



Common Pediatric Upper Extremity Fractures

Physician Assistants in Orthopaedic Surgery (PAOS)
2024

PHOENIX CHILDREN'S Hospital
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ORTHOPAEDIC SURGERY

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Outline


- Epidemiology
- Principles of care
- Upper extremity
 - Clavicle
 - Humerus
 - Elbow
 - Forearm
 - Hand

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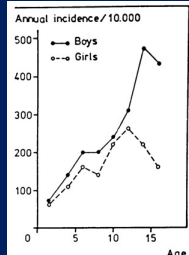
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Epidemiology

- One in three children will have a fracture¹
- Boys more likely to fracture¹⁻⁴



| Age Group | Boys (%) | Girls (%) |
|-----------|----------|-----------|
| 0-2 y | 55.7% | 44.3% |
| 3-5 y | 61.4% | 38.6% |
| 6-12 y | 69.5% | 30.5% |



| Age | Boys (Annual incidence/10,000) | Girls (Annual incidence/10,000) |
|-------|--------------------------------|---------------------------------|
| 0-2 | ~100 | ~100 |
| 3-5 | ~200 | ~150 |
| 6-12 | ~300 | ~250 |
| 13-18 | ~450 | ~150 |

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FIG. 1. The age- and sex-specific incidence of all fractures in children ages 0 to 18 years. (Published with permission of Scandinavian University Press.)

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Epidemiology

- Upper extremity 76% of fractures^{2,3}
 - 39% radius/ulna
 - 29% phalanges

| Fracture | % total | Age (range), y | Mean GCS, % |
|-----------------|-----------|----------------------------|-------------|
| Clavicle | 4.7(5) | 7.5 (1 y 8 mo–16 y 4 mo) | 51.5 (41.5) |
| Humerus | 11.2(10) | 7.8 (1 y 8 mo–17 y 9 mo) | 52.4(8) |
| Radius | 1.7(2) | | |
| Ulna | 11.9(8) | | |
| Radius/ulna | 29.2(27)* | 8.2 (7 mo–17 y 4 mo) | 56.4(4) |
| Skull | 7.4(5) | | |
| Patella | 4.5(3) | | |
| Distal radius* | 2.1(2) | | |
| Distal ulna* | 2.1(2) | | |
| Carpal base | 2.0(2) | 12.1 (10 y 6 mo–18 y 6 mo) | 47.1(3) |
| Metacarpals | 4.9(4) | 12.7 (11 y 1 mo–18 y) | 54.5(4) |
| Phalangeal base | 28.2(22) | 10.8 (1 y 3 mo–17 y 4 mo) | 49.4(8) |

*Including the 117 radius/ulna fractures, 298 fractures involved the radius and 19 fractures were isolated fractures of the ulna.

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| Fracture type | Percentage |
|---|------------|
| Distal forearm | 22.7 |
| Hand, phalanges | 18.9 |
| Carpal/metacarpal (scaphoid excluded) | 8.3 |
| Clavicle | 8.1 |
| Ankle | 5.5 |
| Tibia, diaphysis | 5.0 |
| Tarsal/metatarsal (talus, or calcus excluded) | 4.5 |
| Foot, phalanges | 3.4 |
| Radius-ulna, diaphysis | 3.4 |
| Supracondylar region of the humerus | 3.3 |
| Proximal end of the humerus | 2.2 |
| Facial skeleton | 2.1 |
| Skull | 1.8 |
| Forearm shaft | 1.6 |
| Radial neck fracture | 1.2 |
| Vertebral fracture | 1.2 |

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Principles of care – Anatomy⁵

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Principles of care – Fracture healing⁵

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Principles of care – Modeling/Remodeling⁵

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Principles of care^{6,7}

S **A** **L** **T** **E** **R**

Straight across Above Lower or Below Two or Through ERasure of growth plate or CRush

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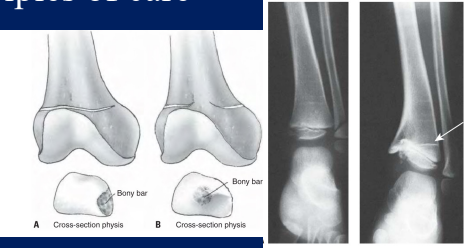
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Principles of care⁷

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Principles of care⁷



The image contains two diagrams labeled A and B, each showing a cross-section of a physis with a 'Bony bar' indicated. To the right are two X-ray images of a knee joint, with an arrow pointing to a bony bar in the second X-ray.

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Clavicle^{8,9}:

AKA everything is going to be fine

- Nonoperative management
 - Sling
 - Figure of 8
 - Shoulder immobilizer
- Operative indications
 - Open fracture
 - Skin tenting
 - Neurovascular compromise
 - Polytrauma (sometimes)

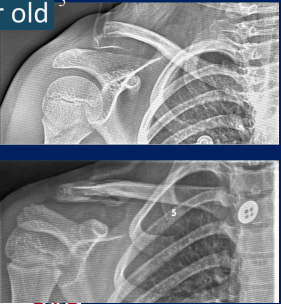


The image shows an X-ray of a clavicle fracture on the left and a photograph of a young child wearing a white sling on the right.

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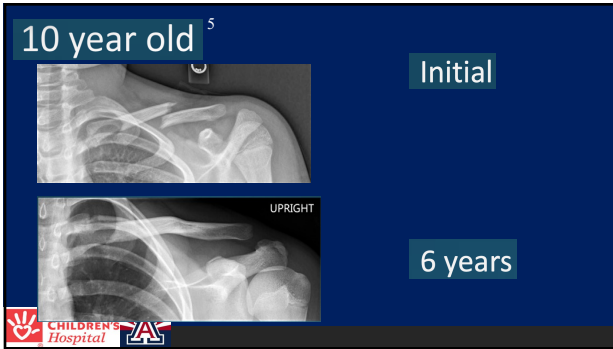
6 year old⁵



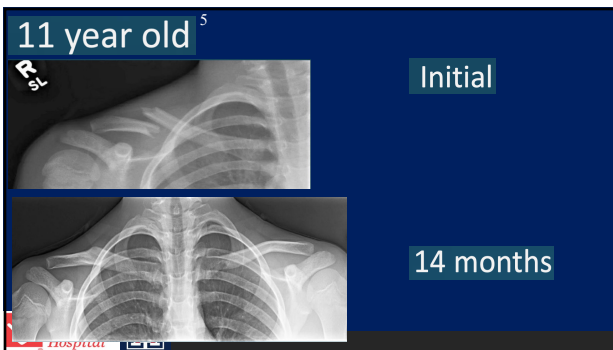
The image shows two X-rays of a 6-year-old child's shoulder. The top X-ray is labeled 'Initial' and shows a fracture of the clavicle. The bottom X-ray is labeled '3 months' and shows the same shoulder with the fracture healed.

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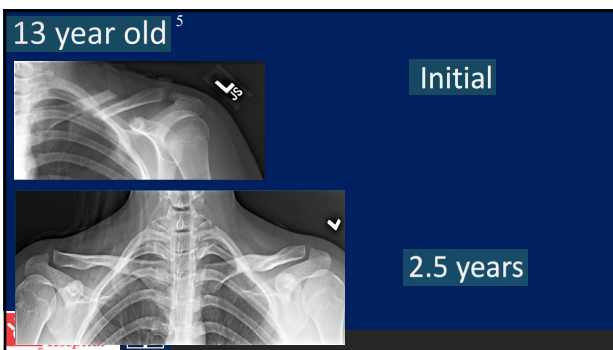
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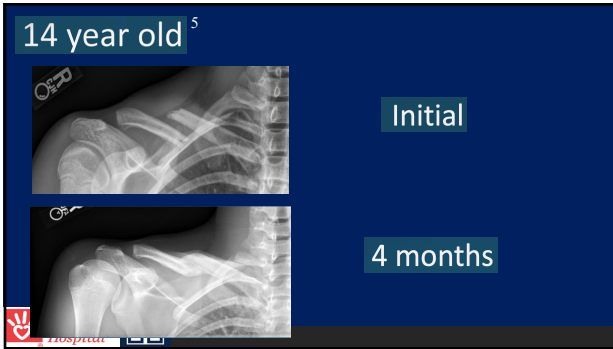
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Clavicle^{8,9}

- Symptomatic nonunion or malunion
- Rare in children under 10
- Incidence: 4.4%
- More common in refracture cases

Female

Male

| | Nonunion cohort (N = 25) | Primary fracture cohort (N = 345) | P value |
|--|--------------------------|-----------------------------------|---------|
| Age (y) | 14.3 ± 3.7 | 13.2 ± 2.1 | .37 |
| Sex | 19% male | 19% male | .992 |
| TYPE OF INJURY (type) | 13% I (13%) | 12% I (12%) | .25 |
| Clavicle-acromion shortening (mm) | 8.3 ± 2.6 | 8.9 ± 8.3 | .35 |
| Superior-to-inferior displacement (mm) | 9.8 ± 9.3 | 8.5 ± 8.0 | .537 |
| Angulation (degrees) | 14.5 ± 18.9 | 15.8 ± 1.6 | .92 |
| Comminuted | 28% | 18% | .35 |

Reported values are means ± standard deviations unless identified otherwise. Bolded values represent significance with a P value < .05.

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Figure 1. (A) A 14-year-old girl who sustained a 100% displaced midshaft clavicle fracture with 12 mm of end-to-end shortening and 6 mm of acromioclavicular joint distraction was initially treated conservatively with a figure-of-8 brace. (B) The patient was subsequently seen 6 follow-up that presented again 73 months later with a symptomatic nonunion. (C) At 12 weeks after nonunion repair with local bone graft, the fracture had healed, and the patient was no longer in full sport with no limitations and no functional deficits.

Figure 2. (A) A 12-year-old girl with a 33° angulated and minimally displaced clavicle fracture sustained while performing karate. (B) At 7 months after injury, the patient was diagnosed with a nonunion. (C) Final radiograph when 19 months after nonunion repair with local bone graft demonstrating a healed clavicle.


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Clavicle⁹

- Adolescent fractures

| Clavicular Fracture Location | Recommendation | Grade of Recommendation* |
|------------------------------|--|--------------------------|
| Medial | Nonoperative management in cases that do not meet specific indications | C |
| | Operative treatment for injuries that are acutely displaced and symptomatic, injuries with medial acromioclavicular joint compression, and open fractures | C |
| Lateral | Nonoperative management in cases that do not meet specific indications | C |
| | Operative management in cases with severe displacement or intra-articular involvement, soft tissue entrapment, and open fractures | C |
| Midshaft | Nonoperative management in most cases that do not meet specific indications | B |
| | Operative management in open (or impending) fractures or after discussion with patient in cases of older adolescents with severe displacement or angulation, refracture, or desire for faster return to function | C |

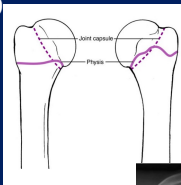
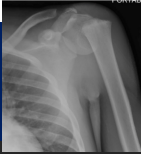

*According to Wright¹¹, grade A indicates good evidence (Level I studies with consistent findings) for or against recommending intervention; grade B, fair evidence (Level II or III studies with consistent findings) for or against recommending intervention; grade C, poor quality evidence (Level IV or V studies with consistent findings) for or against recommending intervention; and grade I, insufficient or conflicting evidence not allowing a recommendation for or against intervention. †Severe displacement is defined in the adult clavicular fracture literature as ≥2 cm of displacement.



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Proximal Humerus¹⁰





- Primary ossification center within first few months of life
- Secondary ossification centers
 - Greater tuberosity (age 3)
 - Lesser tuberosity (age 5)
- 80% of growth of humerus
- Physis closes at age 14 girls and 16 in boys with high variability

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Proximal Humerus¹⁰

- Treatment
 - Nonoperative
 - Most children
 - Older children with acceptable alignment
 - Operative
 - Open fractures
 - Neurovascular compromise
 - Within 2 years of skeletal maturity AND >50% displacement or 30 degrees of angulation

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Proximal Humerus⁵

4 year old
Initial 6 months

12 year old
Initial 6 months

13 year old
Initial 6 months

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Humeral Shaft¹⁰

- Birth injury
 - Look for associated brachial plexus injury
 - Does not need reduction
- Treatment
 - Ace wrap over arm and body
 - Pin sleeve of shirt to the chest
 - 1-3 weeks of immobilization

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Humeral Shaft¹⁰

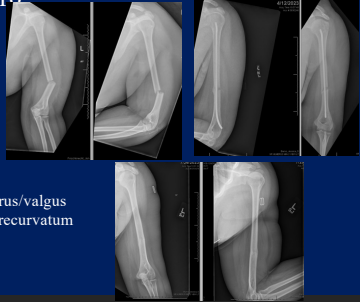
- Treatment
 - Nonoperative
 - Most children
 - Older children with acceptable alignment
 - Coaptation splint or sling to start
 - Hanging arm cast (if shortened)
 - Sarmiento brace

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Humeral Shaft¹⁰


- Treatment
 - Operative
 - Open fractures
 - Skin breakdown
 - Obesity
 - >3 cm shortening
 - >30 degrees angulation varus/valgus
 - >20 degrees procurvatum/recurvatum



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Humeral Shaft¹⁰



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Elbow¹¹⁻¹³

- Variants in anatomy
- Ossification centers

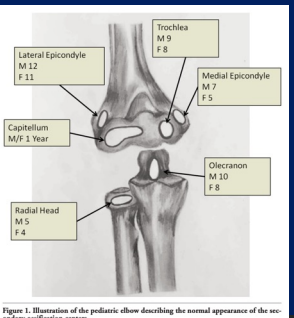


Table 1. Summary of the appearance of ossification centers of the pediatric elbow (in years).

| Ossification center | Girls | Boys | Approximate |
|---------------------|-------|------|-------------|
| C | 1 | 1 | 1 |
| R | 4 | 5 | 3 |
| M | 5 | 7 | 5 |
| T | 8 | 9 | 7 |
| O | 8 | 10 | 9 |
| L | 11 | 12 | 11 |

Figure 1. Illustration of the pediatric elbow describing the normal appearance of the secondary ossification centers.

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Elbow 11-13

- Baumann's angle
- Anterior humeral line

The slide contains three anatomical diagrams. On the left, two views of the elbow joint illustrate Baumann's angle, which is the angle between the longitudinal axis of the humeral shaft and the line connecting the center of the humeral head to the center of the radial head. On the right, a lateral radiograph of the elbow shows the anterior humeral line, a vertical line drawn from the greater tuberosity to the olecranon, which should pass through the center of the humeral head.

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Elbow 11-13

- Get a true lateral radiograph

The diagram shows a lateral view of the elbow joint with dashed lines indicating the orientation of the humerus and radius/ulna. A central dashed line represents the true lateral plane, which is perpendicular to the humeral shaft.

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Elbow 11-13

- Su

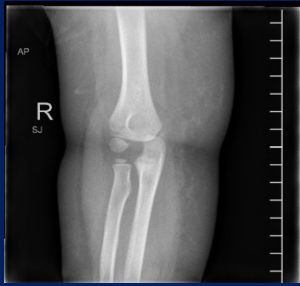
The slide displays four fluoroscopic images (A, B, C, D) of a pediatric elbow. Image A shows a preoperative lateral view of a supracondylar humerus fracture. Image B shows the postoperative AP view with two pins inserted through the medial and lateral columns. Image C shows the postoperative lateral view. Image D shows the postoperative lateral view demonstrating the spread of the pins.

Fluoroscopic images of a pediatric patient managed with lateral-only percutaneous pinning for a type III supracondylar humerus fracture. A, Preoperative lateral view demonstrating complete displacement. B, AP view following pin placement demonstrating the spread of the pins through the medial and lateral columns. C, Lateral view demonstrating the spread of the pins in the AP plane.

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Elbow 14-16

- Diagnosis?
- Next step?




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Elbow 14-16

- Lateral condyle
 - Intra articular fracture
 - Internal oblique



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Elbow 14-16

- Lateral condyle


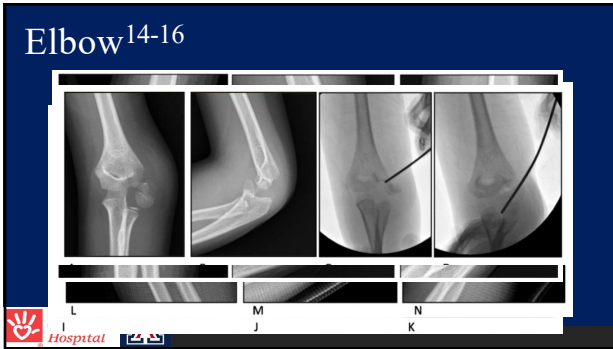


Figure 3 Postreduction CT scan of right elbow in posterior plus splint.

(A) Anteroposterior radiograph showing a lateral condyle fracture (white arrow), (B) lateral radiograph showing the typical posterior fragment associated with a lateral fracture (white arrow).

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Elbow 11-13

- Medial epicondyle
 - Avulsion fracture
 - Associated with elbow dislocation
 - Evaluate for incarcerated fragment
- Largely treated nonop
 - Long arm cast
 - Hinged elbow brace*

Figure 5. A) Lateral radiograph showing an incarcerated medial epicondyle fracture (white arrow). B) Anteroposterior radiograph depicting the same (white arrow).

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Monteggia 17-19

- Monteggia
 - Fracture dislocation
 - Watch radiocapitellar line
 - Chronic Monteggia - missed

Figure 2. A) Monteggia fracture. White arrow represents ulnar bowing. The radial head is not directed at the capitulum. B) Lateral image more clearly demonstrates the malalignment of the radiocapitellar joint representing an associated posterior radiocapitellar dislocation.

FIGURE 3. Typical cast used for Radial type I fractures.

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Monteggia¹⁷⁻¹⁹

- Monteggia
 - Classification – direction of radial head
- Treatment
 - Closed reduction/casting
 - Surgical fixation ulna

| | Nonoperative Treatment (N = 78) | Failed Nonoperative Treatment (N = 18) | P |
|-------------------------------|---------------------------------|--|------|
| Mean age (SD) | 7.4 ± 1.9 | 7.4 ± 2.4 | 0.12 |
| Male/female (%) | 47/31 | 42/6 | 0.17 |
| Type I | 32/57 | 2/42 | |
| Type III | 16/25 | 14/20 | |
| Type IV | 8/19 | 1/9 | |
| Ulna fracture pattern by P/D | | | 0.04 |
| Distal shaft | 30/50 | 0/20 | |
| Proximal | 11/19 | 18/19 | |
| Length-acute | 36/55 | 18/19 | |
| Transverse | 8/12 | 1/20 | |
| Spiral-oblique | 11/20 | 4/20 | |
| Type III fracture | 11/17 | 1/19 | |
| Proximal | 2/3 | 0/9 | |
| Ulna fracture location by P/D | | | 0.16 |
| Proximal | 42/63 | 15/19 | |
| Distal shaft | 21/31 | 3/20 | |
| Mean distance (SD) (cm) | 20.8 ± 13.7 | 16.9 ± 9.4 | 0.04 |

Note: values represent a P-value < .05.

Table 1: Bado Classification of Monteggia Fracture-Dislocation

| Bado Classification | Radial head dislocation | Ulna fracture | Incidence |
|---------------------|-----------------------------------|---------------------------|-----------|
| I | Anterior | Apex anterior diaphyseal | 60% |
| II | Posterior | Apex posterior diaphyseal | 15% |
| III | Lateral or anterolateral | Metaphyseal | 20% |
| IV | Anterior/any with radius fracture | Diaphyseal | 5% |

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Radial Neck Fracture⁷

- Age 7-12
- Malunion leads to loss of forearm rotation
- Acceptable displacement <30 degrees, <3 mm translation

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Radial Neck Fracture⁷

- Treatment
 - Closed reduction and long arm casting

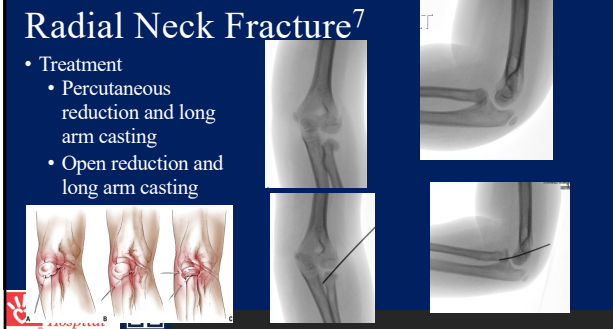


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Radial Neck Fracture⁷

- Treatment
 - Percutaneous reduction and long arm casting
 - Open reduction and long arm casting



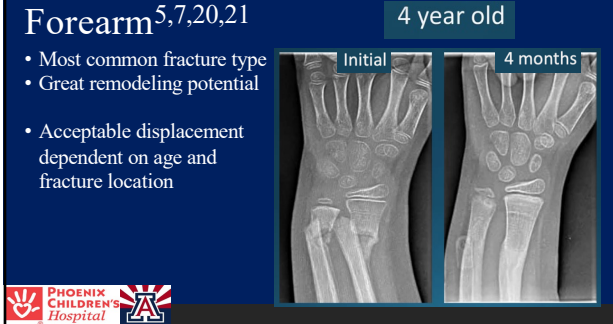
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Forearm^{5,7,20,21}

4 year old

- Most common fracture type
- Great remodeling potential
- Acceptable displacement dependent on age and fracture location




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Forearm^{5,7,20,21}

- Both bone forearm fractures – acceptable angulation



| Patient Age (Years) | Radius Angulation | Rotation | Shortening |
|--|---------------------------------|----------|------------|
| Children younger than 5 | <20° | <45° | <1 cm |
| Girls younger than 8 Boys younger than 10 | <15° | <45° | <1 cm |
| Girls older than 8 Boys older than 10 | <15° (distal) | <30° | <1 cm |
| Girls older than 8 Boys older than 10 | <10° (proximal) | <30° | <1 cm |
| Girls older than 12 Boys older than 14 | <10° (distal) <5° (proximal) | <15° | None |



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Forearm⁵

- Both bone forearm fractures
 - Shaft
 - Closed reduction and casting
 - Bayonet apposition in the middle and distal third acceptable
 - Children age <8/10 <15 degrees
 - Children age >8/10 <10 degrees
 - Surgical fixation within 2 years of skeletal maturity

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Forearm⁷

- Both bone forearm fractures – cast index

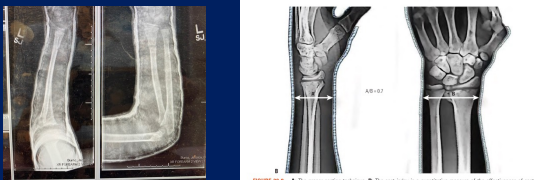

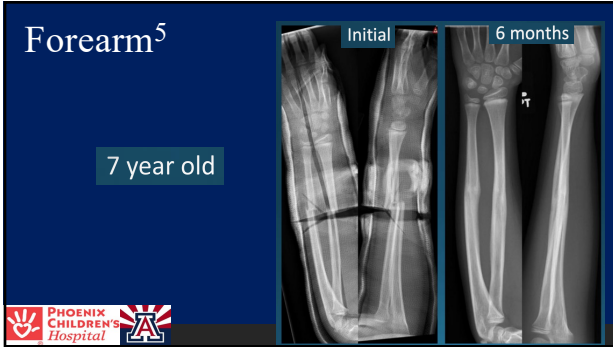


FIGURE 22-6. A: The proper casting technique. B: The cast index is a quantitative measure of the effectiveness of cast molding. A cast index smaller than 20 is considered with reasonable effectiveness of reduction of distal radius fractures. Adapted from Cheng DS, Haythorn JC, Laskay JL, et al. Short arm plaster cast for distal pediatric forearm fractures. J Pediatr Orthop 1994;14(2):171-173.



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Forearm^{5,7,20,21}

- Both bone forearm fractures – functional motion
- 28-146° flexion arc
- 54° supination, 65° pronation

| Task | Elbow Flexion | | | Elbow Extension | | | Pronation | | | Supination | | |
|----------------------|---------------|--------------|--------|-----------------|-------------|--------|--------------|-------------|--------|--------------|-------------|--------|
| | Children | Adolescents | P | Children | Adolescents | P | Children | Adolescents | P | Children | Adolescents | P |
| Functional tasks | | | | | | | | | | | | |
| Hand to head | 120.5 ± 9.9 | 125.3 ± 7.9 | <0.01 | — | — | — | -25.8 ± 17.1 | -15.7 ± 8.9 | <0.01 | 55.5 ± 13.9 | 52.7 ± 12.1 | 0.35 |
| Hand to mouth | 141.4 ± 5.9 | 143.7 ± 4.3 | 0.07 | — | — | — | -19.4 ± 14.3 | -9.6 ± 17.3 | <0.05 | 54.4 ± 9.3 | 51.4 ± 16.1 | 0.70 |
| Hand to occiput | 146.4 ± 6.6 | 146.1 ± 8.9 | 0.84 | — | — | — | 33.0 ± 19.3 | 35.8 ± 15 | 0.32 | 47.1 ± 20.5 | 39.9 ± 20 | <0.05 |
| Hand to back | 114.8 ± 10.5 | 125.1 ± 12.6 | <0.001 | — | — | — | 34.8 ± 22.3 | 43.4 ± 24.2 | 0.10 | -5.46 ± 11.3 | 42.8 ± 19.5 | 0.44 |
| Dressing from pants | 127.3 ± 5.9 | 132.1 ± 6.2 | <0.001 | 61.4 ± 11.9 | 65.3 ± 15.5 | 0.21 | 39.9 ± 9.5 | 56.4 ± 11.2 | <0.001 | 21.2 ± 12.9 | 119.2 ± 2 | <0.001 |
| Eating with fork | 130.3 ± 8.9 | 129.4 ± 5.9 | 0.67 | 63.6 ± 18.7 | 64.2 ± 19.2 | 0.89 | 60.0 ± 11.5 | 68.4 ± 13 | <0.05 | 29.7 ± 18.5 | 140 ± 18 | <0.01 |
| Reading magazine | 96.8 ± 17.1 | 96.9 ± 17.7 | 0.95 | 63.2 ± 17.5 | 64.4 ± 23.6 | 0.23 | 61.1 ± 18.9 | 69.4 ± 20.4 | 0.07 | 17.9 ± 16.9 | 64.2 ± 15.1 | <0.001 |
| Standing from chair | 95.5 ± 15.7 | 104.5 ± 11.5 | <0.01 | 35.1 ± 20.1 | 21.2 ± 14.3 | <0.001 | 42.6 ± 16.6 | 52.7 ± 13 | <0.01 | 9.9 ± 6.2 | -7.7 ± 11.3 | <0.001 |
| Contemporary tasks | | | | | | | | | | | | |
| Picking up phone | 147.2 ± 3 | 148.5 ± 2.9 | 0.17 | 51.4 ± 13 | 43.3 ± 21.3 | <0.05 | 55.4 ± 13 | 61.1 ± 22.2 | 0.08 | 56.4 ± 14 | 41.3 ± 6.6 | <0.01 |
| Typing with keyboard | 100.5 ± 13 | 95.5 ± 21.2 | 0.18 | 67.1 ± 8.8 | 69.9 ± 20.9 | 0.40 | 64.1 ± 14 | 66.5 ± 18 | 0.55 | 2.2 ± 14 | -11.4 ± 11 | <0.001 |
| Using computer mouse | 87.4 ± 14 | 94.2 ± 16.9 | <0.05 | 38.5 ± 9.4 | 41.2 ± 20.5 | 0.42 | 32.1 ± 13 | 61.7 ± 14 | <0.01 | 0.7 ± 18.6 | -4.9 ± 12 | <0.001 |
| Testing | 97.8 ± 12.7 | 101.2 ± 16 | 0.32 | 55.8 ± 12.5 | 46.0 ± 24.3 | <0.05 | 41.8 ± 16 | 51.1 ± 13.6 | <0.05 | 19.1 ± 15.5 | 109.9 ± 14 | <0.05 |

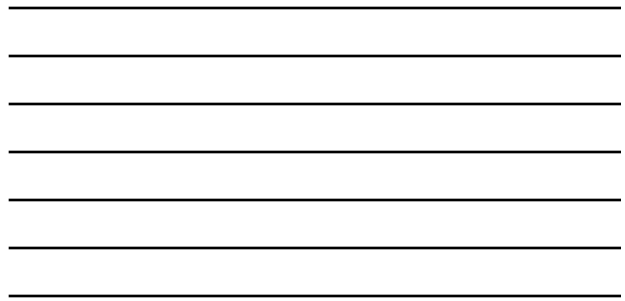
Bold indicates significant P values.

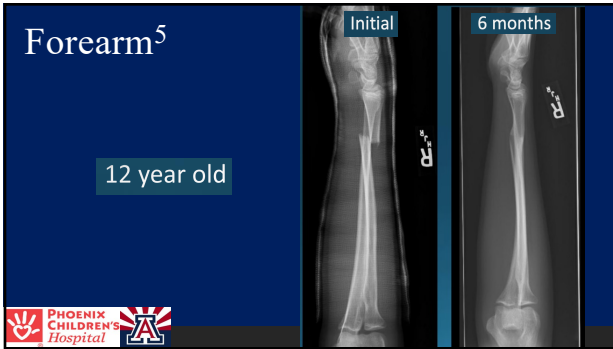
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Forearm⁵ 6 year old

- Both bone forearm fractures
 - Distal radius
 - Closed reduction and casting
 - Bayonet apposition in the middle and distal third acceptable
 - Children <5 <20 degrees
 - Children <8/10 <15 degrees
 - Children >8/10 <15 degrees
 - Within 2 years of skeletal maturity <10 degrees

Initial

3 months

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Forearm⁵

Fracture Remodeling Calculator

Nearest Physis:


Sex:

Distance from Physis (mm):

Initial Angulation (degrees):

Patient Age at Fracture (years):

Calculate



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Forearm⁵

12 year old

Initial 1 year



15 year old

Initial 6 months

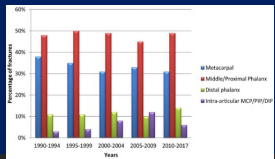





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Hand^{22,23}

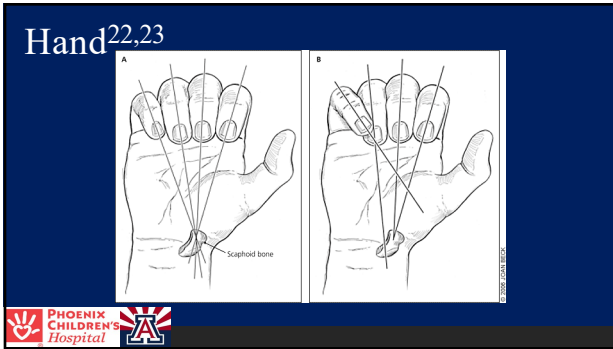
- Phalanx fractures
 - Common
 - Evaluate for intra articular involvement
 - Evaluate for clinical deformity



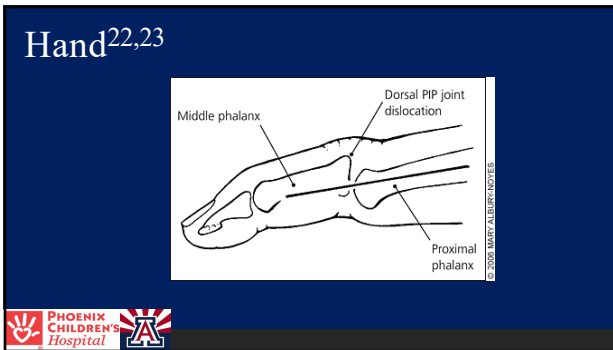
| Year | Metacarpal | Middle/Proximal Phalanx | Distal Phalanx | Intra-articular MCP/PIP/DP |
|-----------|------------|-------------------------|----------------|----------------------------|
| 1990-1994 | ~45% | ~35% | ~15% | ~5% |
| 1995-1999 | ~45% | ~35% | ~15% | ~5% |
| 2000-2004 | ~45% | ~35% | ~15% | ~5% |
| 2005-2009 | ~45% | ~35% | ~15% | ~5% |
| 2010-2014 | ~45% | ~35% | ~15% | ~5% |



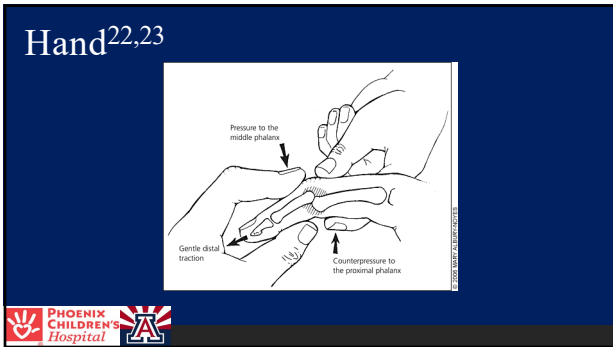
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Table 3. Fracture Management Divided by Age Group and Anatomic Site

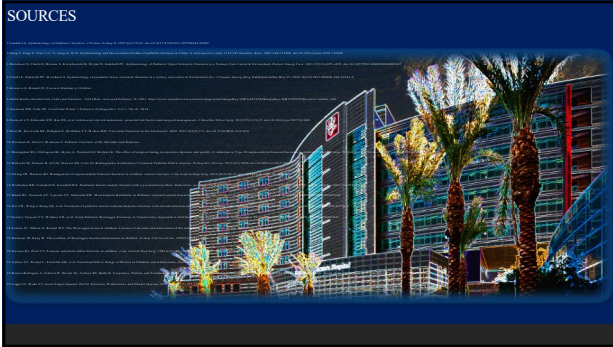
| Fracture management | | Closed reduction | ORIF | PP |
|--|------------|------------------|-----------|---------|
| Subgroup 0-5 years | | | | |
| Extra-articular (222 fractures) | | | | |
| Metacarpal (3) | 28 (87%) | 3 (10%) | 1 (3%) | — |
| Proximal Middle-phalanx (119) | 94 (79%) | 13 (11%) | 12 (10%) | — |
| Distal-phalanx (7) | 45 (92%) | 5 (7%) | 1 (13%) | — |
| Intra-articular fractures (12 fractures) | | | | |
| MCP/PIP/DP (12) | 5 (42%) | 7 (58%) | — | — |
| Subgroup 6-11 years | | | | |
| Extra-articular (308 fractures) | | | | |
| Metacarpal (21) | 284 (98%) | 3 (1%) | 4 (1%) | — |
| Proximal Middle-phalanx (84) | 824 (95%) | 18 (2%) | 21 (3%) | — |
| Distal-phalanx (154) | 138 (90%) | 20 (13%) | 4 (3%) | — |
| Intra-articular fractures (49 fractures) | | | | |
| MCP/PIP/DP (49) | 28 (72%) | 11 (28%) | — | — |
| Subgroup 12-17 years | | | | |
| Extra-articular (232 fractures) | | | | |
| Metacarpal (18) | 1814 (92%) | 39 (2%) | 35 (2%) | — |
| Proximal Middle-phalanx (112) | 1031 (92%) | 54 (5%) | 34 (3%) | — |
| Distal-phalanx (29) | 242 (82%) | 25 (12%) | 19 (6%) | — |
| Intra-articular fractures (33 fractures) | | | | |
| MCP/PIP/DP (33) | 188 (58%) | 141 (42%) | — | — |
| Total fractures: 654 | | | | |
| | | 393 (60%) | 251 (38%) | 10 (1%) |

Note: ORIF, open reduction internal fixation; PP, percutaneous pinning; MCP = metacarpophalangeal; PIP = proximal interphalangeal; DP = distal interphalangeal.



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SOURCES



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