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EPIPHYSEAL FRACTURES OF THE DISTAL HUMERUS

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To Mignon, Louis, Pierre and André

CONTENTS

1. **INTRODUCTION**

1.1. Anatomy

1.2. Ossification

1.3. Blood supply to the distal humerus

1.4. Incidence

2. **CARRYING ANGLE**

3. **LATERAL CONDYLAR FRACTURES**

3.1. Incidence

3.2. Introduction

3.3. Patients and methods

3.4. Results

3.5. Discussion

(a) Mechanism of injury
(b) Pathology
(c) Classification
(d) Diagnosis
(e) Management
(f) Complications
(i) Lateral condylar overgrowth and loss of carrying angle
(ii) Cubitus valgus
(iii) Delayed union and non-union
(iv) Neurological deficit
(v) Fishtail deformity of the distal humerus
(vi) Avascular necrosis
(vii) Physeal arrest
(viii) Elbow stiffness
(ix) Infections

3.6. Conclusions

4. **FRACTURE-SEPARATION OF THE DISTAL HUMERAL EPIPHYSIS**

4.1. Introduction

4.2. Patients and methods

4.3. Results

4.4. Discussion

(a) Mechanism of injury
(b) Pathology
(c) Classification
(d) Diagnosis
(i) After appearance of the capitellar ossification centre
(ii) Before appearance of the capitellar ossification centre
(iii) Minimally displaced fractures
(e) Management
(f) Complications
(i) Cubitus varus

4.5. Conclusions

5. **MEDIAL CONDYLAR FRACTURES**

5.1. Introduction

5.2. Case report

5.3. Discussion

(a) Mechanism of injury
(b) Pathology
(c) Classification
(d) Diagnosis
(e) Management
(f) Complications
(i) Ulnar nerve injury
(ii) Associated fractures and dislocations
(iii) Elbow stiffness
(iv) Nonunion
(v) Cubitus varus
(vi) Cubitus valgus
(vii) Avascular necrosis of the medial condyle
(viii) Fishtail deformity of the distal humerus
(ix) Miositis ossificans

5.4. Conclusions

6. **T-CONDYLAR FRACTURES**

6.1. Mechanism of injury

6.2. Pathology

6.3. Classification

6.4. Diagnosis

6.5. Management

6.6. Complications

6.7. Conclusions

6.8. Table

7. **CONCLUSIONS**

8. **REFERENCES**

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OVERVIEW

This dissertation discusses distal humeral epiphyseal injuries in children, i.e. lateral condylar fractures, medial condylar fractures, fracture-separation of the distal humeral epiphysis and T-condylar fractures. Medial and lateral epicondylar fractures, being apophyseal, are excluded.

The research was done at the Red Cross Children's Hospital Trauma Unit. It was based on two clinical retrospective studies and one case report:

- a: 60 lateral condylar fractures presenting from 1984 to 1987 were reviewed.
- b: 12 fracture-separations of the distal humeral epiphysis presenting from 1984 to 1989 were reviewed.
- c: One case report of a medial condylar fracture with associated elbow dislocation

The distal humeral epiphysis is the second most commonly injured epiphysis in the body, after that of the distal radius (Peterson 1972). Supracondylar fractures are the most common fractures around the elbow in children, making up 65% of the total (Canale 1987). Lateral condyle fractures have an incidence of 17.4%, compared to 3.2% for medial condylar fractures and 0.8% for T-condylar fractures (Canale 1987). At the Red Cross Children's Hospital, 60 displaced supracondylar fractures, 20 lateral condylar fractures and 2 to 3 fracture-separations of the distal humeral epiphysis are seen every year. Medial condylar fractures are rare.

1. INTRODUCTION

1.1 Anatomy

The distal end of the humerus is flattened and expanded. The articular portion consists of the capitellum laterally and the trochlea medially. The non-articular portion consists of the medial and lateral epicondyles, the coronoid fossa anteriorly and the olecranon fossa posteriorly. The articular surface slants forward 40° upon the axis of the humeral shaft.

1.2 Ossification

During the first 6 months after birth the border of ossification of the distal humerus is symmetrical. The ossification centre of the lateral condyle usually appears towards the end of the first year, but can appear between 1 and 26 months after birth. The lateral ridge of the trochlea also ossifies from this centre. At about 6 years the medial epicondyle begins to ossify and at about 8 years the trochlea begins to ossify. Multiple centres may be present initially. The lateral epicondyle is the last to ossify with the ossification centre appearing between 8 and 13 years. Ossification progresses more quickly in girls than in boys. The distal humerus epiphysis fuses to the shaft between 12 and 16 years.

1.3 Blood supply to the distal humerus

Although there is a rich anastomotic arterial network around the elbow the blood supply to the epiphysis is limited to the soft tissue attachments to the epiphysis, because there is no communication between the intraosseus metaphyseal and epiphyseal vasculature. Secondly no blood vessels enter through the articular surface, but only at the capsular attachment and posteriorly to the lateral condylar portion which is extra-articular. Haraldsson (1957 and 1959), in a study of 33 cadaver elbows, of which 6 were from children, showed that the lateral condylar epiphysis was supplied by two groups of vessels which entered posteriorly and which did not communicate with the metaphyseal vessels. These vessels arise from the inferior ulnar collateral artery, which is a branch of the brachial artery. Two vessels supply the medial crista of the trochlea. The one vessel enters medially through the nonarticulating medial crista of the trochlea and the lateral vessel enters posteriorly.

1.4 Incidence

The epiphysis of the distal humerus is the second most commonly injured in the body, being much less commonly injured than the distal radial epiphysis. Peterson (1972) in a review of 3330 epiphyseal injuries in the literature found that the epiphysis of the distal humerus was injured in 16.7%. Boys are injured twice as commonly as girls, probably due to their more daring games. The age of peak

incidence for distal humeral injuries was 4 to 5 years for girls and 5 to 8 years for boys. These ages were much younger than that for other epiphyseal injuries, e.g. distal radius, ankle and femur, which had a maximal incidence for girls between the ages of 8 to 13 years and for boys 11 to 14 years. In my opinion, this difference in peak incidence can probably be explained on the basis that the lateral and medial condylar fractures of the distal humeral epiphysis are intra-articular fractures, i.e. Salter Harris type IV and therefore not dependent on a weak growth plate which leads to Salter Harris type I and II injuries which occur more commonly during adolescence at the other epiphyses in the body. However Salter Harris I and II injuries of the whole distal humeral epiphyses occurs in the age group 0 to 4 years 8 months which does not conform with this theory.

Injuries to the distal humerus account for most elbow injuries. The distal humerus accounts for 86.4% of fractures of the elbow region. (Wilkins 1984). At the Campbell Clinic (Canale 1987) fractures of the lateral condyle accounted for most of the injuries to the distal humeral epiphysis, so that 20 fractures of the lateral condyle were seen for every 4 fractures of the medial condyle and for every one T-condylar fracture. At Red Cross Children's Hospital 20 fractures of the lateral condyle are treated every year compared to 2 fracture-separations of the distal humeral epiphysis. Fractures of the medial condyle and T-condylar fractures are very rarely seen at Red Cross Children's Hospital.

2. CARRYING ANGLE

The carrying angle varies between 0° and 23° with no significant difference for the sexes. In a clinical study Smith (1960) found the average carrying angle in 80 girls to be 6.1° and in 70 boys to be 5.4°. The range for girls was 0° to 12° and for boys was 0° to 11°. Beals (1976) examined elbow radiographs of 422 patients but did not correlate the radiographic findings clinically. He found the carrying angle to vary between 0° and 35° with a mean of 15.0° in the 0 - 4 year age group and 17.8° in adults. The mean carrying angles for males and females were essentially the same.

The carrying angle in extension is caused by the spiral configuration of the humero-ulnar joint. The forearm is superimposed on the upper arm in flexion, because the axis of the elbow joint bisects the angle between the long axes of the humerus and forearm. The carrying angle is functionally of slight importance but cosmetically of greater importance. The carrying angle allows heavy objects carried by the extended arm to clear the legs whilst the humerus is passively supported against the chest wall. The cosmetic appearance is more important, especially to the female.

3. LATERAL CONDYLAR FRACTURES

3.1 Incidence

Fractures of the lateral condyle of the humerus are by far the most common injuries to the distal humeral epiphysis. Fractures of the lateral condyle constitute 54.2% of injuries to the distal humeral epiphysis (Wilkins 1984).

3.2 Introduction

Cubitus valgus and non-union classically were the complications of this injury. The pattern of complications of this injury has changed with more aggressive management which aims for anatomical reduction.

The aims of this study were: (i) to assess the incidence and severity of angular deformities, and (ii) to assess delayed union and non-union in reduced and slightly displaced fractures, immobilised for 4 weeks only. The period of immobilisation in the literature varies between 3 weeks (Wilkins 1984) and 8 weeks (Foster 1985). Furthermore, Foster recommends internal fixation and bone grafting if radiographic union is not present at 8 weeks.

3.3 Patients and methods

A retrospective study was done of 60 fractures in 60 patients who presented to the Red Cross Children's Hospital in Cape Town over a 3-year period from 1984 to 1987. Their folders and radiographs were reviewed. Although all 60

patients were requested to return for the study, only 32 (53%) returned for clinical review and radiographs of both elbows.

Our management was based on the stage of displacement, which was divided into three groups, similar to the description by Jakob et al (1975) and Foster et al (1985).

Stage I is when the displacement is 2mm or less on AP and lateral views; Stage II is when the fragment is displaced more than 2mm but not rotated; Stage III is when the fragment is widely displaced and/or rotated.

Stage I cases were managed with a backslab and collar and cuff.

Stage II cases were treated conservatively or operatively. Of the 8 Stage II cases available for late review, 2 were treated operatively and 6 conservatively. Of the 6 conservatively treated patients, 3 were reduced by pronating the forearm and flexing the elbow without anaesthetic. Of the 3 cases who were not reduced, 1 presented late with established malunion. Because of the difficulty in interpreting reduction on x-rays taken at follow up through plaster, we have abandoned conservative management of Stage II fractures.

All Stage III fractures had an open reduction and internal fixation with two Kirschner wires, leaving the K-wires protruding through the skin to avoid a second anaesthetic for removal of the wires. The posterior soft tissue attachments should not be disturbed to avoid avascular

necrosis of the lateral condyle. The blood supply enters mainly posteriorly. Post-operatively the arm was immobilised in a backslab and collar and cuff for 3 weeks. The wires were removed at 4 weeks.

The 32 patients available for late review were assessed clinically and radiographically, comparing both elbows. The patients were asked about pain, stiffness, cosmesis and ulnar nerve symptoms. The scar, range of movement and carrying angle were assessed clinically. Both elbows were compared radiographically for delayed union, non-union, malunion, avascular necrosis, lateral condylar overgrowth, fishtail deformity of the distal humerus, physeal bar formation and soft tissue ossification. The maximum metaphyseal diameter on both humeri were compared, in an attempt to quantify lateral condylar overgrowth.

The results were rated according to my modification of the rating system of Hardacre et al (1971). (Table I)

TABLE I : ASSESSMENT OF RESULTS

(Hardacre et al 1971 : modified)

	Excellent	Good	Poor
Carrying angle change (compared to normal side)	≤ 3°	4° - 9° varus ≤ 2°	≥ 10° varus ≥ 3°
Extension/flexion elbow (loss)	≤ 5°	6° - 14°	≥ 15°
Pronation/supination (loss)	≤ 5°	6° - 14°	≥ 15°
Radiographs			AVN/non-union
Symptoms	Nil	scar prominent	ulnar nerve deficit

3.4 Results

Of the 60 patients, 53 (88%) were boys and 7 (12%) were girls. Their ages varied between 1 year 7 months and 12 years, with an average of 5 years 10 months. The right side was injured in 15 cases (25%) and the left side in 45 (75%). 58 patients presented within 5 days of injury. 2 presented late, 1 at 3 months after injury and 1 at 5 months after injury. The associated injuries were 3 dislocated elbows and 2 undisplaced fractures of the olecranon. The dislocations were postero-medial. 17 patients (28%) had Stage I displaced fractures, 15 patients (25%) Stage II and the majority, 28 patients (47%) Stage III displaced fractures. 20% (12 cases) were Milch type I and 80% (40 cases) were Milch type II fractures.

32 patients (53%) were available for late review. The average follow up period was 19.5 months, with a range of 6 months to 35 months.

The results were divided into excellent, good and poor according to Table I. The overall results were 47% (15 cases) excellent, 31% (10 cases) good and 22% (7 cases) poor results. There were 8 Stage I cases, all having had an excellent or good result (Table II). 7 Stage I cases had a decrease in the carrying angle. There were 8 Stage II cases (Table III). The 2 cases treated operatively had an excellent and a good result. The 3 cases who had anatomical closed reductions had excellent results. One case presented late with a malunion and a stiff elbow. The

2 cases in which reduction was not achieved or maintained, had poor results. There were 16 Stage III fractures which had open reduction and internal fixation. In these, the results were excellent or good in 12, but poor in 4 (Table IV). The poor results were:

(a) 1 patient presented 5 months after injury with a stiff elbow and non-union. Open reduction was performed. He developed avascular necrosis (AVN) of the lateral condyle, but subsequently revascularised (Figures 1a and b).

(b) 1 patient developed AVN after early surgery, but united without delay.

(c) 2 other patients had a limited range of elbow movement.

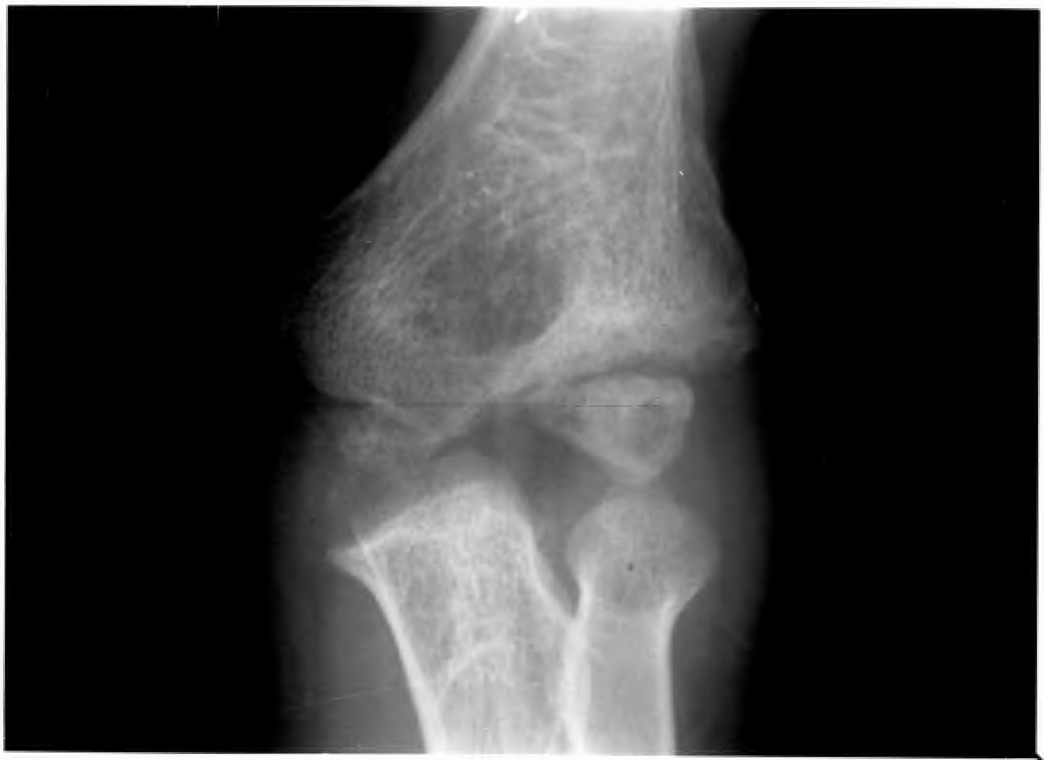


Figure 1a Avascular necrosis of the capitellum following open reduction and internal fixation of a Stage III fracture who presented 5 months after injury.

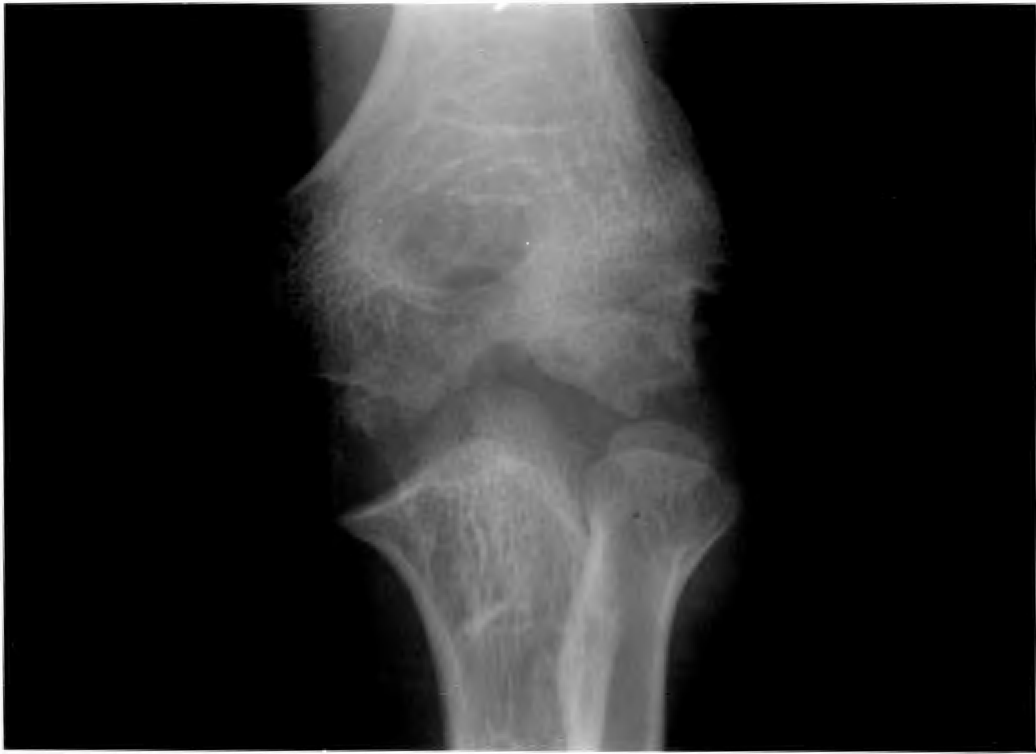


Figure 1b 7 months after surgery. The capitellum has revascularised. A fishtail deformity of the distal humerus is developing, probably caused by a gap in continuity of the physeal plate due to AVN.

TABLE II : RESULTS STAGE I

No.	Normal CA *	Change in CA **	Extension Flexion Loss	Pronation Supination Loss	Radio-graphs	Symptoms	Rating ***
1	9°	-5°	-	-	-	-	G
2	2°	-4° (cubitus varus)	-	-	LCO	-	G
3	6°	-3°	-	-	-	-	E
4	6°	-2°	-	-	-	-	E
5	2°	-4° (cubitus varus)	-	-	LCO	-	G
6	10°	-4°	-	-	-	-	G
7	5°	0°	5° (flexion)	-	-	-	E
8	0°	-4° (cubitus varus)	-	-	LCO	-	G

* CA = carrying angle

** minus = decreased carrying angle

plus = increased (valgus) carrying angle

LCO = lateral condylar overgrowth

*** E = excellent; G = good; P = poor

TABLE III : RESULTS STAGE II

a:

	Conservatively treated	Normal CA	Change in CA	Extension Flexion Loss	Pronation Supination Loss	X-rays	Symptoms	Rating
1	Reduced	8°	0°	-	-	-	-	E
2	Reduced	7°	-2°	-	-	LCO**	-	E
3	Reduced	3°	0°	5° loss flex	-	-	-	E
4	Not Reduced	4°	+2°	17° loss ext	-	Fishtail delayed malunion	-	P
5	Not Reduced	Late presenter Not measured due to FFD		FFD*60° 10° loss flex	-	malunion	stiff elbow	P
6	Not Reduced	5°	0°	25° loss flex	-	delayed malunion	stiff elbow	P

b:

Operatively treated	Normal CA	Change in CA	Extension Flexion Loss	Pronation Supination Loss	X-rays	Symptoms	Rating
1	8°	-3°	-	-	LCO **	-	E
2	10°	+5°	10° loss extension 5° loss flexion	-	? malunion	-	G

* FFD = fixed flexion deformity

** LCO = lateral condylar overgrowth

TABLE IV : RESULTS STAGE III

All treated with open reduction and internal fixation

No.	Normal CA	Change in CA	Extension Flexion Loss	Pronation Supination Loss	X-rays	Symptoms	Rating
1	8°	0°	-	-	-	scar	G
2	10°	- 2°	-	-	LCO**	-	E
3	6°	0°	-	-	-	-	E
4	8°	- 3°	-	-	LCO	-	E
5	8°	0°	-	-	AVN	-	P
6	0°	-5° (cubitus varus)	-	-	LCO	-	G
7	10°	- 2°	-	-	LCO	-	E
8	8°	- 4°	-	10° loss pronation	LCO	prominent LCO	G
9	4°	0°	-	-		-	E
10	5°	+ 1°	-	-	-	-	E
11	6°	+ 7°	10° FFD 7° flexion loss	-	malunion	-	G
12	8°	0°	-	-	-	-	E
13	Late presenter Not measured due to FFD		90° FFD 20° flexion loss	-	AVN	stiff elbow	P
14	7°	0°	-	-	delayed union	-	E
15	10°	cannot measure	20° FFD 20° flexion loss	-	-	-	P
16	8°		30° FFD	-	-	stiff elbow	P

* FFD = fixed flexion deformity

** LCO = lateral condylar overgrowth

3.5 Discussion

(a) Mechanism of injury

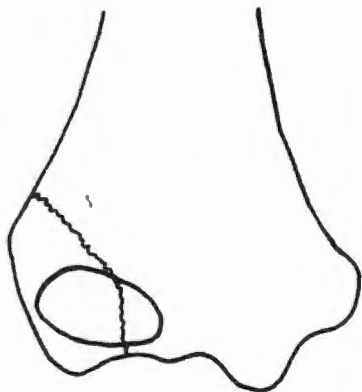
The mechanism of injury remains controversial, but the most accepted theory is that it is caused by a varus force applied to the forearm with the elbow extended and the forearm in supination. The lateral condyle is then pulled off by the extensor muscles and lateral collateral ligament. This theory was confirmed by Jakob et al (1975) who reporoduced this fracture in 4 of 7 elbows to which they applied a varus angulation force to supinated forearm with the elbow extended.

The alternative theory is that the lateral condyle is pushed off by the radial head in a valgus force. Jakob et al (1975) could not reproduce this fracture with a valgus force applied to the extended elbow in either pronation or supination, but it was not specified on how many cadaver elbows a trial had been made.

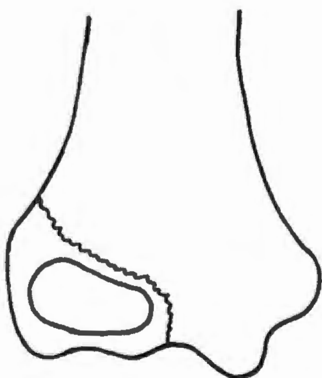
(b) Pathology

Fractures of the lateral condyle are all Salter Harris type IV injuries. There are two fracture patterns. The fracture starts posterolaterally in the metaphysis cortex and extends intraarticularly medial to the lateral trochlea lip, when it is a Milch type II fracture (page 22a). In a Milch type I fracture the fracture line extends into the capitellotrochlear groove. On radiographs the fracture line now divides the capitellar ossification centre, because this centre extends into the trochlea. In a Milch

DIAGRAM I



Milch type I fracture. The fracture line passes through the ossification centre of the capitellum. The ulna does not translocate laterally.



Milch type II fracture. The fracture line passes medially to the capitellar ossification centre. The ulna may translocate laterally.

type II the fracture line runs medial to the capitellar ossification centre (Milch 1964). There is usually a tear in the brachioradialis muscle. The condylar fragment is displaced laterally and anteriorly by the extensor muscles and lateral collateral ligament attached to it. The superior pole of the fragment may rotate up to 180° to come to lie inferiorly and the fracture surface may rotate laterally.

(c) Classification

The injury is classified according to the stage of displacement, dividing it into undisplaced and displaced (Fontanetta et al 1978, Rang 1983, Canale 1987); or into 3 stages (Jakob et al 1975, Wilkins 1984, Foster et al 1985) or even 4 stages (Badelon et al 1988); or according to the anatomical location of the fracture line (Milch 1964), Diagram I. For the purposes of this study I used the commonly used 3 stage classification. However this study has shown that simply classifying fractures presenting early into undisplaced and displaced fractures is the most useful from a management point of view, as poor results were due to incomplete anatomical reduction. The Milch classification was not helpful in acute management, because all displaced fractures should be internally fixed, whether they are Milch type I or II.

(d) Diagnosis

Following a history of injury the patient presents with elbow pain and loss of function of the elbow. There is localised swelling and tenderness over the lateral

condyle. There is less deformity than with supracondylar fractures. The radiographic features, as well as the differential diagnosis from fracture separation of the distal humeral epiphysis, are discussed under fracture separations of the distal humeral epiphysis (pages 42-47).

(e) Management

Lateral condyle fractures must be anatomically reduced. There is some difference of opinion about the method, especially in Stage II fractures, as well as about the duration of immobilisation. Stage I fractures are treated conservatively, but Foster et al (1985) and Wilkins (1986) recommend percutaneous pinning in selected, unreliable patients. For Stage II fractures Wilkins (1984) and Foster et al (1985) used closed reduction and percutaneous pinning, Apley (1982) closed reduction and plaster slabs and Jakob et al (1975), Rang (1983), Havraneck and Hajkova (1985) and Canale (1987) recommend open reduction and internal fixation. Stage III fractures are universally treated by open reduction and internal fixation.

In Stage I fractures with conservative management we had excellent or good results in all cases. In Stage II excellent or good results were obtained if anatomical reduction was achieved and maintained until union. Because of the poor results in fractures which malunited and because of the difficulty in interpreting follow up radiographs through the plaster backslab in these patients, I recommend open reduction and internal fixations of all Stage II fractures as suggested by Jakob (1975), Rang

(1983), Havranck and Hajkovo (1985) and Canale (1987). All Stage III cases should also be managed operatively.

The method of internal fixation which is most popular is two smooth pins, although a cancellous screw or even sutures have been used. Two smooth Kirschner wires are placed either crossed or parallel. The wires cross the growth plate. Obviously the fracture must be anatomically reduced, otherwise the wires will hold the fragments apart. The wires are left percutaneously, so that they can be removed easily without an anaesthetic.

The duration of immobilisation varies in the literature between 3 weeks (Wilkins 1984) and 8 weeks (Foster 1985). Our average immobilisation was 3.3 weeks and the wires were removed at 4 weeks. There was neither displacement after removal of the wires nor non-union. I agree with Wilkins that 3 - 4 weeks' immobilisation is adequate and that the wires may be removed after 4 weeks.

The patient who presents late with an untreated displaced fracture of the lateral condyle poses a problem in management. There were 2 late presenters in my series. I agree with Jakob et al (1975) that Stage II fractures presenting late should be left alone as open reduction carries a risk of AVN. I had one Stage III late presenter who presented 5 months after injury. Open reduction was done to provide stability and to prevent cubitus valgus and tardy ulnar nerve palsy. We used a lateral approach. Wilkins (1986) agrees that open reduction in Stage III injuries should be performed. Although this patient

developed AVN, he revascularised but his elbow remained stiff. Subsequently a third patient presented with a late Stage III fracture. To limit the soft tissue dissection we approached the distal humerus through the elbow joint by taking off the olecranon tip extra-articularly. This gave a better exposure. His follow up is still short.

Jakob (1975) had poor results in 7 patients who had delayed open reduction between 3 weeks and 3 months after injury. The most important complication was an average loss of elbow range of movement of 34°. Two patients had a valgus deformity and three patients had avascular necrosis of the capitellum. In 3 patients the elbows were still subluxed. All his late open reductions were done through a lateral approach. He also reported 5 cases who presented late and were left untreated. Three patients had a similar loss of elbow range of movement of 31° with 2 patients having normal movement. More importantly, one patient had a complete tardy ulnar nerve palsy and another patient had weakness of grip. One patient had a dislocated elbow, three patients had non-union and valgus deformities of the elbow. The functional results in the operatively treated group were therefore actually better than the functional results in the non-operatively managed group. Jakob et al also did not report if the avascular capitellums revascularised as in the case in my series, or not. I can therefore not agree with Jakob et al's recommendation that delayed open reduction is not indicated, but that immediate anterior transposition of the ulnar nerve is indicated. I agree with Wilkins (1986) that open reduction and internal

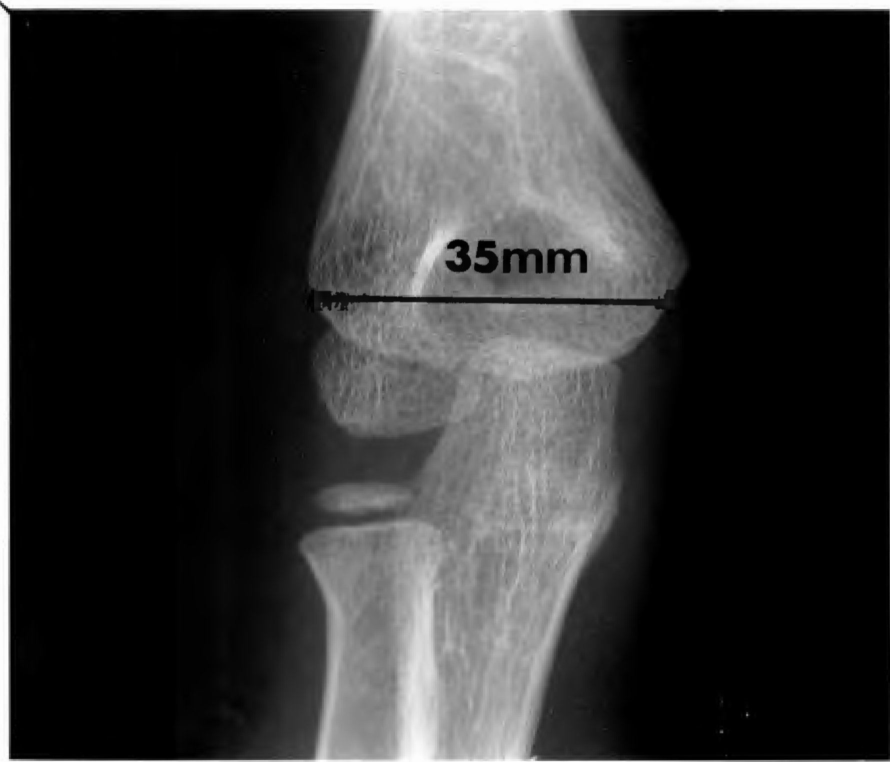
fixation is indicated in cases where the lateral condyle is widely displaced and rotated (Stage III) and also Stage II cases with non-union. I would suggest an approach through the olecranon cartilage or triceps and elbow joint, because this gives excellent exposure of the distal humerus' articular surface as well as allowing a less extensive dissection of the soft tissue attached to the lateral condyle.

(f) Complications

(i) Lateral condylar overgrowth and loss of carrying angle

Mild loss of carrying angle is the most common complication in reduced fractures. It occurred in 14 (44%) cases, concurring with Foster et al (1985) and So et al (1985). Like So et al (1985) I also found loss of carrying angle to be more common in undisplaced than displaced fractures. 7 out of 8 (87%) had loss of carrying angle if undisplaced initially, and 7 out of 24 (29%) with initially displaced fractures. Loss of carrying angle is only 3° on average, with a range of 2° to 5°. Cubitus varus occurred only if the carrying angle in the normal elbow was small (4 cases). Loss of carrying angle is probably caused by lateral condylar overgrowth. This is supported by the fact that 7 of the 8 undisplaced fractures had a decrease in carrying angle. Three cases with Stage II and III injuries had an increased carrying angle with the appearance of lateral condylar overgrowth. This was probably due to slight malunion. The range of elbow movement is not affected. In an attempt to quantify lateral condylar

overgrowth, the maximum transverse diameter of the metaphysis of both distal humeri was measured (Figures 2a and b). This measurement increased on average by 4mm, when compared to the normal elbow. This measurement did not take into account longitudinal overgrowth of the lateral condyle, because this is technically difficult to measure accurately.



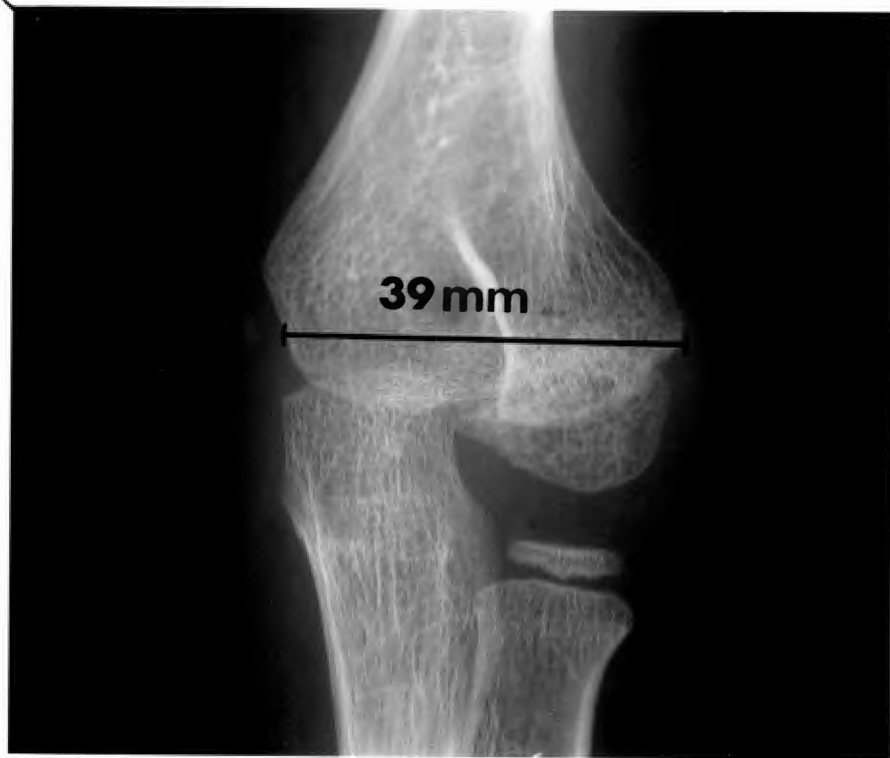
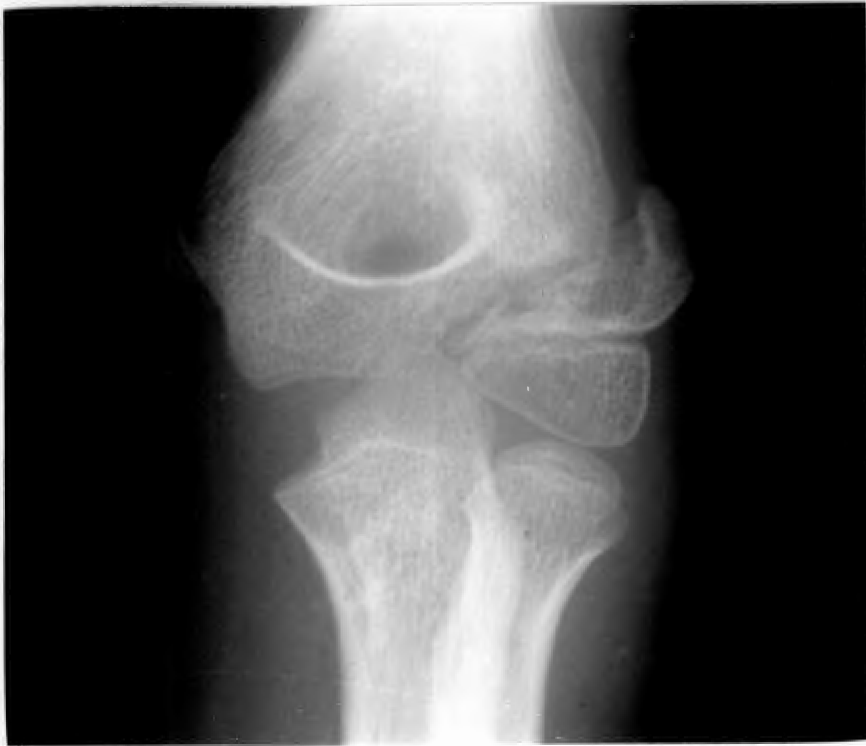


Fig. 2 The transverse diameter of the metaphysis of the fractured side (a) was compared with that of the normal elbow (b), in this case illustrating 4mm of lateral condyle overgrowth.



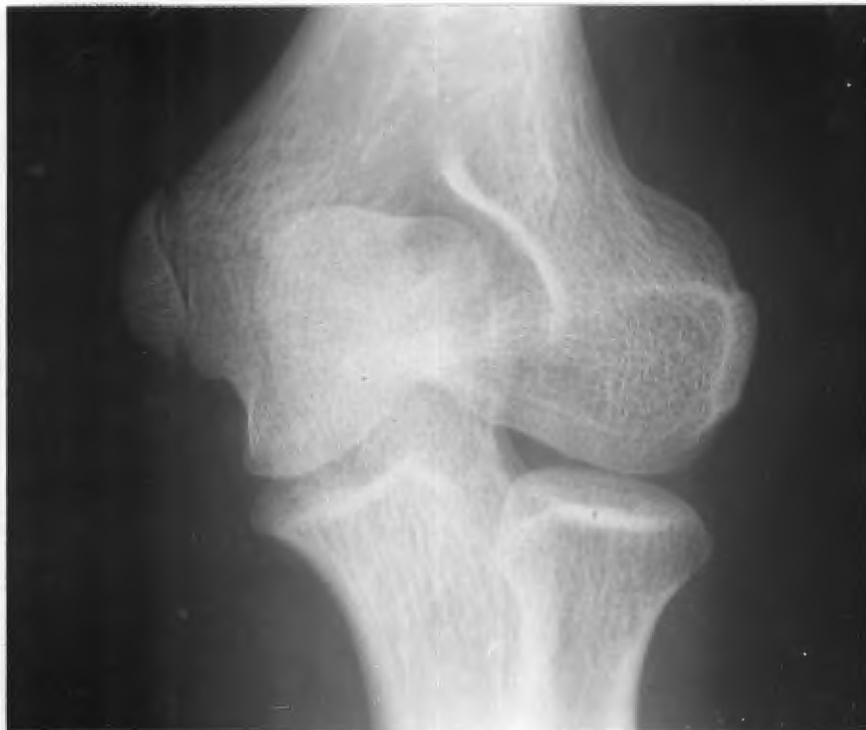


Fig. 3a Delayed union of inadequately reduced Stage II fracture 10 weeks after injury.

Fig. 3b At 2 years 6 months after injury a fishtail deformity of the distal humerus has developed.

(ii) Cubitus valgus

Although cubitus valgus is the classic complication of lateral condyle fractures, it usually follows on non-union and therefore on the conservative treatment of displaced fractures. Increase in the carrying angle in my series occurred only in displaced fractures and was probably due to malunion. It occurred in 4 cases (12%). This compares with the 19.2% reported by Jakob et al (1975) and 8.3% by So et al (1975). The carrying angle increased by 1° to 7°. 3 of these cases had limitation of elbow movement (15° to 17° loss). One of these had a fishtail deformity of the distal humerus which in this case was due to malunion and not to AVN (Figures 3a and b).

Is it necessary to treat cubitus valgus at all? Jakob et al (1975) recommended no osteotomy, because osteotomy would not protect the ulnar nerve, as discussed under neurological injuries; and the function of the elbow is not improved by the osteotomy. Osteotomy is rarely indicated for cosmetic reasons.

Wilkins (1984) recommended Milch's combination angulation and translocation osteotomy for cubitus valgus. He described the use of a closing wedge or an opening wedge osteotomy with lateral displacement of the distal fragment to avoid a prominent medial epicondyle. Wilkins uses a posterior approach for this procedure. Milch (1964) notched the inferior surface of the osteotomised humerus

and then fixed the medial cortex of the distal fragment in this notch. The forearm was angulated to the desired degree and then fixed with crossed Kirschner wires. If the medial epicondyle is not prominent after correction of the varus, which happens in a Milch type I fracture, then lateral displacement of the distal fragment is not necessary. Milch did not report the results of his osteotomies.

(iii) Delayed union and non-union

Foster et al (1985) recommended internal fixation and possible bone grafting if the fracture is not united radiographically at 8 weeks. However, late open reduction frequently leads to AVN of the capitellum as reported by Hardacre et al (1971) and Jakob et al (1975). 3 of my patients had delayed union at 8 weeks; 2 were due to unreduced conservatively managed Stage II fractures, and the third patient had an open reduction 5 months after injury. All 3 patients were allowed to mobilise at 3 to 4 weeks irrespective of the radiographic appearance. All 3 cases united. One patient had a malunion causing a fishtail deformity of the distal humerus (Figures 3a and b). All 3 patients had limited range of movement. No patient developed non-union. I recommend managing delayed union conservatively because radiographic evidence of union appears late (Figures 4a and b) and because late open reduction has an increased risk of AVN. The good results with the use of K-wires indicate that a screw, as suggested by Jeffery (1958), is not necessary for internal fixation

and that 3-4 weeks of immobilisation is adequate.

Non-union should be left alone if the patient is asymptomatic, because osteosynthesis leads to some elbow stiffness. Osteosynthesis is only indicated in patients with pain or apprehension due to lateral instability (Masada et al 1990). Masada et al (1990) combined osteosynthesis with anterior transposition of the ulnar nerve, because 23 of their 30 patients with non-union had definite hypoaesthesia, muscle weakness and clawing. 2 incisions were made, postero-laterally and medially. The extensor muscle attachment was preserved, fibrous tissue cleared from the joint, the fracture surface nibbled and the fragment fused in its anatomical position, provided that elbow movement was not limited after temporary reduction. The proximal part of the olecranon was routinely excised. If reduction blocks elbow movement, the fragment was fused in the displaced position that allowed movement. If there was a valgus deformity, a corrective osteotomy was also done. The ununited fragment was fixed with Kirschner wires and a wedge shaped bone graft was added in 3 cases. Postoperatively a long cast was worn until union. It was found that osteosynthesis did not affect ulnar nerve function, but that it resolved pain and apprehension with elbow use.

(iv) Neurological deficit

Acute neurological injury is rare.

Tardy ulnar nerve palsy develops as a complication of

cubitus valgus following on non-union of untreated displaced lateral condyle fractures. Motor loss occurs first. It is difficult to know how to manage these patients, because there are no series comparing different methods of management. The results of prophylactic osteotomy are not known. Even after osteotomy the ulnar nerve may be irritated due to post-traumatic arthritis of the elbow. Furthermore, because the olecranon remains laterally subluxed after an osteotomy in Milch type II, the cruciate ligament covering the nerve in its tunnel remains taut and may continue to compress the nerve. Hardacre et al (1971) recommended that the patient be taught the early symptoms of ulnar neuritis so that the ulnar nerve could be transposed anteriorly as soon as symptoms developed. Jakob et al (1975) recommended that the nerve be transposed prophylactically as soon as the child with cubitus valgus presents. I would reserve Jakob's approach for unreliable parents and patients. In reliable parents and patients the ulnar nerve should be transposed as soon as symptoms appear. Osteotomy is probably not indicated.

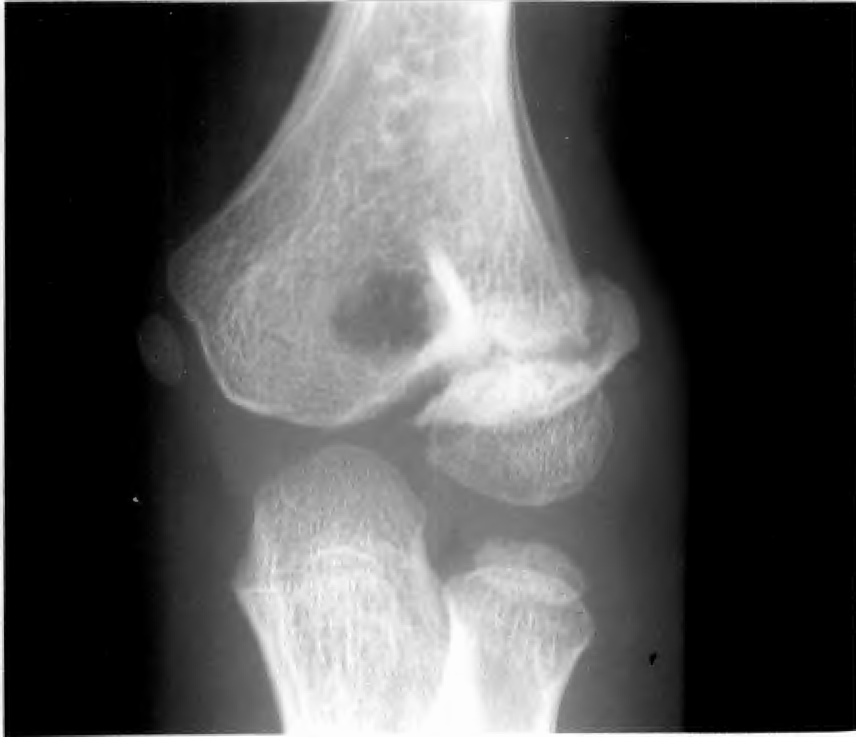


Fig 4a Inadequately reduced Stage II fracture shows delayed union at 8 weeks

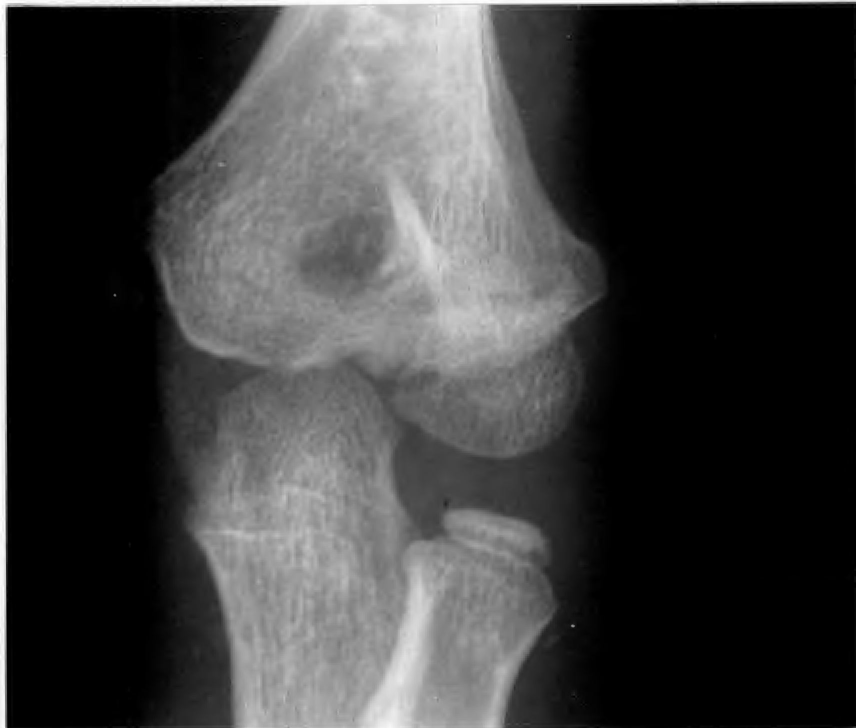


Fig 4b The fracture united without operative intervention 5 months post injury.

(v) Fishtail deformity of the distal humerus

There were two fishtail deformities in my series. Rutherford (1985) had an incidence of 23% of fishtail deformity. In the literature there is controversy whether this is due to avascular necrosis, malunion or growth arrest. My one case is in accordance with the findings of Rutherford (1985) that fishtail deformity is due to malunion and separation of the two portions of the epiphyseal plate (Figures 3a and b). My second case had a gap in the physeal plate probably on the basis of AVN (Figure 1b). The pathogenesis is described under avascular necrosis. The case with malunion had a poor result (Table III), but the second case had normal function.

(vi) Avascular necrosis

There are two patterns of avascular necrosis associated with lateral condyle fractures. In the first type the whole or most of the lateral condylar fragment becomes avascular because most of the blood supply to the fragment is interrupted. This occurred in 2 cases in my series. In one case it followed late open reduction in a displaced lateral condyle fracture that presented 5 months after injury (Case 13, Table I). The lateral condyle revascularised and the fracture united, but the elbow remained stiff, and clinically had a poor result. The second case developed partial AVN following early open reduction and Kirschner wire fixation (Case 5, Table IV). He clinically had a good result after revascularisation. It is important to avoid the soft tissues attached to the

posterior aspect of the lateral condyle, because this is where the main blood supply enters. This case also revascularised and united.

The second pattern of AVN occurs when the transphyseal vessels to the lateral ossification centre of the lateral crista of the trochlea is interrupted. This causes a fishtail deformity of the distal humerus. This may result in degenerative joint disease.

(vii) Physeal arrest

It is surprising that physeal arrest is rare, considering that lateral condyle fractures are Salter Harris type IV injuries. This would lead to cubitus valgus, which would be an increasing deformity with growth. However cubitus valgus occurs mostly as a complication of non-union. There were no cases of physeal arrest in my series.

(viii) Elbow stiffness

The elbow range of movement was limited by 15° or more in 8 patients. The 8 patients could be subdivided as follows: 2 patients presented late with stiff elbows, 4 patients had malunion (1 was also a late presenter), 3 patients had decreased movement after open reduction without malunion. Pronation and supination were normal.

The causes of elbow stiffness are avoidable, namely excessive duration of immobilisation and malunion. Lateral condyle fractures do not have to be immobilised for longer

than 4 weeks. Elbow stiffness should be treated by active mobilisation.

Myositis ossificans has not been described in lateral condyle fractures in children.

(ix) Infections

There were no infections in this series, although the Kirschner wires were left extruding through the skin for easy removal. By leaving the wires percutaneously a second anaesthetic for removal of the wires is avoided. The wires must be bent over so that they cannot migrate.

3.6 Conclusions

Displaced lateral condyle fractures should be anatomically reduced by open reduction and internal fixation. Lateral condylar overgrowth with a mild decrease in carrying angle is the most common complication of reduced fractures. Delayed unions are successfully managed conservatively. Non-unions are rare in reduced fractures. Poor results are due to late presenters, inadequate reduction and extensive soft tissue dissection with resultant avascular necrosis of the capitellum.

4. FRACTURE-SEPARATION OF THE DISTAL HUMERAL EPIPHYSIS

4.1 Introduction

Fracture-separation of the distal humeral epiphysis is a rare injury, with reports in the literature varying from case reports to a series of 16 patients (de Lee et al 1980). In Red Cross Children's Hospital we see 2 to 3 cases per year, compared to about 20 fractures of the lateral condyle of the humerus and 60 displaced supracondylar fractures per year. I report 12 cases.

Careful evaluation of the radiographs usually makes it possible to distinguish fracture-separation of the distal humeral epiphysis from fractures of the lateral condyle of the humerus and elbow dislocation. Arthrography is helpful in difficult cases.

4.2 Patients and methods

Twelve patients with fracture-separation of the distal humeral epiphysis were treated at Red Cross Children's Hospital from July 1984 to February 1989. Their ages ranged from birth to 4 years 8 months. In 8 cases the left humerus was fractured and in 4 cases the right humerus. The mechanism of injury was a fall in 7 cases, child abuse in 3 cases, motor vehicle accident in 1 case and a birth injury in 1 case. Three cases presented after a delay of more than 7 days. The delay followed child abuse in 1 case, birth injury in another case and 1 patient was treated elsewhere and presented 3 months after injury.

The initial diagnosis was wrong in 4 cases, the wrong diagnosis being that of a fracture of the lateral condyle in 3 cases and elbow dislocation in 1 case. The displacement was posteromedial in 11 cases and anterior in 1 case. No patient had neurovascular damage.

A Thurston-Holland fragment (Salter Harris type II) was present in 7 cases. The 5 patients who had Salter Harris type I injuries were younger than 2 years. Two patients who were abused had evidence of other healing fractures (Fig 5). The patient who was involved in a motor vehicle accident also had flexor tendon injuries at the wrist to the same limb. She was treated elsewhere and presented 3 months after injury to our unit with a stiff elbow.

Three patients had closed reduction followed by immobilisation in pronation for 3 weeks and 4 patients had open reduction and Kirschner wire fixation through a lateral approach for the mistaken diagnosis of fracture of the lateral condyle. The other 5 patients were not reduced, because 2 were only slightly displaced and 3 presented more than a week after injury.

Ten patients were available for long term review. Clinically their sypmtoms, carrying angle, range of movement of the elbow and pronation and supination were assessed. Full length radiographs were obtained of both arms in extension and supination for measurement of their carrying angles according to the humeral-elbow-wrist angle (HEW) described by Oppenheim et al (1984), as well as lateral radiographs. Their follow up varied between 6 and

31 months, with an average of 13 months.

4.3 Results

(a) Carrying angle

A cubitus varus of between 5° and 15° was noted in 3 of the 10 patients who had radiographic measurement of their humeral-elbow-wrist angles at follow up (Table V). Two of these patients had attempted closed reduction under general anaesthetic on admission and 1 patient had an open reduction and fixation with Kirschner wires. All 3 patients were younger than 2 years.

(b) Range of movement

Elbow range of movement was limited by less than 25° in 5 patients. This slight decrease in elbow range of movement did not interfere with function. The patient who presented 3 months after injury and who also had tendon repairs performed on the ipsilateral forearm, had a flexion deformity of the elbow of 55°. All patients had full pronation and supination.

4.4 Discussion

(a) Mechanism of injury

The injury is usually due to a fall, child abuse or a birth injury. Most fractures are of the extension type with the epiphyseal fragment displaced posteriorly. Flexion type injuries are very rare, with 1 case reported by K.E.

Wilkins (1984) and 1 case reported by McIntyre et al (1984). Although Ruo (1987) reported 8 flexion type fractures, his illustration is not convincing and casts doubt on his own series. One case in my series was displaced anteriorly and 11 were displaced postero-medially.

(b) Pathology

The distal fragment includes the medial epicondyle as part of the epiphysis until the age of about 7 years. At this age the medial epicondyle separates from the distal humeral epiphysis. The collateral ligaments are attached to the medial epicondyle and so to the distal fragment, so that the fragment displaces with the radius and ulna, maintaining the elbow joint. Because the fracture is more distal than a supracondylar fracture the fracture surfaces are greater than in a supracondylar fracture. This greater surface area should prevent tilting of the distal fragment, provided that the reduction is exact.

Part of the blood supply to the medial crista of the trochlea courses through the physis so that avascular necrosis of the trochlea is a theoretical possibility following interruption of this blood supply.

(c) Classification

De Lee et al (1980) classified fracture-separation of the distal humeral epiphysis into three groups, based on the roentgenographic appearance of the distal fragment.

Group A : Newborn to nine months old, characterised by (i) no ossification centre present in the capitellum and (ii) no metaphyseal fragment on the distal fragment.

Group B : Seven months to three years old, characterised by (i) an ossification centre present in the capitellum and (ii) a very small or no metaphyseal fragment; and

Group C : Three to seven years old, characterised by (i) a well-developed ossification centre present in the capitellum and (ii) a large metaphyseal fragment.

For the purposes of management I classify these injuries into minimally displaced and displaced groups. The displaced group is subdivided into those before the appearance of the ossification centre of the capitellum and those after appearance of the ossification centre. This classification is helpful in diagnosis and management.

(d) Diagnosis

Fracture-separation of the distal humerus must be distinguished from a fracture of the lateral condyle in the older child and elbow dislocation in the younger child.

(i) After appearance of the capitellar ossification centre (usually older than 1 year)

It can be differentiated from a fracture of the lateral condyle as follows:

(i) The displacement of the capitellum is posteromedial instead of anterolateral as with lateral condylar

fractures. The exception would be a rare flexion type fracture-separation of the epiphysis, which would be displaced anteriorly. The displacement of the capitellum is measured in relation to a line drawn on the anterior cortex of the humeral shaft on the lateral radiograph. This line should bisect the middle third of the capitellar ossification centre. Posterior displacement of the capitellar centre in relation to this line can be the only radiographic feature of a Salter Harris type I injury.

(ii) A line bisecting the radius (Støren 1958) should always pass through the capitellar ossification centre on all views in fracture-separation of the epiphysis, because the epiphysis is displaced with the radius and ulna. In a displaced lateral condylar fracture the capitellum is displaced in relation to the radial shaft line (Fig 6).

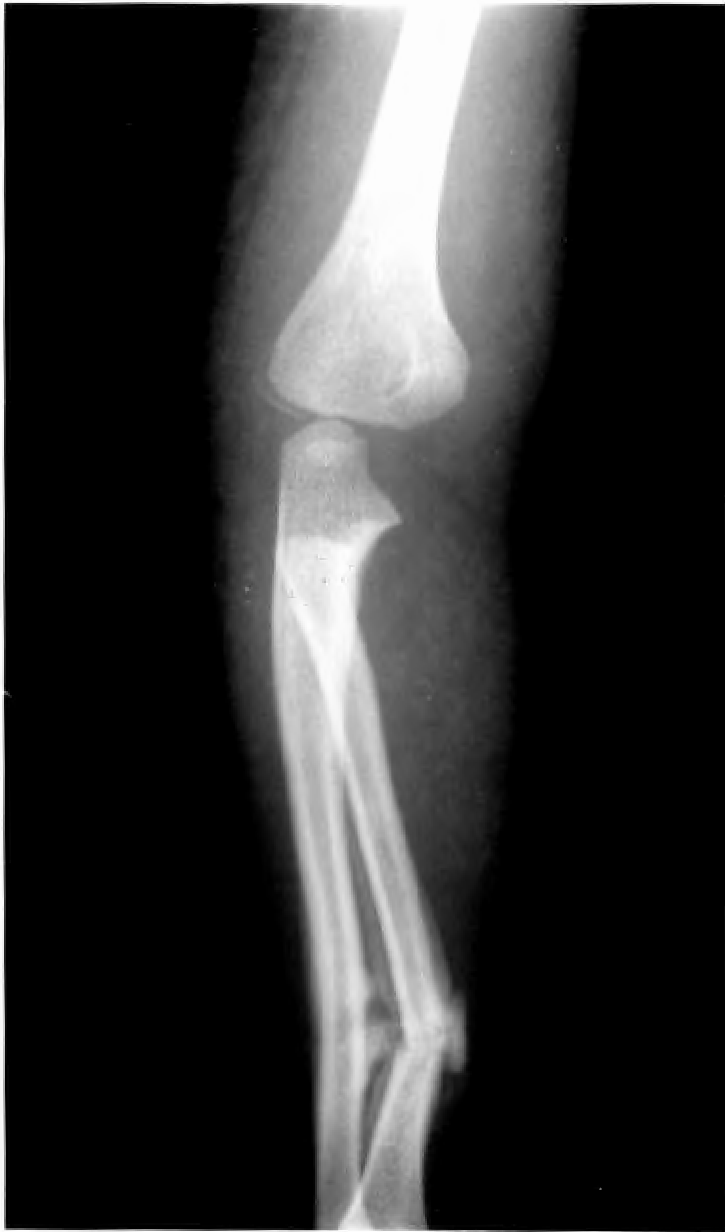
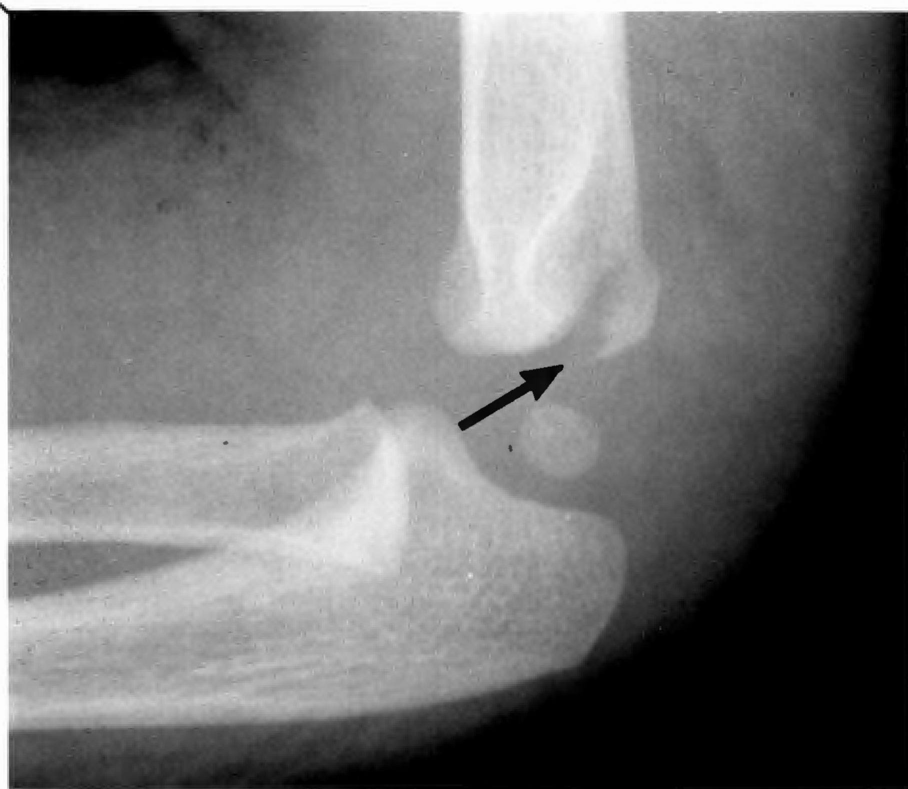
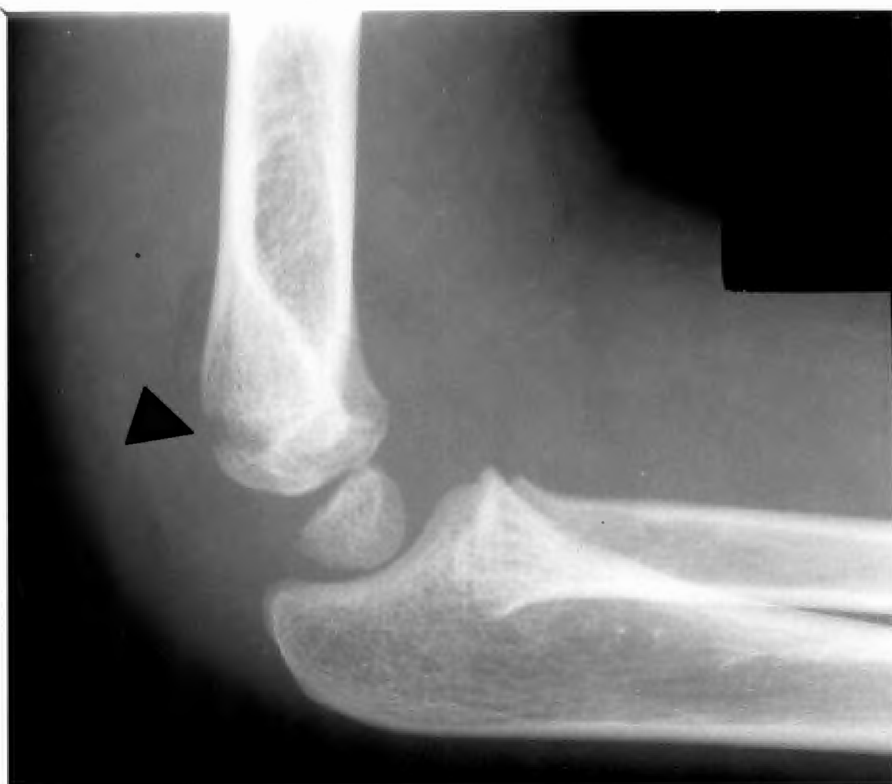


Fig 5: Fracture-separation of the distal humerus may be caused by child abuse

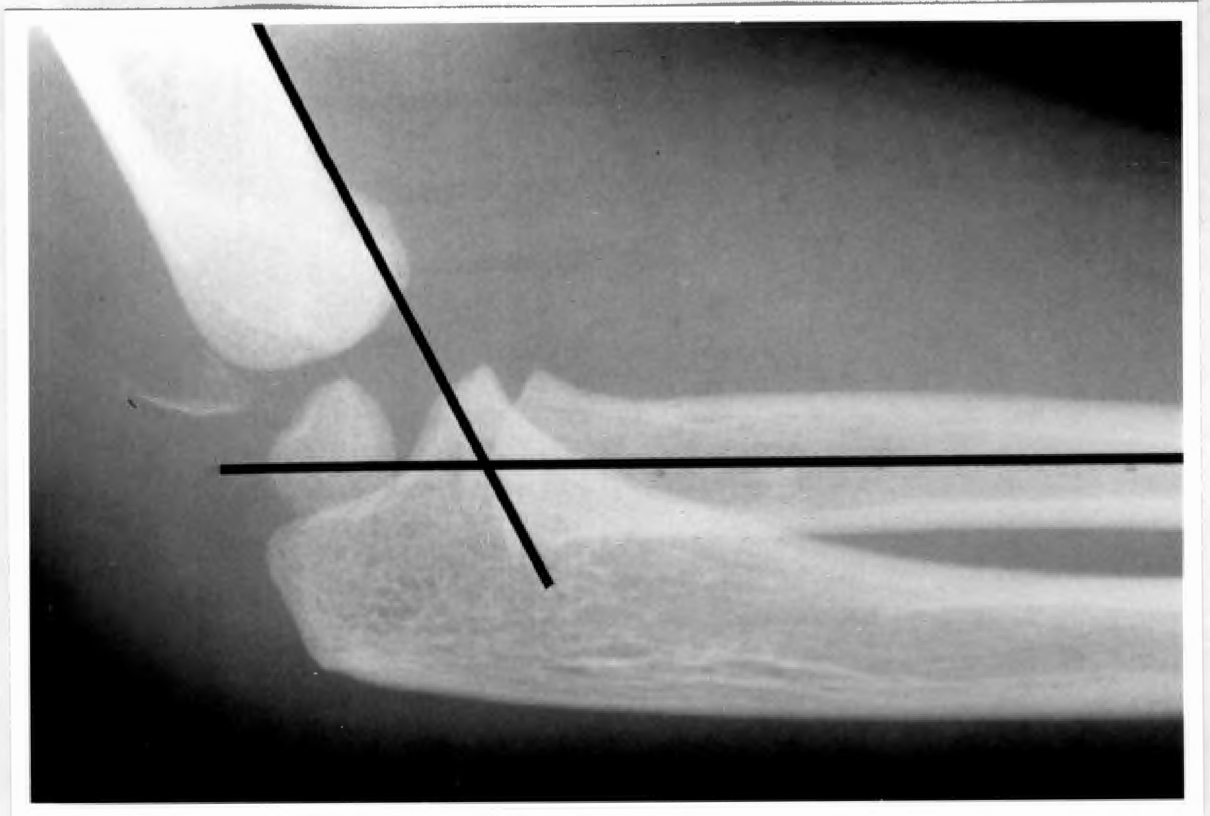


Fracture-separation of the distal humeral epiphysis

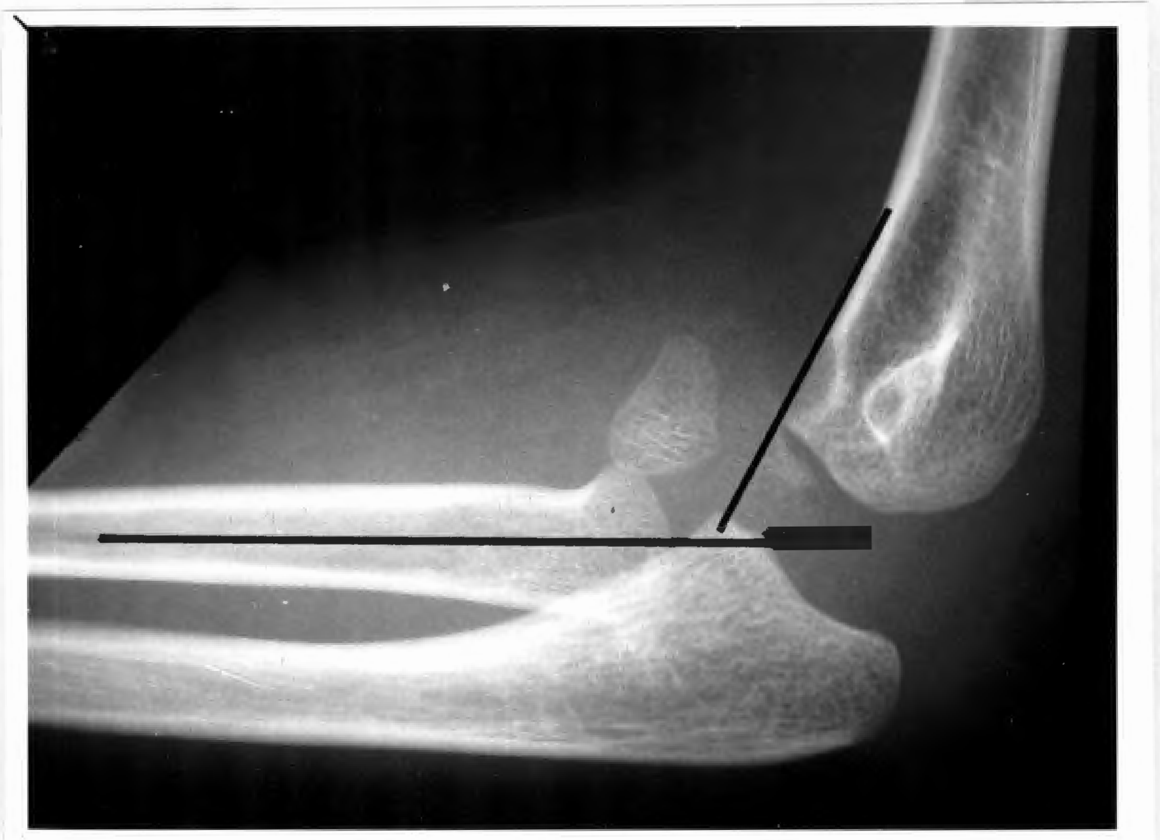


Fracture of the lateral condyle

Fig 6 (a) : Minimally displaced fractures (see text)



Fracture-separation of the distal humeral epiphysis



Fracture of the lateral condyle

Fig 6 (b) : Displaced fractures (see text)

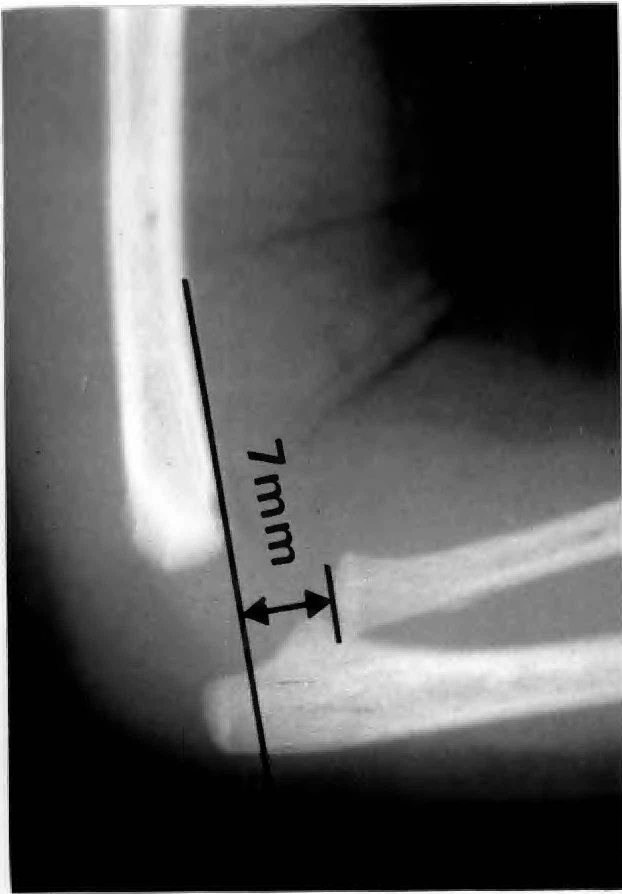
(ii) <u>Before appearance of the capitellar ossification centre (before 1 - 2 years)</u>

The capitellar ossification centre appears between the ages of one month and 26 months (Wilkins). Accurate diagnosis of an elbow injury is very difficult if the centre is not yet present. The only helpful feature on standard radiographs is the decreased gap between the radial metaphysis and the anterior humeral line when compared to a similar view of the normal elbow (Fig 7). This posterior displacement of the proximal radius and ulna is due to posterior displacement of the humeral epiphysis and should not be confused with a posterior dislocation of the elbow although elbow dislocation had not been reported before the age of 4 years (Wilkins). An arthrogram will give the answer if there is any doubt about the diagnosis (Fig 8) (Mizuno et al 1979; Akbarnia et al 1986; Yates et al 1987). Recently the use of ultrasound in diagnosis was reported (Dias et al 1988).

(iii) <u>Minimally displaced fractures</u>

These fractures are the most difficult to diagnose accurately. If the fracture is still hinging on one side, then the side of the hinge is helpful in distinguishing a fracture-separation from a fracture of the lateral condyle. This has not been described before. Because the fracture-separation is an extension injury, it hinges posteriorly and opens up more anteriorly (Fig 6a). The

lateral condyle fracture hinges anteroinferiorly and therefore opens up more posteriorly (Fig 6a). This hinging is a radiographic differentiating feature between lateral condylar fractures and fracture separation of the epiphysis. However arthrography remains helpful in confirming the diagnosis (Yates and Sullivan 1987)(Fig 8).



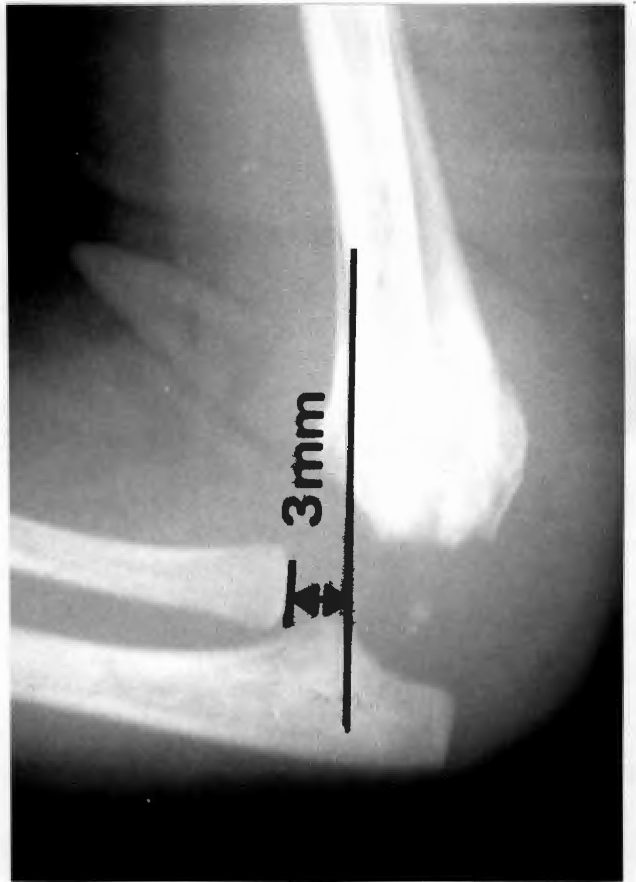
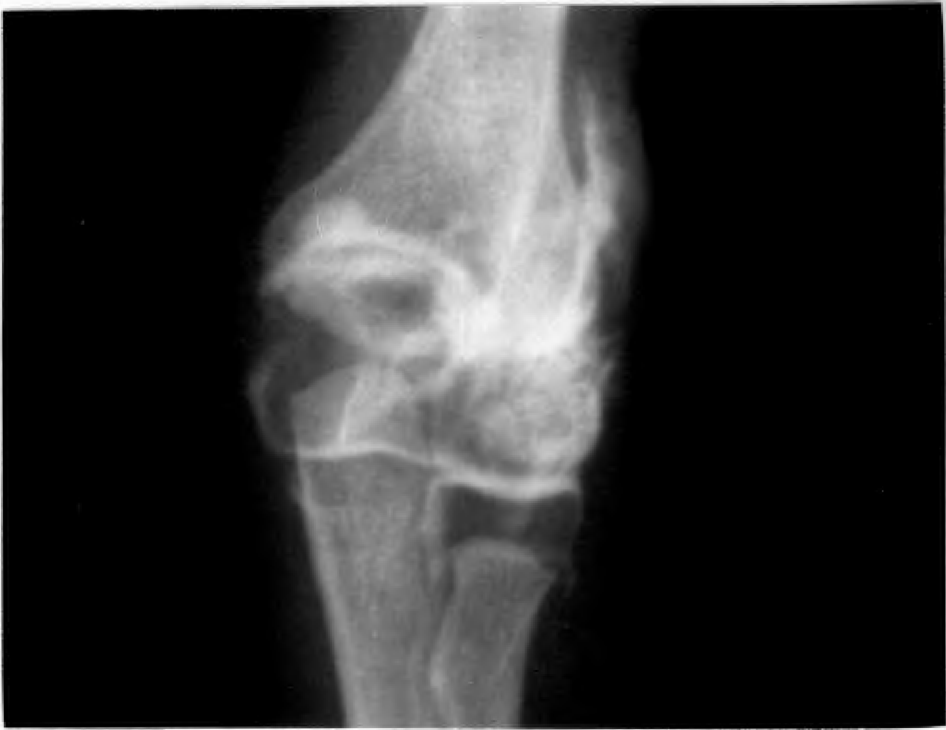


Fig 7 : The decreased gap between the radial metaphysis and the anterior humeral line is the only diagnostic feature before appearance of the capitellar ossification centre.



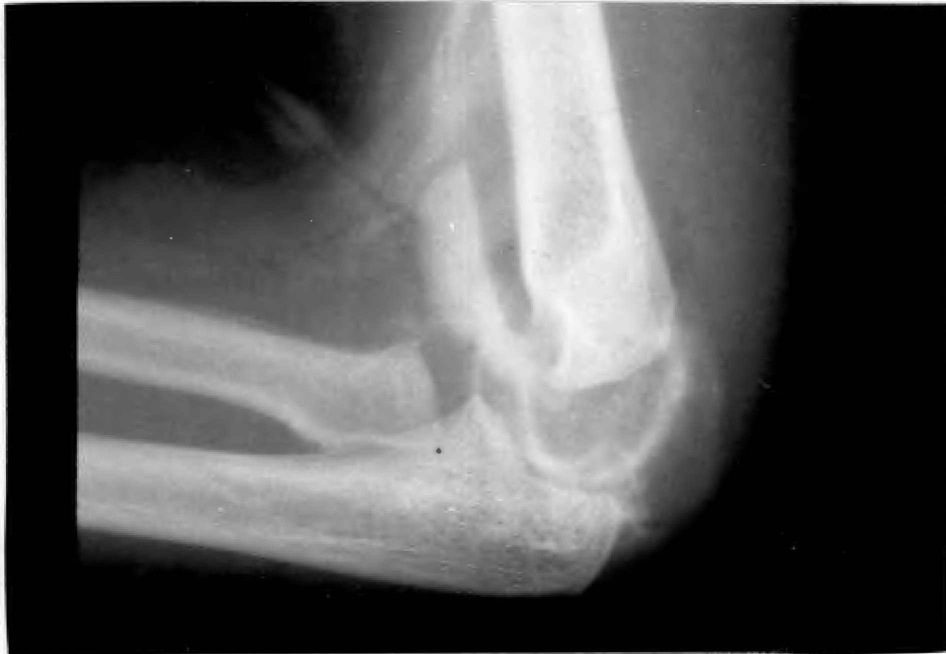


Fig 8 : This arthrogram demonstrates the intact articular cartilage in a fracture-separation of the distal humeral epiphysis.

(e) Management

Most authors (Siffert, de Lee et al, K.E. Wilkins, Holda et al) recommend treatment as for supracondylar fractures, i.e. closed reduction followed by immobilisation with plaster backslabs. Peiro et al (1981) preferred closed reduction and Kirschner wire fixation, whereas McIntyre treated younger patients conservatively and older patients operatively, arguing that younger patients can remodel but that older patients need accurate reduction. Mizuno et al (1979) recommended open reduction and Kirschner wire fixation through a posterior approach taking off the triceps insertion with a piece of olecranon cartilage.

Reviewing the literature and combining it with my series, I found the incidence of cubitus varus to be 25% with most cases occurring in children younger than two years (Table VI). I therefore recommend that in children younger than 2 years closed reduction is followed by percutaneous pin fixation with image intensifier control so that the elbow can be extended and the carrying angle measured clinically immediately following reduction. If the elbow is still in varus, the wires should be removed, further reduction attempted and the patient then managed in straight lateral traction (Piggott et al 1986) to monitor and maintain a valgus carrying angle. Open reduction is not recommended. In children over the age of 2 years the fracture separations are managed as supracondylar fractures, i.e. closed reduction and immobilisation in pronation and flexion of 100° in a plaster backslab for 3 weeks.

(f) Complications

(i) Cubitus varus is the most common complication and can be severe enough to be cosmetically unacceptable. If one combines the series of Siffert (1963), Mizuno et al (1979) de Lee et al (1980), Holdo et al (1980), McIntyre et al (1984) and mine (Table V), then cubitus varus of between 5° and 15° occurred in 12 of 48 patients (25%). Cubitus varus is therefore as common following fracture-separation of the distal humerus as following supracondylar fractures, where it occurs in approximately 30% of reported cases (Labelle et al 1982). Ten of these 12 cases of cubitus varus occurred in patients younger than 2 years, although this injury is only slightly more common in this age group (Table VI). Neither closed nor open reduction and Kirschner wire fixation prevented cubitus varus. Closed reduction failed in 6 cases and open reduction and Kirschner wire fixation in 3 cases in the combined series. (It is not clear how many of the 3 cases with cubitus varus in de Lee et al's study were reduced.) The cubitus varus is due to medial tilt of the distal fragment, as in supracondylar fractures. None of the combined series had increasing deformities due to growth plate arrest.

The surface area at the fracture is greater with separation of the epiphysis than with supracondylar fractures, so that one would expect a stable reduction without rotation and medial tilt. Why then is cubitus varus so common before the age of 2 years? It is probably due to inadequate reduction with medial tilt. Baumann's angle cannot be used

to check the reduction, because the separation takes place at the margin where one would normally draw the line. The secondary ossification centre of the capitellum can only be used to judge the accuracy of the reduction when it is clearly visible. Furthermore before the age of 2 years it is usually a Salter Harris type I injury, which does not have a metaphyseal fragment that makes an inadequate reduction obvious. Why did open reduction fail in 3 cases in the combined series? This is more difficult to explain, but it is probably also due to inadequate reduction. In all 3 cases the preoperative diagnosis was a fracture of the lateral condyle. It is impossible to adequately visualise the medial cortex from a lateral approach.

No other complications were seen with this injury.

4.5 Conclusions

Cubitus varus is as common following fracture-separations of the distal humeral epiphysis as it is after supracondylar fractures. Cubitus varus occurs mostly in children younger than 2 years. Accurate reduction must be achieved to prevent cubitus varus.

TABLE V : CUBITUS VARUS (Combined series)

	Carrying Angle (number of patients)				
Authors	Cubitus varus	Decreased	Normal	Not Known	* Total
De Lee et al	3	6	3	-	12
Holda et al	5	0	2	-	7
McIntyre et al	0	4	8	-	12
Mizuno et al	0	0	4	-	4
Siffert	1	0	0	2**	3
de Jager and Hoffman	3	2	4	1***	10
	12	12	22	3	48
Percentage	25%	25%	44%	6%	100%

* Only patients of whom the carrying angles were known are presented

** Siffert : 1 patient reported as "no cubitus varus"; 1 patient CA not reported

*** de Jager and Hoffman : 1 patient had fixed flexion deformity

TABLE VI : AGE * AT INJURY (Combined series)

Author	0 -2 years	Older than 2 years	Total
de Lee et al **	11	5	16
Holda et al	3	4	7
McIntyre et al	6	6	12
Mizuno et al	0	6	6
Siffert	3	0	3
de Jager and Hoffman	8	4	12
Total	31	25	56
Percentage	55%	45%	100%

* Age range 0 - 13 years 9 months

** de Lee et all reported that 11 children were younger than 2.5 years and 5 older than 2.5 years

5. MEDIAL CONDYLAR FRACTURES

5.1 Introduction

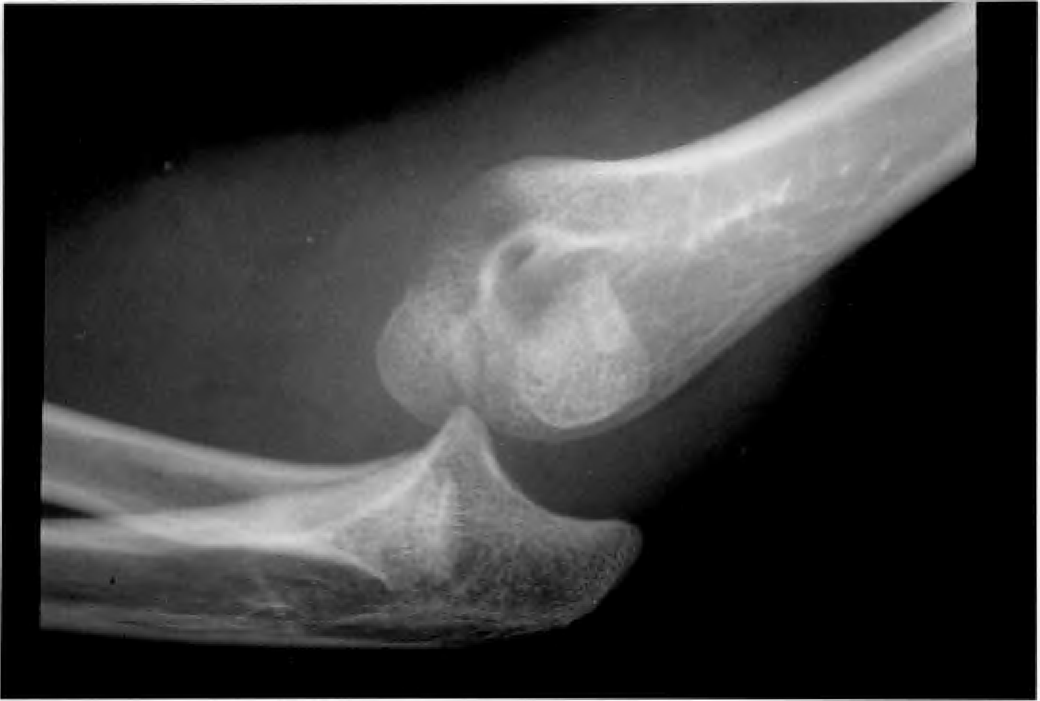
This rare injury is largely ignored in the standard textbooks, receiving only scant mention in standard textbooks such as Rang (1983), Smith(1972) and Wadsworth (1982), but Wilkins (1984) discussed the injury extensively. He found the incidence to be less than 1% of all elbow fractures in children, reviewing 4051 fractures of the distal humerus and finding only 14 medial condylar fractures in children amongst these. Even so, I found descriptions of 79 cases in the English literature up to 1988. Only 1 of these cases had an associated elbow dislocation (Bensahel 1986).

5.2 Case report

Only one case with a medial condyle fracture was managed at Red Cross Children's Hospital in the period July 1984 to February 1989. This 9-year old (at injury) boy presented the same day after falling on his right arm.

He had a swollen painful elbow and was neurologically and vascularly intact. Radiographs revealed a fracture dislocation of the elbow with the medial condyle displaced with the ulna (Fig 9). This is only the second case of a fracture of the medial condyle in a child with associated dislocation of the elbow to be reported in the literature. Open reduction was done through a medial approach. The

ulnar nerve was found lying between the fracture surfaces. The medial epicondyle was part of the condylar fragment. The fragment was fixed with two Kirschner wires. Postoperative immobilisation with posterior plaster splints in 90° flexion was continued for 4 weeks. The wires were removed after 4 weeks.



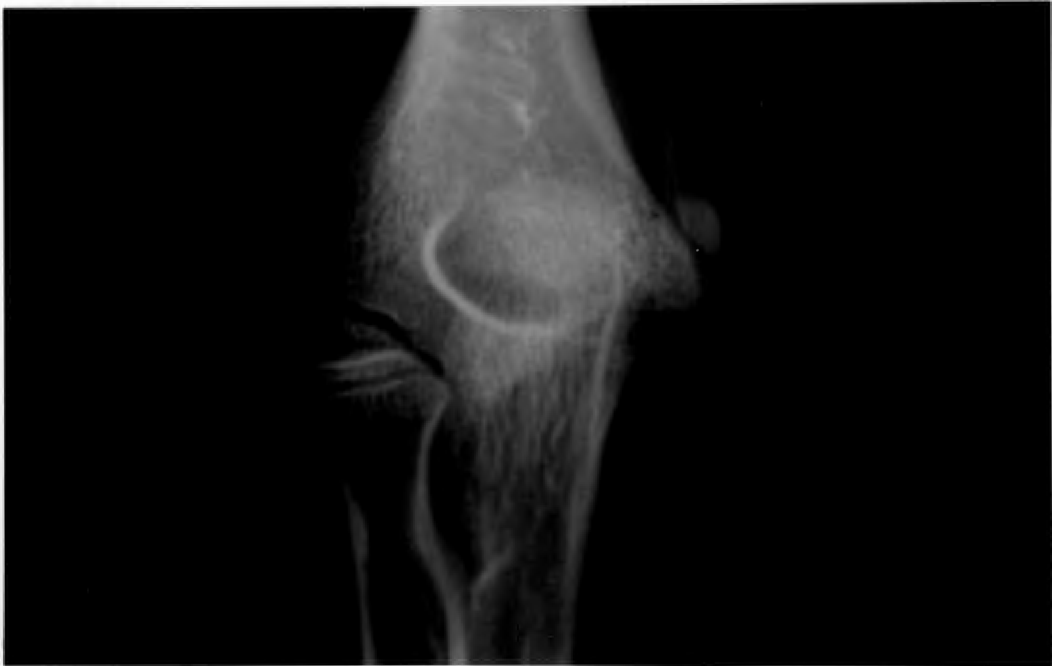
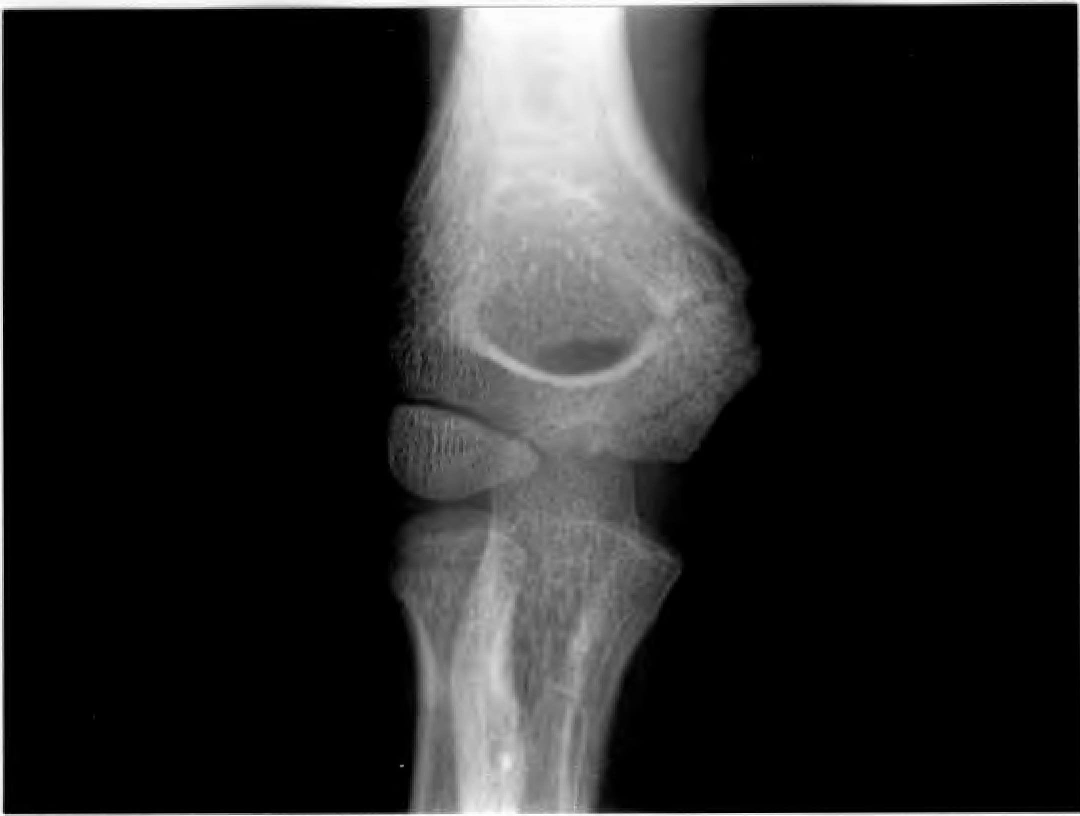


Fig 9 : Medial condylar fracture with posterior dislocation of the elbow.



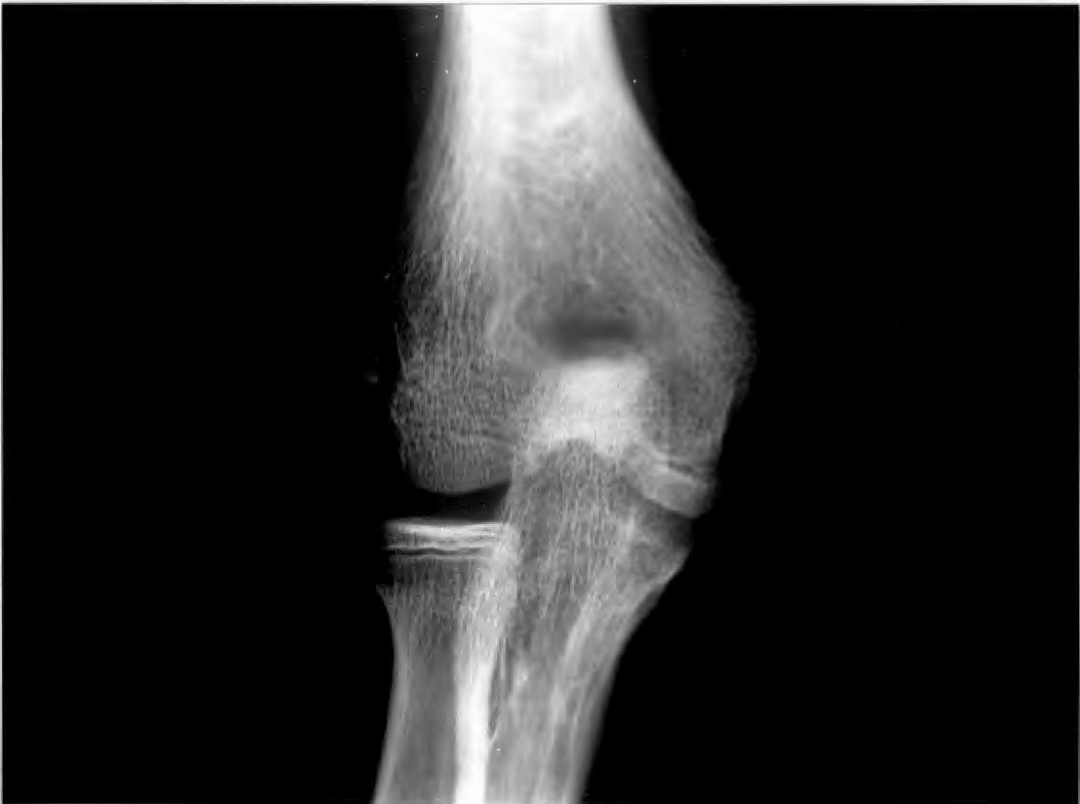


Fig 10 : (a) Anatomical reduction maintained 6 weeks post injury

(b) Fishtail deformity of the distal humerus 4 years 3 months after injury

Follow up at 4 years 3 months showed an excellent result with full range of movement of the elbow and a normal carrying angle. Radiographs (Fig 10b) showed that he developed a fishtail deformity of the distal humerus due to avascular necrosis of part of his growth plate, because radiographs 6 weeks after injury showed that there was no malunion (Fig 10a).

5.3 Discussion

I reviewed the English literature, combining the results in Table VII. 79 cases of medial condylar fracture in children had been reported until 1988.

(a) Mechanism of injury

There are two mechanisms of injury, either direct or indirect. In the direct injury the child falls on the point of the flexed elbow. The edge of the olecranon probably splits the trochlea. In the indirect injury the child falls on the outstretched arm. The medial condyle is then probably avulsed by the medial collateral ligament due to a valgus force in extension. Chacha (1970) even suggested that it may be due to a varus force in extension.

(b) Pathology

The fracture is a Salter Harris type IV injury, with the fracture line extending from the capitellotrochlear groove (de Boeck 1987) so that the fragment includes the whole

Authors	No.of frac-tures	Age	Sex		Side		Mechanism		Delayed (wks)			Classification		Associated Injuries	Missed Diagnosis *
			M	F	R	L	Dir	Indir	<1	1-3	>3	Undis-placed	Dis-placed		
Bensahel et al (1)	27	6mo-11yr	19	8	n/a		8	5 (n/a 14)	20	1	6	12	15	1 post dislocation elbow 1 ant dislocation radius 1 multiple fracture 2 battered children	n/a
Chacha (2)	2	9 yr	1	1	2	-	2	-	2	-	-	-	2	-	-
Cothay (3)	1	4 yr	-	1	1	-	n/a	n/a	1	-	-	-	1	-	1 (medial epicon
DeBoeck et al (4)	1	6 mo	n/a		-	1	-	1	1	-	-	-	1	1 battered baby	-
El Ghawabi (5)	8	8yr-14yr	6	1	5	3	n/a	n/a	n/a	n/a	n/a	5	3	1 ulnar nerve	n/a
Fahey et al (6)	1	8yr6mo	1	-	1	-	n/a	n/a	1	-	-	-	1	-	-
Fowles et al (7)	7	6yr-14yr	7	-	4	3	n/a	n/a	5	1	1	-	7	1 fracture olecranon	1 (medial epicon
Kilfoyle (12)	** 11	3yr6mo-13yr	n/a		n/a		n/a	n/a	n/a	n/a	n/a	4	5	2 multiple injuries	n/a
Papavasiliou et al (13)	15	3yr-12yr	11	4	n/a		n/a	n/a	13	-	2	11	4	3 battered children	n/a
Potter (15)	2	8yr,12yr	1	1	2	-	1 (1 n/a)	-	1	1	-	-	2	1 ulnar nerve	1 (dislocated el
Varma et al (17)	4	7yr-12yr	2	2	2	2	1 (3 n/a)	n/a	2	-	2	-	4	n/a	n/a
TOTAL	79														

* Diagnosis in brackets was the wrong diagnosis made

** 9 followed up and reported

Authors	Treatment: Closed		Operative		Limited ROM	Mal-union	Non-union	Cubitus varus	Cubitus valgus	AVN medial condyle	Fish-tail	Remarks
	Undis-placed	Dis-placed	Dis-placed	Method								
Bensahel et al (1)	12	6 *	9	n/a	2	n/a	2	n/a	n/a	1	-	
Chaca (2)	-	-	2	Kirschner -wires Pidcock pin	1	n/a	1	1(↓15°)	1	-	-	Nonunion followed removal of wires at 2½ weeks
Cothay (3)	-	1	** 1	K-wires	n/a	n/a	1	n/a	n/a	*** 1	-	** ORIF same patient at 6 months : completely devascularised
De Boeck et al (4)	-	-	1	K-wires	-	-	-	-	-	-	-	
El Ghawabi (5)	3	-	5	1:K-wires 4:Catgut	4	1	2	2	-	n/a	n/a	Myositis ossificans in 1 patient
Fahey et al (6)	-	-	1	K-wires	-	n/a	-	-	-	-	-	
Fowles et al (7)	-	1	4 early 2 late	K-wires	4	1	1	2(↓14°:18°)	-	1	3	Poor results in patients not treated or treated late
Kilfoyle (12)	4	2	3	Screw K-wires Wire	2	n/a	-	2(°n/a)	2 (4?)	-	-	2 medial condylar overgrowth
Papavasiliou et al (13)	11		2 early 2 late	2:K-wires 2:osteo-otomies	2	n/a	n/a	4(5°-40°)	(6?)	2	-	6 medial condylar overgrowth
Potter (15)	0	-	2	Catgut	-	n/a	-	n/a	n/a	n/a	n/a	
Varma (17) et al	0	1	3	1:Catgut 2:K-wires	3	1	2	1(40°)	n/a	n/a	1	Late presenter treated conservatively

* Bensahel et al: 4 treated by closed reduction and percutaneous pinning. There is also a discrepancy in treatment numbers in the article

*** AVN of medial condyle seen on illustration, but not reported in article

trochlea (Fowles 1980) with the medial epicondyle (Varma 1972). Fowles described a case in which only part of the trochlea was involved. The only soft tissue attached to the fragment is the common flexor origin and medial collateral ligament (Fowles 1980). These displace the fragment medially and anteriorly (Fahey 1971, Varma 1972) and rotates it in two planes (Chacha 1970) so that the fracture surface faces medially (Fahey 1971, Potter 1954) and the fragment is displaced medially and anteriorly (Fahey 1971, Varma 1972). The soft tissue also carries the only blood supply to the fragment and should not be dissected off during internal fixation, otherwise avascular necrosis of the medial condyle will result. The ulnar nerve may be trapped between the displaced fragment and the lower end of the humerus (Potter 1954).

(c) Classification

Management differs for undisplaced and displaced fractures and therefore this simple classification is the best (Papavasiliou et al 1987). Kilfoyle (1965) classified these fractures into three types. The first type is a greenstick fracture of the medial metaphysis. The second type is an undisplaced fracture of the medial condyle and the third type a displaced fracture. He admits that the first type may be an incomplete transcondylar fracture.

(d) Diagnosis

There is swelling and tenderness over the medial aspect of the elbow following injury. The possibility of child

battering must be kept in mind (Bensahel et al 1986, Papavasiliou et al 1987, de Boeck et al 1987). Medial condyle fractures must be differentiated from medial epicondyle fractures (Cathay 1967, Fowles et al 1980) and even elbow dislocation prior to obtaining radiographs (Potter 1954). A metaphyseal fragment is present with medial condylar fractures but not with epicondylar fractures. Elbow dislocation is usually associated with fractures of the epicondyle. If there is any doubt about the diagnosis of a displaced fracture an arthrogram may be helpful or, alternatively, the fracture should be explored surgically.

(e) Management

Undisplaced fractures are managed in a plaster backslab in 90° flexion for 3 to 4 weeks with good results (Kilfoyle 1965, El Ghawabi 1975, Bensahel et al 1986, Papavasiliou et al 1987). Displaced fractures should be reduced open and securely fixed with two Kirschner wires to achieve a good result (Fahey et al 1971, Fowles et al 1980, Bensahel et al 1986, de Boeck et al 1987, Papavasiliou et al 1987). The approach could be medial or posteromedial. The soft tissue attached to the medial condyle must not be disturbed, otherwise avascular necrosis will result as in the case of Cothay (1967). The ulnar nerve must be identified, because it may be trapped between the fragment and the humerus. Anatomical reduction of the articular surface must be achieved. The fracture is held with two Kirschner wires. Catgut suture is inadequate, because nonunion and malunion

followed this type of internal fixation in the series of El Ghawabi (1975) and Varma et al (1972). The wires are removed at 4 weeks and the elbow mobilised. If the wires are removed earlier the fracture may redisplace and end up with nonunion, as in the case of Chacha (1970). If the elbow is immobilised for longer than 4 weeks stiffness may result. Closed reduction and percutaneous Kirschner wires for displaced fractures is inadequate management, because the reduction is and results in nonunion or malunion, as in the series of Bensahel et al (1986) and Cothay (1967).

The patient who presents more than 3 weeks after injury should have a careful open reduction, if displaced, preserving the soft tissue attachments, to avoid avascular necrosis of the medial condyle. The elbow remains unstable if the medial condyle is not reduced, with elbow stiffness and progressive cubitus varus developing.

(f) Complications

(i) Ulnar nerve injury

Two ulnar nerve neuropraxias were reported. (Potter 1954, El Ghawabi 1975). At exploration the ulnar nerve was found lying between the medial condyle and the humerus. Both recovered fully.

(ii) Associated fractures and dislocations

Posterior dislocation of the elbow (Bensahel et al 1986, de Boeck 1987), anterior dislocation of the radius (Bensahel et al 1986) and fracture of the olecranon (Fowles et al

1980) were reported with medial condylar fractures.

(iii) Elbow stiffness

Elbow stiffness occurs mostly in untreated patients with nonunion of the medial condyle. Surgery on these patients does not improve the range of movement much. (Varma et al 1972, Bensahel et al 1986).

(iv) Nonunion

Nine cases of nonunion were described, an incidence of 11% (Table VII). It was due to managing displaced fractures conservatively (Cothay 1967, Varma 1972, Bensahel 1986) or inadequate internal fixation, such as catgut or a single Kirschner wire (Varma et al 1972) or by removing the wires too early (Chacha 1970).

(v) Cubitus varus

Cubitus varus was reported in 12 cases or 15% (Table VII).

It varied between 4° and 40°. It either followed avascular necrosis of the medial condyle as a complication of surgery, when the deformity was less severe (3 cases) or conservative treatment or no treatment of displaced fractures (8 cases) or nonunion following too early removal of K wires (1 case). The most severe deformities occurred with nonunion.

(vi) Cubitus valgus

A mild cubitus valgus was reported in 3 cases (Table VII) but medial condylar overgrowth was reported in another 8 cases (Papavasiliou et al 1987, Kilfoyle 1965) without reporting their carrying angle. Based on my experience in lateral condyle fractures I expect a mild cubitus valgus in these cases.

(vii) Avascular necrosis of the medial condyle

Avascular necrosis of the medial condyle occurred in 5 cases (Table VII). In 2 cases it followed late surgery, in 1 case acute surgery and in 2 cases, inexplicably, after conservative treatment. Perhaps the last 2 cases had extensive stripping of soft tissue off the medial condyle during the injury.

(viii) Fishtail deformity of the distal humerus

This occurred in 4 cases (Table VII) plus my reported case. Fowles et al (1980)reported 2 cases, but a third case can be seen on their radiographs. Another fishtail deformity can be seen on the illustration of Varma et al (1972), although they did not report it as such. This deformity either follows malunion or avascular necrosis of the lateral ridge of the trochlea, as in my case report. In both instances a gap develops in the growth plate, so that a deepening notch develops with further growth.

(ix) Myositis ossificans

Heterotopic ossification is extremely rare with any injury to the distal humeral epiphysis, with the only case described by El Ghawabi (1975) in medial condylar fractures. He did not report if this patient had only active mobilisation of the elbow, or added passive mobilisation. His patient had conservative treatment, nonunion and a loss of 100° of total elbow range of movement.

5.4 Conclusions

This rare injury must be differentiated from medial epicondylar fractures. The possibility of child battering must be kept in mind. Closed fractures are immobilised in a backslab for 4 weeks, but displaced fractures require open reduction and internal fixation with two Kirschner wires, which are removed after 4 weeks. Poor results can be expected in patients who present more than 3 weeks after injury and in patients with displaced fractures managed conservatively.

6. T-CONDYLAR FRACTURES (Intercondylar fractures)

This is more an injury of adults and is very rare in children, occurring mostly in the older child although a case as young as 1 year 6 months was reported (Beghin et al 1982). I counted 36 cases in the English literature.

6.1 Mechanism of injury

A direct blow to the olecranon probably causes the sharp edge of the olecranon to split the condyles.

6.2 Pathology

The T- or Y- fracture pattern splits both condyles off the humeral shaft. Nearly all fractures are displaced (Table VIII) by the initial trauma and by the origins of the flexor and extensor muscles. In some cases the articular surface cartilage may be intact (Wilkins 1984).

6.3 Classification

Jarvis et al (1984) classified the paediatric T-condylar fractures into three types:

Type I	Undisplaced
Type II	Displaced
Type III	Fracture dislocation. This type is also called the Chutro-Posados fracture

6.4 Diagnosis

Because this is such a rare fracture, it could easily be

missed. The most important diagnostic features are (i) A very swollen elbow. (ii) Because the fragments are usually displaced posteriorly the deformity is similar to an extension type supracondylar fracture. (iii) On radiographs the most important diagnostic feature is the presence of medial and lateral metaphyseal fragments (Beghin et al 1982). T-condylar fractures may be confused with lateral condylar fractures, medial condylar fractures and comminuted supracondylar fractures. If there is doubt about the diagnosis, then traction radiographs and stress radiographs may be helpful. Arthrograms may be difficult to interpret.

6.5 Management

Undisplaced fractures are immobilised in a backslab for 3 weeks. Displaced fractures must be anatomically reduced. A posterior approach gives the best visualisation of the fracture (Papavasilou et al 1986). The triceps could be split or divided and reflected down. The condyles are fixed together first, preferably with a lag screw, but Kirschner wires may be adequate in the younger child, according to Papavasiliou et al. The condyles are then fixed to the humeral shaft, preferably by posteromedial and posterolateral plates to ensure stable fixation so that early active elbow mobilisation can be started. Alternatively screws or even Kirschner wires could be used in the younger child (Jarvis et al 1984) (Wilkins 1984). The ulnar nerve must be identified during surgery. For severely comminuted fractures and more severe compound

fractures olecranon pin traction with elbow mobilisation may be used (Maylahn et al 1958).

6.6 Complications

The loss of elbow range of movement is surprisingly little if the severity of this intraarticular fracture is taken into account. (Table VIII). One radial nerve palsy was reported (Jarvis et al 1984). Cubitus valgus may occur if the fracture is not reduced anatomically, as in the two cases of Papavasiliou et al who were internally fixed through a lateral approach. Avascular necrosis of one or both condyles may occur if the soft tissue is dissected off the fragments (1 case in Papavisiliou et al's series).

6.7 Conclusions

This injury must be kept in mind when bone flakes are seen on both sides of the distal humeral epiphysis after injury.

TABLE VIII : **T-condylar fractures**

Author	No Fractures	Age	Sex		Side		Mechanism		Classification		Treatment		Loss of ROM	Remarks
			M	F	R	L	Direct	In-Direct	Undis-Placed	Dis-Placed	Closed	Oper-ative		
eghin et al	2	3 yr 1 yr6mo	1	1	2	-	n/a	n/a	-	2	-	2	0	1 misdiagnosed as a lateral condylar fracture
arvis t al	16	7 yrs to 17 yrs	9	7	n/a	n/a	n/a	n/a	-	16 *	-	16 *	2:>30° 4: 15-30°	1 radial nerve palsy 2 open fractures
aylahn t al	6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3 **	3	all	
apavasiliou t al	6	7 yrs to 14 years	5	1	n/a	n/a	n/a	n/a	1	5	1	5	2: 15-30°	Cubitus valgus 15° in 2 cases with lateral approach AVN 1 case

* 1 skeletal olecranon traction in compound fracture

** 2 skeletal olecranon traction in closed fractures

7. CONCLUSIONS

Epiphyseal fractures of the distal humerus may be extra-articular or intra-articular. The extra-articular fracture is the fracture-separation of the distal humeral epiphysis. Reduction must be adequate to prevent cubitus varus. The intra-articular fractures of the distal humeral epiphysis are fractures of one or both condyles. If displaced, open reduction and adequate internal fixation is necessary. To prevent stiffness the elbow must not be immobilised for longer than 4 weeks.

8. REFERENCES : General

1. Beals RK. The normal carrying angle of the elbow. Clin Orth 1976;119:194-6.

2. Canale ST, Fractures and dislocations in children. In: Campbell's Operative Orthopaedics. Seventh ed. Crenshaw AH ed. CV Mosby Co. 1987.

3. Gray DJ, Gardner E. Prenatal development of the human elbow joint. Am J Anat 1951;88:429-69.

4. Haraldsson S. The intra-osseous vasculature of the distal end of the humerus with special reference to capitulum. Acta Orthop Scand 1957;27:81-93.

5. Haraldsson S. Experimental investigations of the intra- and extra-osseous vasculature of the distal end of the humerus with special reference to capitulum. Acta Orthop Scand. 1958; Supp 36-40: 85-142.

6. Morrey BF Ed. The elbow and its disorders. WB Saunders Company 1985.

7. Peterson CA, Peterson HA. Analysis of the incidence of injuries to the epiphyseal growth plate. Trauma 1972;12:275-81.

8. Smith FM. Surgery of the elbow W.B. Saunders Co. 1972.

9. Smith L. Deformity following supracondylar fractures

of the humerus. J Bone Joint Surg (Am) 1960;42-A:235-52.

10. Wadsworth TG. Ed. The elbow. Churchill Livingstone 1982.

REFERENCES : Lateral Condyle Fractures

1. Apley AG, Solomon L. Apley's System of Orthopaedics and Fractures, 6th ed. London. Butterworths and Company;1982:391-2.

2. Badelon O, Bensahel H, Mazda K. Vie P. Lateral humeral condylar fractures in children : a report of 47 cases. J Pediatr Orthop 1988; 8:31-4.

3. Canale ST. Fractures and dislocations in children. In: Crenshaw AH, ed. Campbell's Operative Orthopaedics. Vol 3, 7th ed. CV Mosby Company 1987:1864-70.

4. Fontanetta P, Mackenzie DA, Rosman M. Missed, maluniting, and malunited fractures of the lateral humeral condyle in children. J Trauma 1978;Vol 18:5:329-35.

5. Foster DE, Sullivan JA, Gross RH. Lateral humeral condylar fractures in children. J Pediatr Orthop 1985;5:16-22.

6. Flynn JC, Richards JF. Non-union of fractures of the lateral condyle of the humerus. J Bone Joint Surg (Am) 1971;53-A:1096-1101.

7. Hardarcre JA, Nahigian SH, Froimson AI, Brown JE. Fractures of the lateral condyle of the humerus in children. J Bone Joint Surg (Am) 1971;53-A:1083-95.

8. Havranek P, Hajkova H. Treatment of children's epiphyseal injuries in the elbow region. Acta Univ Carol Med 1985;31 3/4:243-68.

9. Herring JA. Lateral condylar fracture of the elbow. J Pediatr Orthop 1986; 6:724-7.

10. Jakob R, Fowles JV, Rang M. Kassab MT. Observations concerning fractures of the lateral humeral condyle in children. J Bone Joint Surg (Br) 1975:57-B:430-6.

11. Jeffery CC. Non-union of the epiphysis of the lateral condyle of the humerus. J Bone Joint Surg (Br) 1958:40-B:396-405.

12. Masada K, Kawai H, Kawabata H, Masatomi T, Tsuyuguchi Y, Yamamoto K. Osteosynthesis for old, established non-union of the lateral condyle of the humerus. J Bone Joint Surg (Am) 1990:72-A:32-40.

13. Milch H. Fractures and fracture dislocations of the humeral condyles. J Trauma 1964;4:592-607.

14. Morrisy RT, Wilkins KE. Deformity following distal humeral fracture in childhood. J Bone Joint Surg (Am) 1984:66-A:557-62.

15. Papavasiliou VA, Beslikas TA. Fracture of the lateral humeral condyle in children : an analysis of 39 cases. Injury 1985;16:364-6.

16. Rang M. Children's fractures, 2nd ed. Philadelphia, JB Lippincott and Company, 1983:173-8.

17. Rutherford A. Fractures of the lateral humeral condyle in children. J Bone Joint Surg (Am) 1985;67-A:851-6.

18. Salter RB, Harris WR. Injuries involving the epiphyseal plate. J Bone Joint Surg (Am) 1963;45-A:604-6.

19. So YC, Fang D, Leong JCY, Bong SC. Varus deformity following lateral humeral condylar fractures in children. J Pediatr Orthop 1985;5:569-72.

20. Wadsworth T. Premature epiphyseal fusion after injury of the capitellum. J Bone Joint Surg (Br) 1964;46-B:46-9.

21. Wilkins KE. Fractures and dislocations of the elbow region. In: Rockwood CA, Wilkins KE, King RE. ed. Vol 3. Fractures in children. Philadelphia. JB Lippincott Company, 1984:432-57.

22. Wilkins KE. Physeal fractures of the distal humerus : avoiding the pitfalls. Instructional course lectures. 1986;35:83-93.

REFERENCES : Fracture-separation of the distal humeral epiphysis

1. Akbarnia BA, Silberstein MJ, Rende RJ, Graviss ER, Luisiri A. Arthrography in the diagnosis of fractures of the distal end of the humerus in infants. J Bone Joint Surg (Am) 1986; 68-A:599-602.

2. Barrett WP, Almquist EA, Staheli LT. Fracture separation of the distal humeral physis in the newborn. Case Report. J Pediatr Orthop 1984;4:617-9.

3. DeLee JC, Wilkins KE, Rogers LF, Rockwood CA. Fracture -separation of the distal humeral epiphysis. J Bone Joint Surg (Am) 1980;62-A:46-51.

4. Dias JJ, Lamont AC, Jones JM. Ultrasonic diagnosis of neonatal separation of the distal humeral epiphysis. J Bone Joint Surg (Br) 1988;70-B:825-8.

5. Holda ME, Manoli A, Lamont RL. Epiphyseal separation of the distal end of the humerus with medial displacement. J Bone Joint Surg (Am) 1980;61-A:52-7.

6. Kaplan SS, Reckling FW. Fracture separation of the lower humeral epiphysis with medial displacement. J Bone Joint Surg (Am) 1971;53-A:1105-8.

7. Labelle H, Bunnell WP, Duhaime M, Poitras B. Cubitus varus deformity following supracondylar fractures of the humerus in children. J Pediatr Orthop 1982;2:539-46.

8. McIntyre WM, Wiley JJ, Charette RJ. Fracture-separation of the distal humeral epiphysis. Clin Orthop 1984;188:98-102.

9. Mizuno K, Hirohata K, Kashiwagi D. Fracture-separation of the distal humeral epiphysis in young children. J Bone Joint Surg (Am) 1979;61-A:570-3.

10. Oppenheim WL, Clader TJ, Smith C, Bayer M. Supracondylar humeral osteotomy for traumatic childhood cubitus varus deformity. Clin Orthop 1984;188:34-9.

11. Peiro A, Mut T, Aracil J, Martos F. Fracture-separation of the lower humeral epiphysis in young children. Acta Orthop Scand 1981;52:295-8.

12. Piggot J, Graham HK, McCoy GF. Supracondylar fractures of the humerus in children. J Bone Joint Surg (Br) 1986;68-B:577-83.

13. Ruo GY. Radiographic diagnosis of fracture-separation of the entire distal humeral epiphysis. Clin Radiology 1987;38:635-7.

14. Siffert RS. Displacement of the distal humeral epiphysis in the newborn infant. J Bone Joint Surg (Am) 1963;45-A:165-9.

15. Wilkins KE. Fractures and dislocations of the elbow region. In: Rockwood CA, Wilkins KE, King RE. ed. Vol 3. Fractures in children. Philadelphia, JB

Lippincott Company 1984:366-370,532.

16. Yates C, Sullivan JA. Arthrographic diagnosis of elbow injuries in children. J Pediatr Orthop 1987;7:54-60.

REFERENCES : Medial Condylar Fractures

1. Bensahel H, Csukonyi Z, Badelon O, Badaoui S. Fractures of the medial condyle of the humerus in children. J Pediatr Orthop 1986;6:430-3.

2. Chacha PB. Fracture of the medial condyle of the humerus with rotational displacement. J Bone Joint Surg (Am) 1970;52-A :1453-8.

3. Cothay DM. Injury to the lower medial epiphysis of the humerus before development of the ossific centre. J Bone Joint Surg (Br) 1967; 49-B:766-7.

4. De Boeck H, Casteleyn PP, Opdecam P. Fracture of the medial humeral condyle. J Bone Joint Surg (Am) 1987;69-A:1442-4.

5. El Ghawabi MH. Fracture of the medial condyle of the humerus. J Bone Joint Surg (Am) 1975;57-A:677-80.

6. Fahey JJ, O'Brien ET. Fracture-separation of the medial humeral condyle in a child confused with fracture of the medial epicondyle. J Bone Joint Surg (Am) 1971;53-A:1102-4.

7. Fowles JV, Kassab MT. Displaced fractures of the medial humeral condyle in children. J Bone Joint Surg (Am) 1980;62-A:1159-63.

8. Haddad RJ. Childhood trauma. In: Wadsworth TG. The elbow. Churchill Livingstone 1982:152-3.

9. Hanspal RS. Injury to the medial humeral condyle in a child reviewed after 18 years. J Bone Joint Surg (Br) 1985;67-B:638-9.

10. Harrison RB, Keats TE, Frankel CJ, Anderson RL, Youngblood P. Radiographic clues to fractures of the unossified medial humeral condyle in young children. Skeletal Radiol 1984;11:209-12.

11. Ingersoll RE. Fractures of the humeral condyles in children. Clin Orthop 1965:41:32-42.

12. Kilfoyle RM. Fractures of the medial condyle and epicondyle of the elbow in children. Clin Orthop 1965;41:43-50.

13. Papavasiliou V, Nenopoulos S, Venturis T., Fractures of the medial condyle of the humerus in childhood. J Pediatr Orthop 1987;7:421-3.

14. Peterson HA. Physeal fractures. In: The elbow and its disorders. Ed. BF Morrey. W B Saunders Co. 1985:228.

15. Potter CMC. Fracture-dislocation of the trochlea. J Bone Joint Surg (Br) 1954;36-B:250-3.

16. Smith FM. Surgery of the elbow. WB Saunders Co. 1972:110.

17. Varma BP, Srivastava TP. Fracture of the medial condyle of the humerus in children : a report of 4 cases including the late sequelae. Injury 1972;4:171-4.

18. Wilkins KE. Fractures and dislocations of the elbow region. In: Rockwood CA, Wilkins KE, King RE. eds Vol 3. Fractures in children. Philadelphia. JB Lippincott Company 1984:457-65.

REFERENCES : T-Condylar Fractures

1. Beghin JL, Bucholz RW, Wenger DR. Intercondylar fractures of the humerus in young children. J Bone Joint Surg 1982;64-A:1083-7.

2. Grantham SA, Tietjen R. Transcondylar fracture-dislocation of the elbow. J Bone Joint Surg 1976;58-A:1030-1.

3. Jarvis JG, D'Astous JL. The pediatric T-supracondylar fracture. J Pediatr Orthop 1984;4:697-9.

4. Maylahn DJ, Fahey JJ. Fractures of the elbow in children. Review of three hundred consecutive cases. J Am Med Assn. 1958;166:220-8.

5. Papavasiliou VA, Beslikus TA. T-condylar fractures of the distal humeral condyles during childhood : an analysis of six cases. J Pediatr Orthop 1986;6:302-5.

6. Wilkins KE. Fractures and dislocations of the elbow region. In: Rockwood CA, Wilkins KE, King RE eds. Vol 3. Fractures in children. Philadelphia, JB Lippincott Company 1984:498-501.

7. Zimmerman H. Fractures of the elbow. In: Weber BG, Brunner C, Freuler E. eds. Treatment of fractures in chiladren and adolescents. New York:Springer-Verlag, 1980:382-5.