexion contracture is an ominous finding in regard to return of full extension and normal function of the elbow (41). Ellman also has described a rare anterior angulatory deformity of the radial head that may be due to the compressive stresses on the physis of the radial head and secondary adaptive changes (49,50). A right-hand–dominant pitcher had pain, limited extension by 40°, and supination by 30° after many years of pitching (Fig. 18A and Fig. 18B). Radiographs reveal radial head overgrowth and degenerative changes in the capitellum (Fig. 18C). He was unable to throw, but had no problems with other functional activities.

Osteochondritis and loose bodies from the radial head can cause loss of motion and reduced function. Like the capitellar lesions, they are thought to be due to compression and vascular compromise. Radial head lesions, though, are less frequently observed than capitellar lesions (51). Gugenheim et al. (18) noted that there has never been a report of a case under 9 years of age. Conservative treatment is generally indicated unless large loose bodies are present within the joint. Radial head resection is restricted to cases with significant joint incongruity that proceeds to secondary arthritis, and then only after closure of the growth plate (52).

POSTERIOR COMPARTMENT INJURIES

In the acceleration phase of throwing, the elbow is rapidly extended from a flexed position (53,54). Forceful contraction of the triceps may result in triceps tendonitis, olecranon traction apophysitis, or an avulsion of the olecranon apophysis (35). Extension stress over an extended period of time can lead to olecranon hypertrophy and posterior osteophyte formation that cause impingement (32). Posterior lesions impair throwing biomechanics and are amenable to arthroscopic treatment (55).

A right-hand–dominant pitcher had loss of elbow extension range and posterior pain. Radiographs showed a large loose body in the posterior compartment (Fig. 19A and Fig. 19B). Arthroscopically, the large loose body was removed from the posterior compartment (Fig. 19C). The fragment probably originated from an osteochondritic capitellar lesion. The capitellum with irregularities and lesions is shown arthroscopically (Fig. 19D). Following debridement, only grade I chondromalacic changes are seen in the capitellum (Fig. 19E). Post excision x ray is shown (Fig. 19F). Following skeletal matu-

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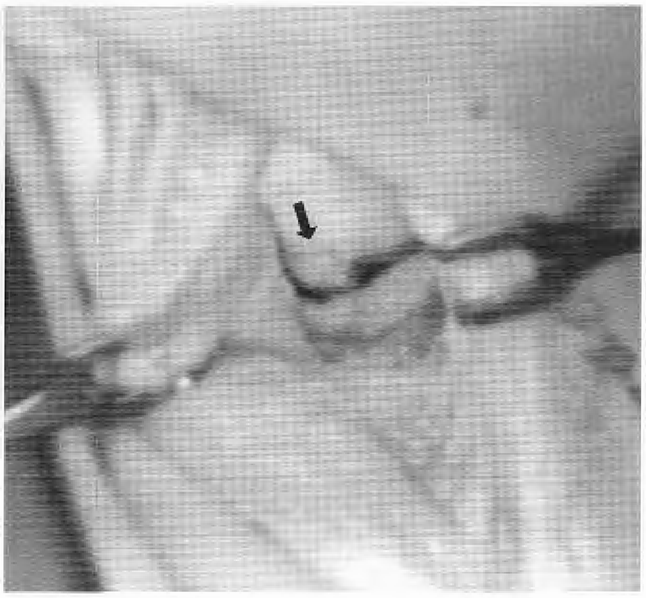

FIG. 17. At arthrotomy, removal of multiple loose fragments was performed.

rity, osteophytes and loose bodies are commonly seen in the posterior compartment. By the time the athlete is a skilled high-level pitcher, loose bodies are relatively common and about half lie in the posterior compartment (41,56).

Triceps tendonitis and muscle strains result in localized pain proximal to the level of the triceps tendon insertion onto the olecranon. Treatment for tendonitis is relative rest, elbow extension strengthening, and assessment and correction of pitching biomechanics. Olecranon bursitis is associated with direct contact and is unusual in pitchers. Septic bursitis must be considered if there is a skin abrasion, erythema, or swelling of the olecranon bursa (55).

Olecranon Apophysitis

The triceps tendon inserts on the olecranon apophysis in the skeletally immature athlete. Because of tension across the physis, failure may occur during pitching. Initially, the physis responds to the repetitive load with an inflammatory reaction that causes olecranon traction apophysitis. The traction apophysitis of the olecranon has been likened to Osgood-Schlatter's disease or traction apophysitis of the tibial tubercle (40). Olecranon pain is located focally at the physis, but there is no radiographic evidence of a fracture. If there is tenderness over the olecranon or radiographic evidence of a physeal separation, "active" rest is enforced. Treatment is ice, biceps stretching, and triceps strengthening.

With continued extension loading and stress on the skeletally immature olecranon, hypertrophy along with traction apophysitis occurs (11,56). Olecranon hypertrophy leads to posterior impingement and the creation of posterior loose bodies (32). However, development of loose bodies and posterior spurs is rare in the posterior compartment of prepubescent and adolescent athletes (55).

Avulsion of the olecranon apophysis is described as nondisplaced, partial, or complete. A technetium bone scan may confirm nondisplaced acute fractures and stress fractures. Avulsion ranges from minimal, with only a fragment of the apophysis, to a significant displacement of the entire olecranon apophysis. A pitcher complained of acute elbow pain after follow-through of one pitch. Lateral radiographs revealed an olecranon apophysis that was widened, with superior displacement of the anterior fat pad (Fig. 20). There are reports of complete avulsions of the olecranon apophysis associated with pitching (20,51,54). Active perpetuation of olecranon apophysitis may contribute to acute failure of the physis. If olecranon separation is left untreated, nonunion may develop (1,54,57).

Anterior Compartment Injuries

Repetitive hyperextension of the elbow may lead to a traction injury of the anterior joint capsule, with fibrosis and contracture. Young pitchers may be more susceptible to these problems because of generalized laxity, poor strength, and improper throwing mechanics (38). In two studies, 10% of Little League pitchers were found to have a mild flexion contracture of <15° (18,29). These relatively small contractures result in little functional significance. However, persistent throwing with a painful elbow or the association of other elbow pathology may result in a contracture of 30° or more (38).

Early roentgenographic changes anteriorly may include trochlear hypertrophy or subtle changes in the ossification centers. Initial complaints are only those of vague elbow discomfort. Subsequently, osteochondritis of the trochlea may develop loose bodies similar to the lesions recognized in the capitellum (20). Initial treatment should be conservative, with active rest and reduction in throwing.

FIG. 16. **(A)** AP and **(B)** lateral views of an elbow of a 14-year-old depict osteochondritis dissecans of the capitellum. Irregularity of the capitellum is seen in the right elbow. **(B)** The arrow points to a loose body. Arthroscopic debridement was required to remove loose bodies. Four years postoperatively, a **(C)** lateral and **(D)** AP view continue to reveal joint irregularity. It was noted that elbow motion was 40° to 120° with limited pronation.

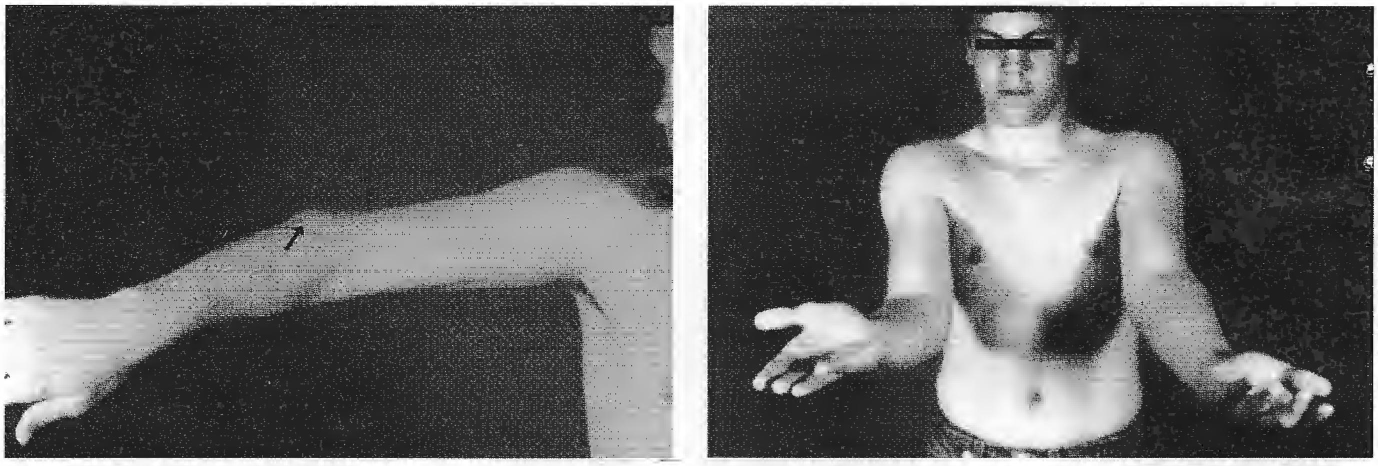

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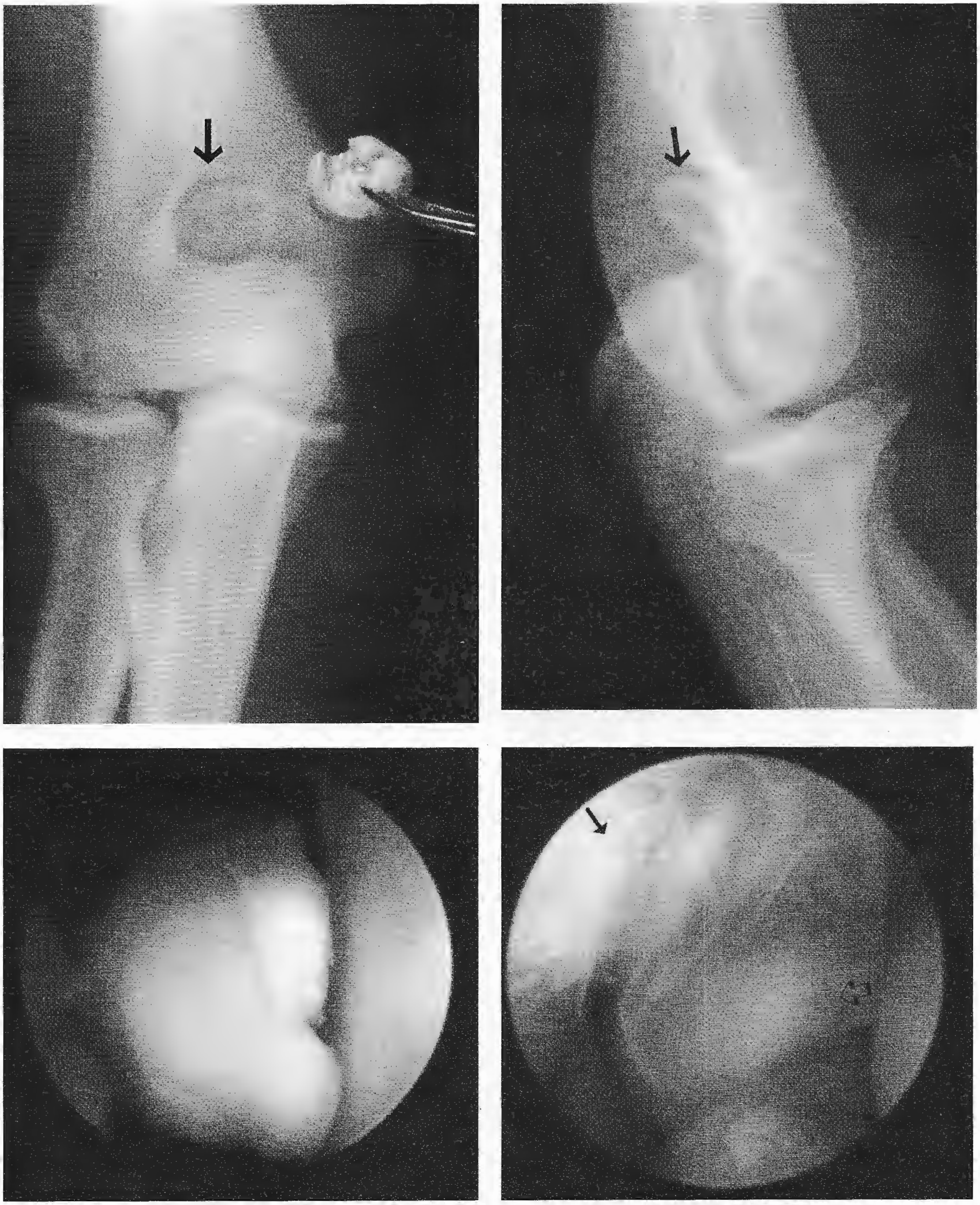
FIG. 18. (A) On physical exam a right-hand–dominant, former Little League pitcher was noted to have a very prominent radial head but with full pronation. **(B)** Extension clinically was limited by 45° degrees and supination by 30°. **(C)** Radiographs reveal radial overgrowth and degenerative changes of the capitellum.

FIG. 19. A right-hand–dominant pitcher was noted to have loss of extension range of motion and posterior pain. **(A)** AP and **(B)** oblique radiographs of the right elbow reveal a large, loose fragment in the posterior compartment. The large loose body removed by arthroscopy is shown **(A)**. The large fragment probably originated from the osteochondritic capitellar lesion. **(C)** An arthroscopic view of the posterior compartment reveals the large loose body being removed. **(D)** The capitellum with irregularity and adhesions is viewed arthroscopically (*arrow*). **(E)** Following debridement, only grade I chondromalacic changes are seen in the capitellum. **(F)** In a postoperative radiograph, the irregularity of the capitellum without the loose body is evident. *(Continued on following page.)*



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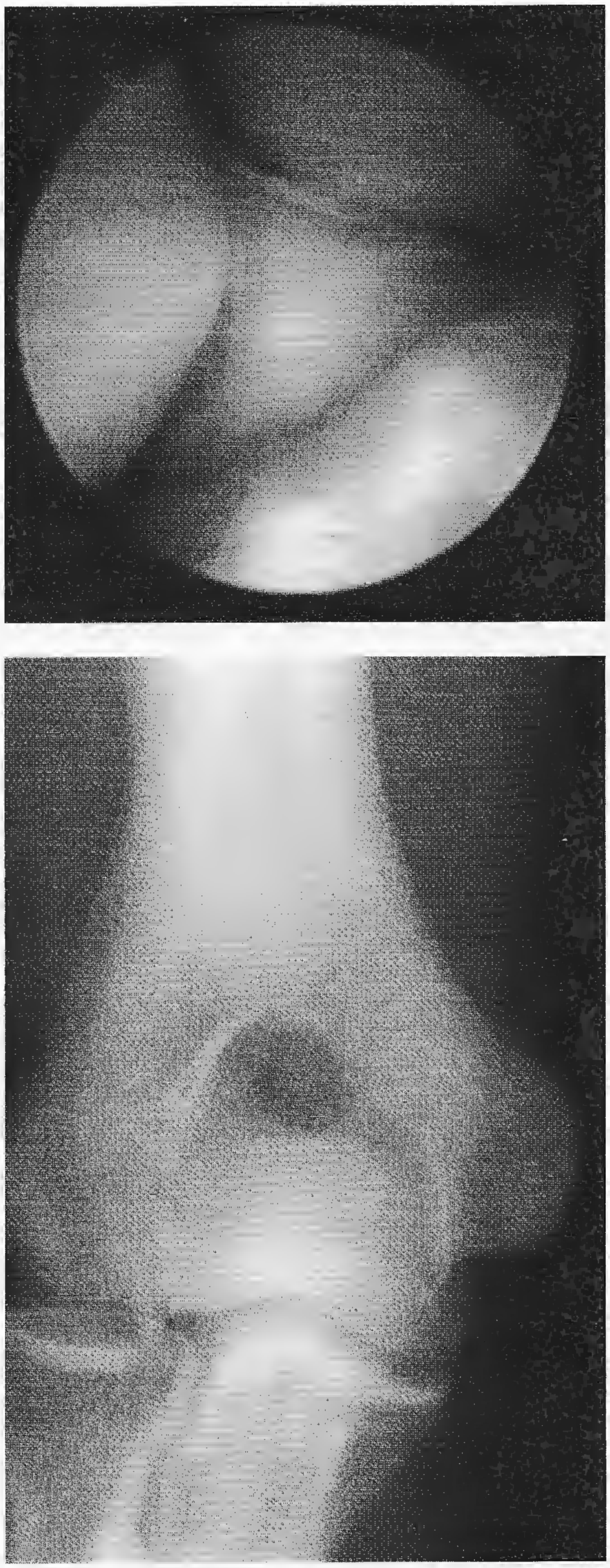

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FIG. 19. *Continued.*

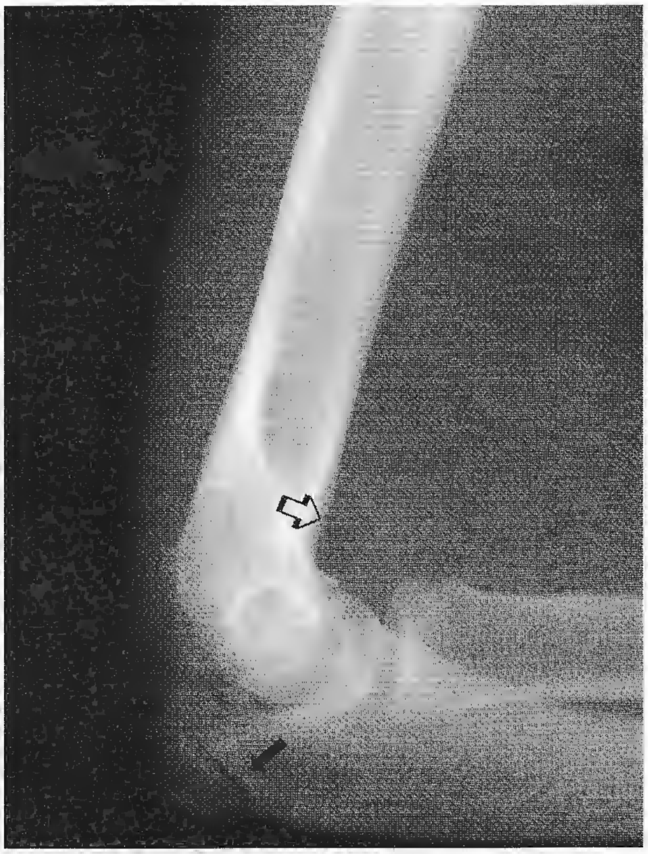

FIG. 20. Lateral view of the elbow of the pitcher who had tenderness over the olecranon apophysis. Lateral radiographs reveal an elevated fat-pad sign (*open arrow*) and increased lucency of the olecranon apophysis (*arrow*). The athlete was treated with relative rest for 3 weeks and a triceps strengthening program. He was able to resume baseball activities at 6 weeks following his injury.

The treatment goal is to regain normal extension range. If radiopaque loose bodies or joint articular surface irregularities are present, arthroscopic evaluation is indicated. Arthroscopic removal of loose fragments and adhesions in the anterior compartment improve motion, function, and pain.

OTHER ELBOW INJURIES IN ADOLESCENTS

Other elbow injuries in the pediatric age group include distal humeral physeal fractures, elbow dislocations, radial head and neck fractures, and neurovascular and soft tissue injuries. A complete differential diagnosis must include tumors, infection, trauma that is nonspecific sport related, congenital anomalies, rheumatologic diseases, child abuse, metabolic, and metastatic causes. Fortunately, those conditions and disorders are rare.

CONCLUSIONS

Knowledge of the unique development of the immature elbow, and the tensile and compression forces involved will allow for an earlier diagnosis and treatment plan to be instituted. Painful joint deforming processes like capitellar osteochondritis dissecans and other unrecognized disorders may result in permanent limitations of motion. Application of the knowledge of the more common injury patterns enable the sports medicine professional to be able to reduce the chance of permanent elbow problems. Ideally, the physician should make a specific diagnosis and institute proper early treatment. It is wise to counsel the young athlete, family, and coach on what should be done, what the potential complications are, and the reasons for the sometimes prolonged delay before returning to throwing. "Play and throw it safe."

Acknowledgements: Special thanks to Carolyn Large and Rick Hood for their assistance.

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