Common Pediatric Fractures

Physician Assistants in Orthopaedic Surgery (PAOS)
Ortho in the West

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ORTHOPAEDIC SURGERY

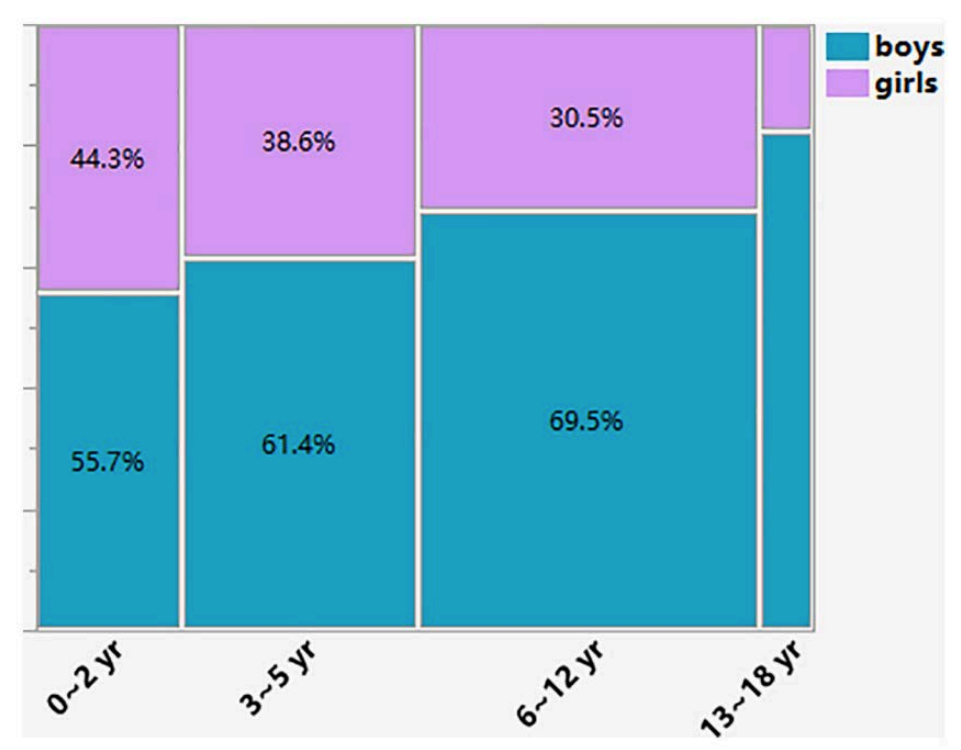
Outline

- Epidemiology
- Principles of care

- Upper extremity
  - Clavicle
  - Elbow
  - Forearm
  - Hand

Epidemiology

- One in three children will have a fracture[1]
- Boys more likely to fracture[1-4]



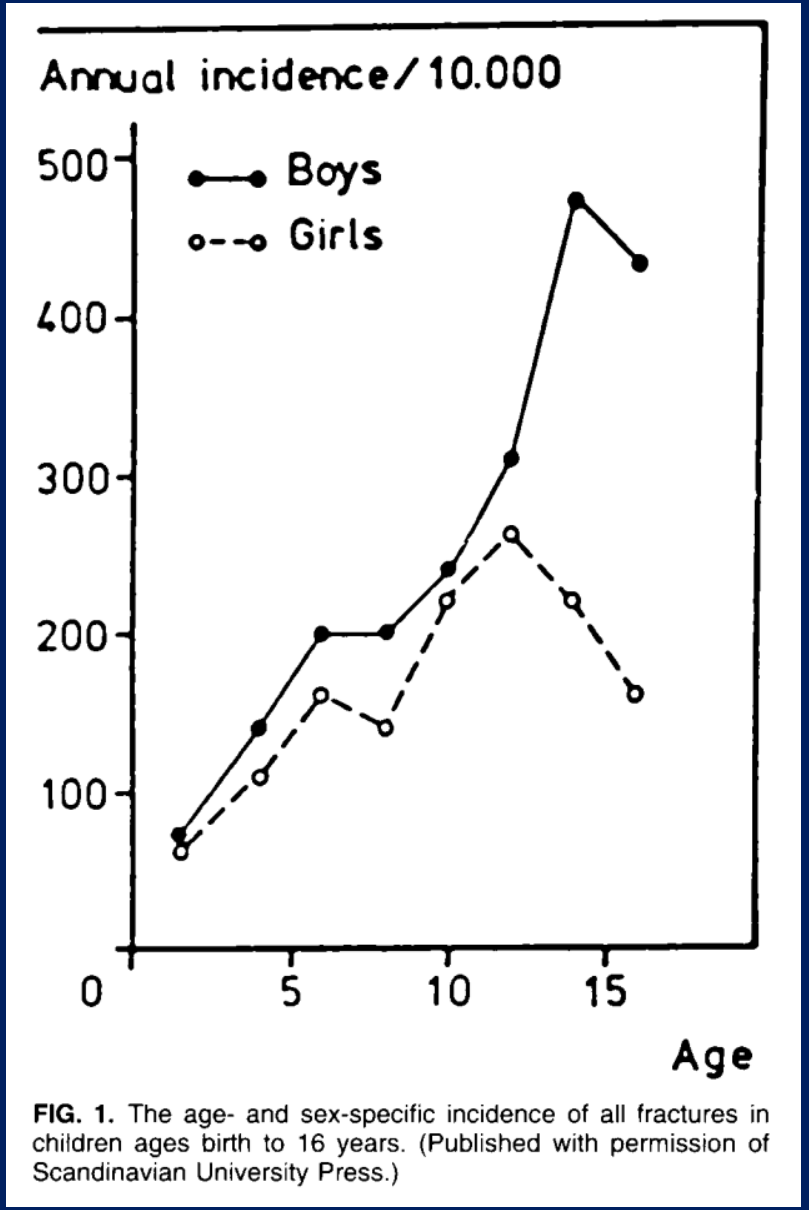


FIG. 1. The age- and sex-specific incidence of all fractures in children ages birth to 16 years. (Published with permission of Scandinavian University Press.)

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Epidemiology

- Upper extremity 76% of fractures[2,3]
  - 39% radius/ulna
  - 29% phalanges

TABLE 1. *The frequency of the most common fracture types*

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, os calcis 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
Femur shaft	1.6
Radial neck fracture	1.2
Vertebral fracture	1.2

TABLE 1. Epidemiology of Upper Extremity Fractures

Fractures	% (n)	Age (Range), y	Boys:Girls, %
Clavicula	9 (70)	7.5 (1 y 8 mo–16 y 4 mo)	51.5:48.5
Humerus	15 (122)	7.8 (1 y 5 mo – 17 y 9 mo)	52:48
Proximal	3 (23)		
Shaft	1 (7)		
Distal	11 (86)		
[illegible]	[illegible]		
Radius/ulna	39 (317)*	9.2 (7 mo–17 y 4 mo)	56:44
[illegible]	[illegible]		
Shaft	7 (53)		
Proximal	4 (31)		
*Ulna isolated**	*2 (19)*		
Carpal bone	2 (15)	12.7 (10 y 6 mo–16 y 6 mo)	67:33
[illegible]	[illegible]	12.7 (1 y 1 mo–18 y)	84:16
Phalangeal bone	29 (232)	10.8 (1 y 5 mo–17 y 4 mo)	60:40

The prevalence of different fractures together with the average age and sex of the patients is shown.

*Concerning the 317 radius/ulna fractures, 298 fractures involved the radius and 19 fractures were isolated fractures of the ulna.

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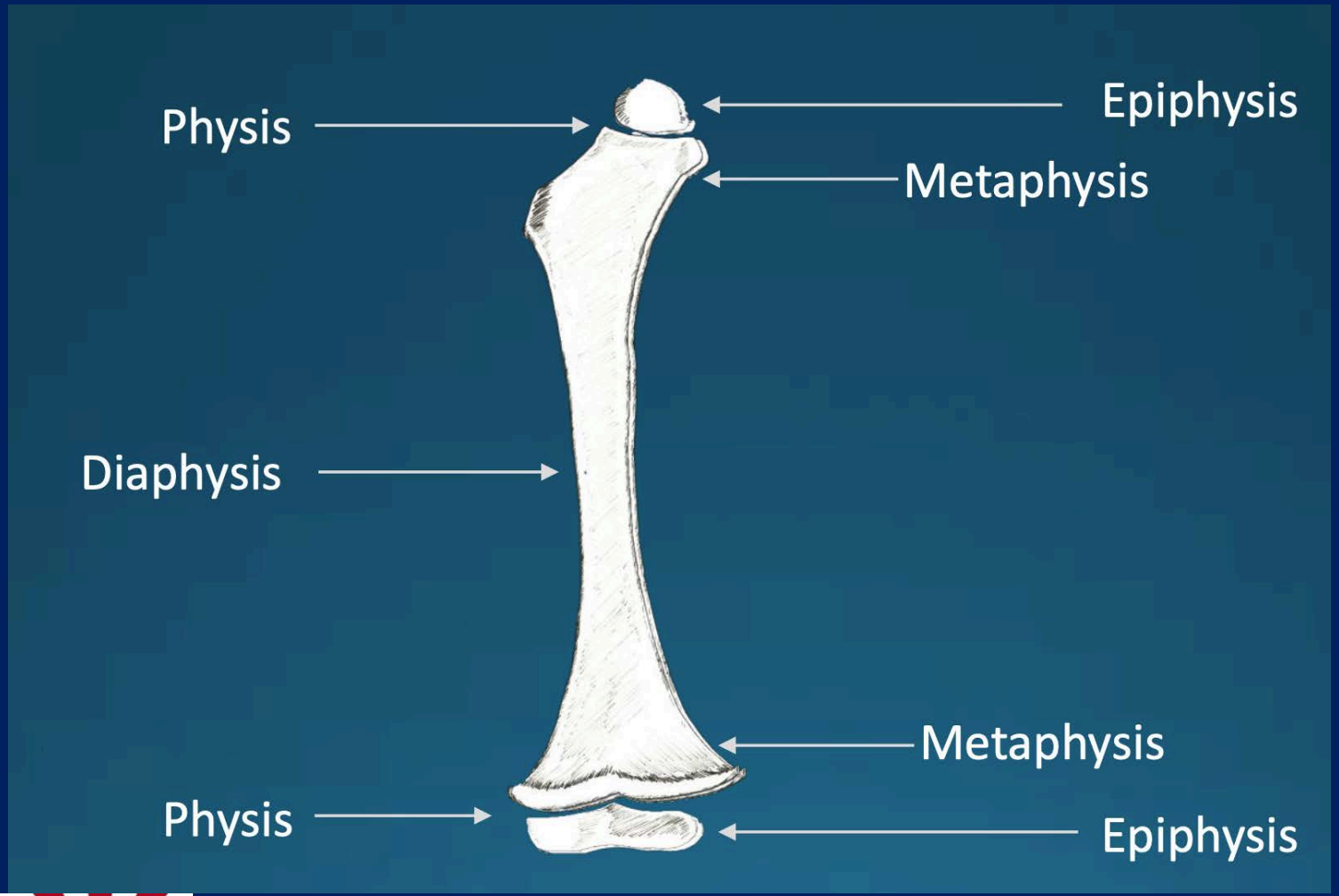
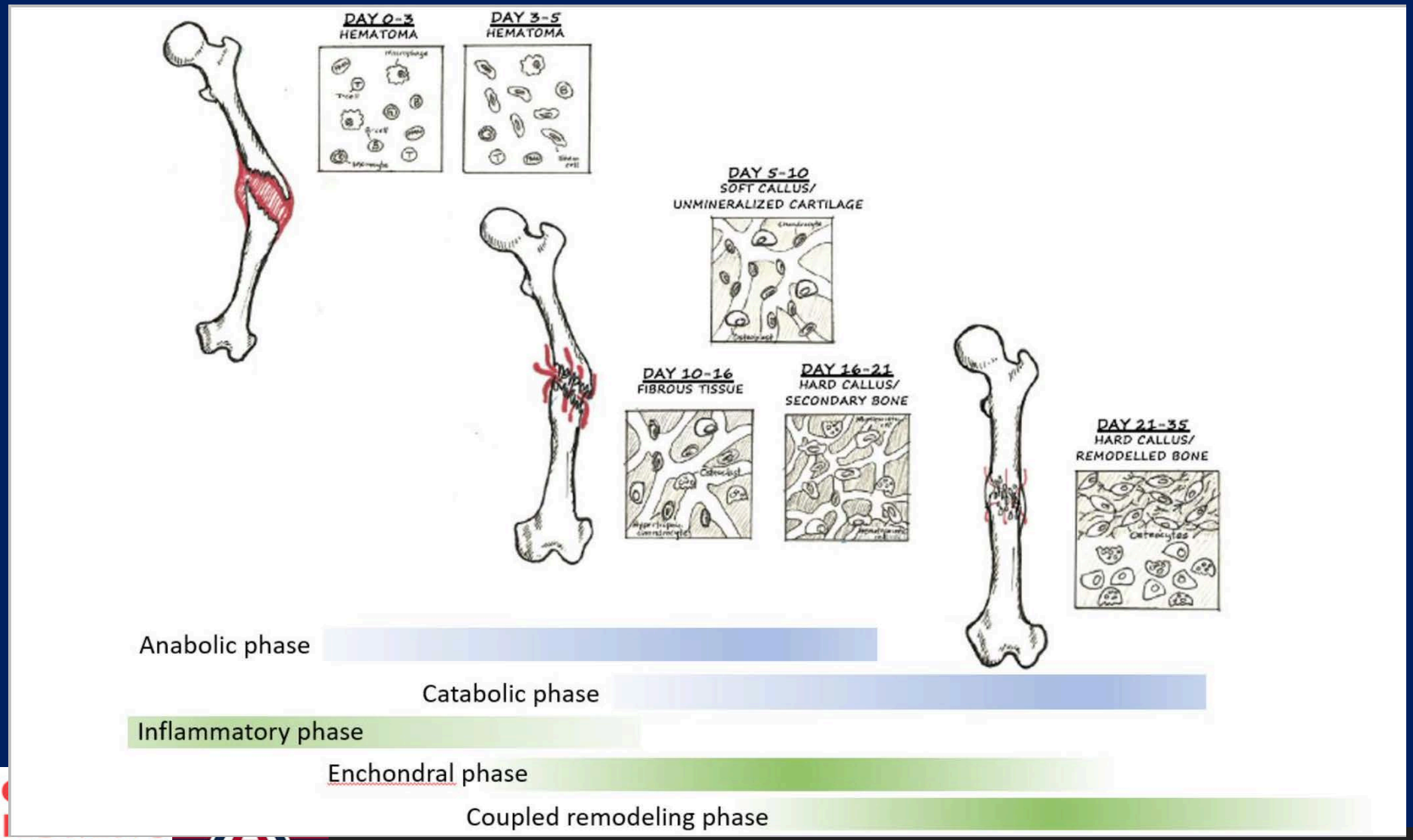
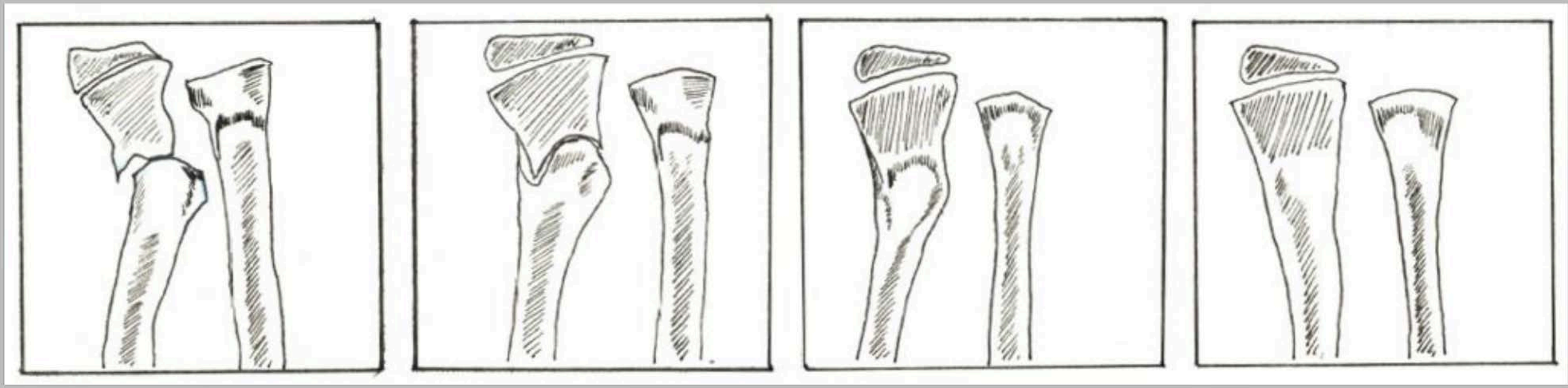
Principles of care – Anatomy[5]



Principles of care – Fracture healing[5]



Principles of care – Modeling/Remodeling[5]



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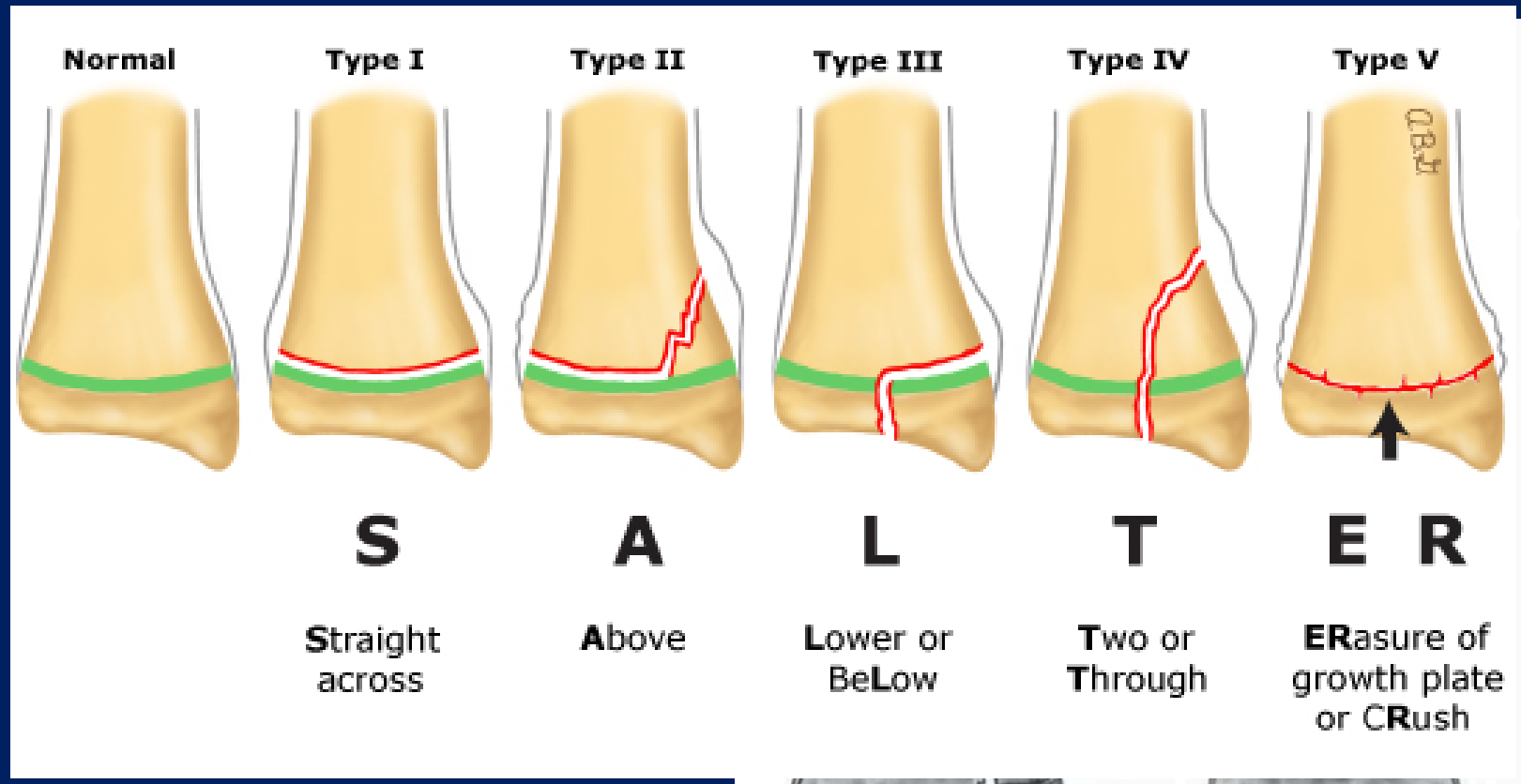
Principles of care[6,7]



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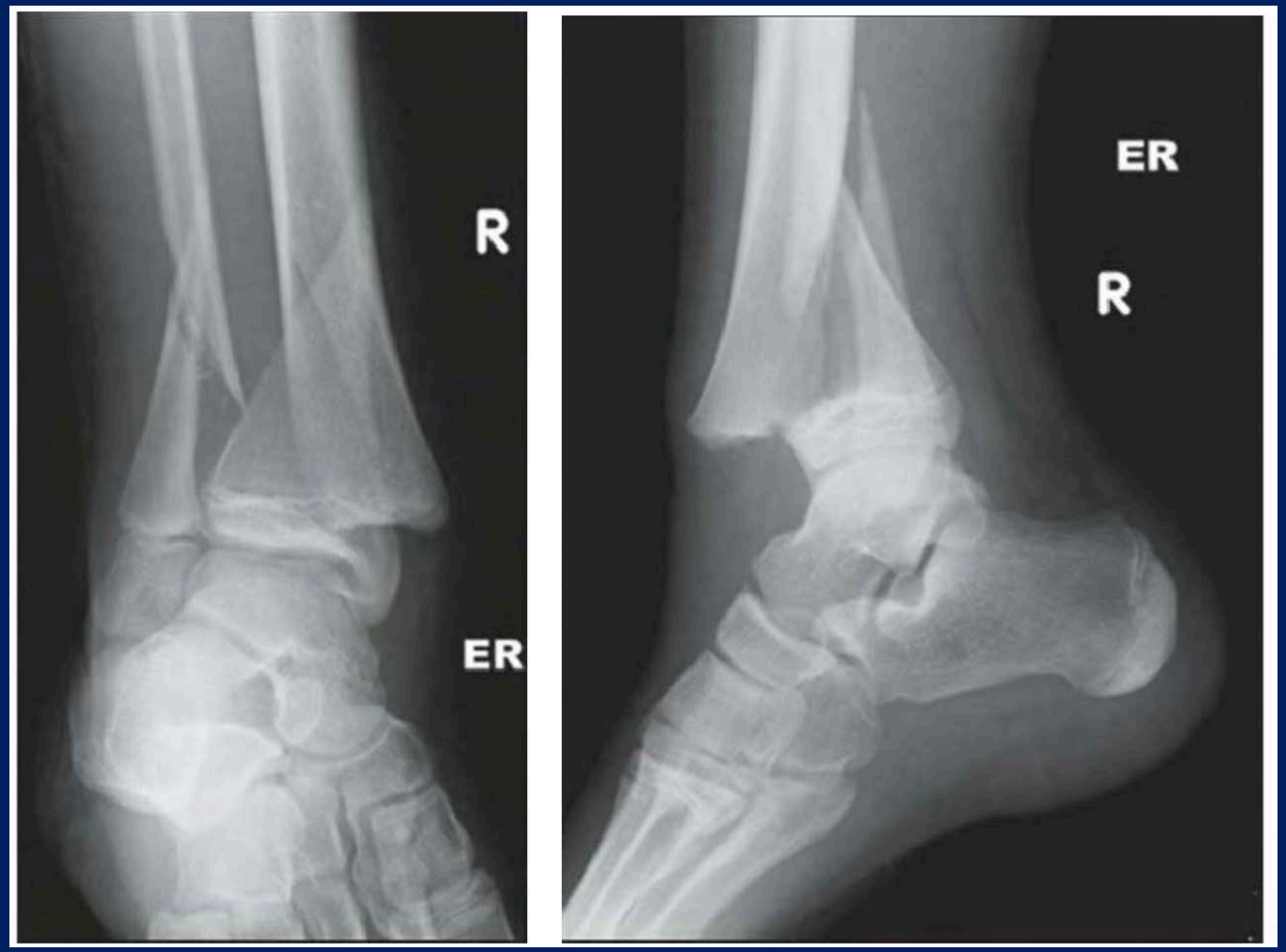
Principles of care[7]



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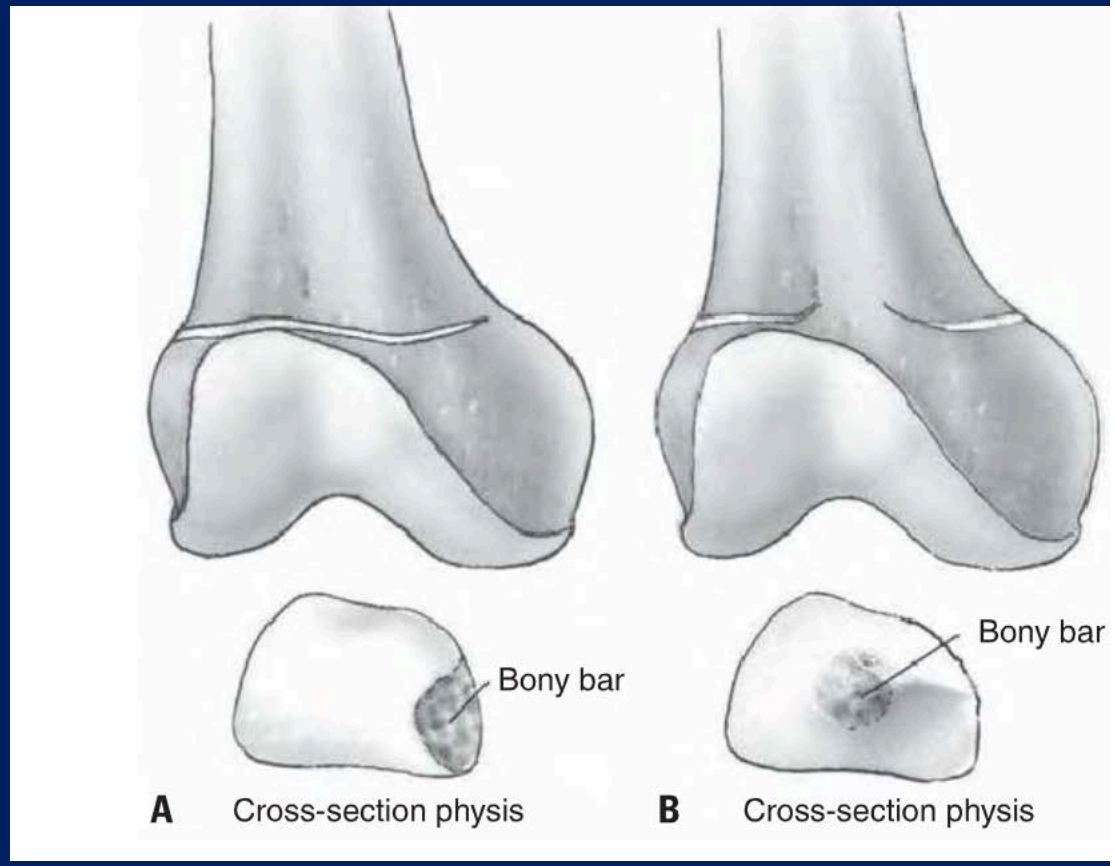
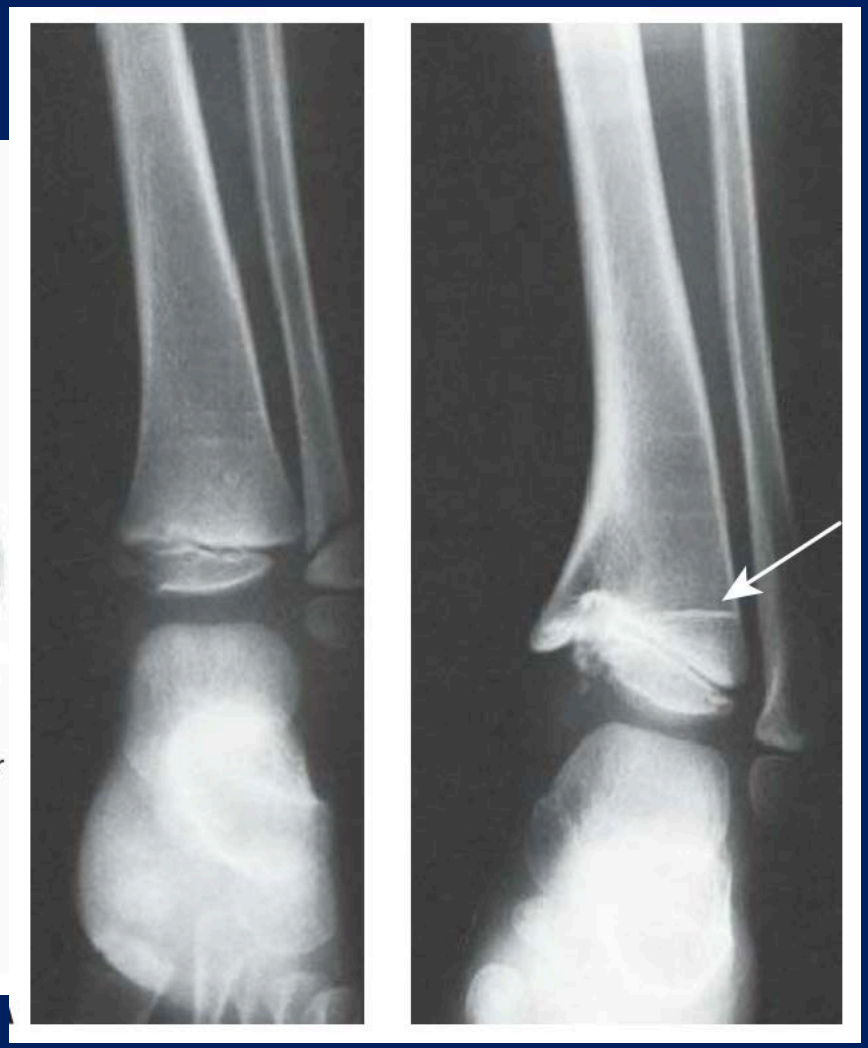
Principles of care[7]





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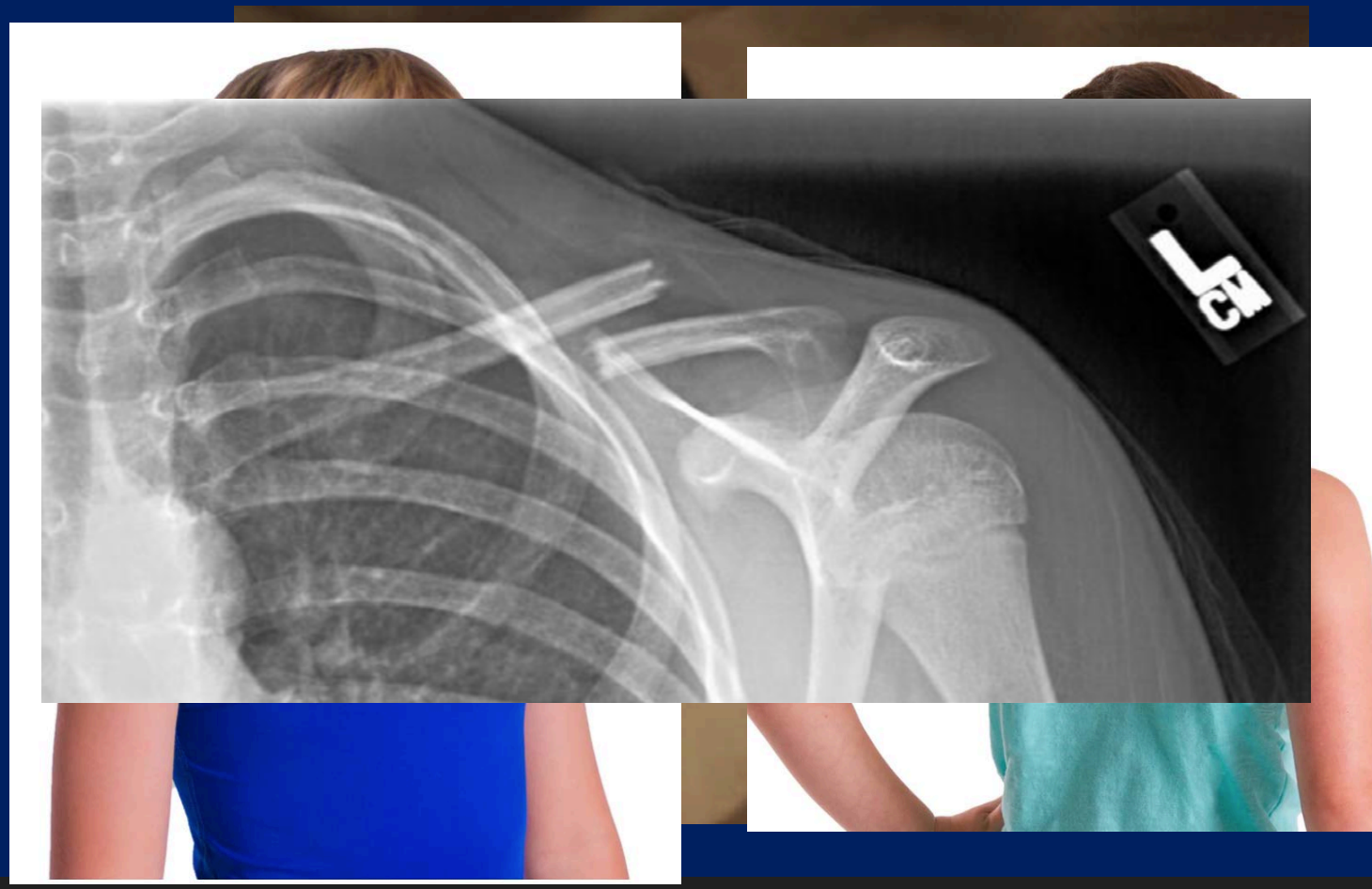
Clavicle[8]:

AKA everything is going to be fine

- Nonoperative management
  - Sling
  - Figure of 8
- Operative indications
  - Open fracture
  - Skin tenting



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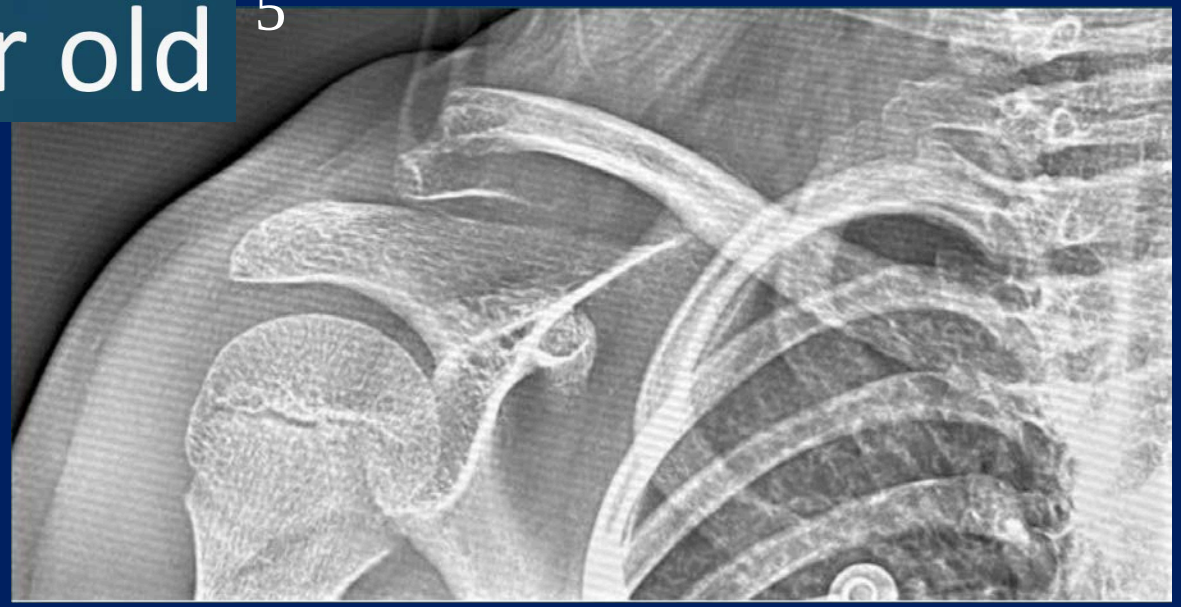
6 year old [5]



Initial

3 months

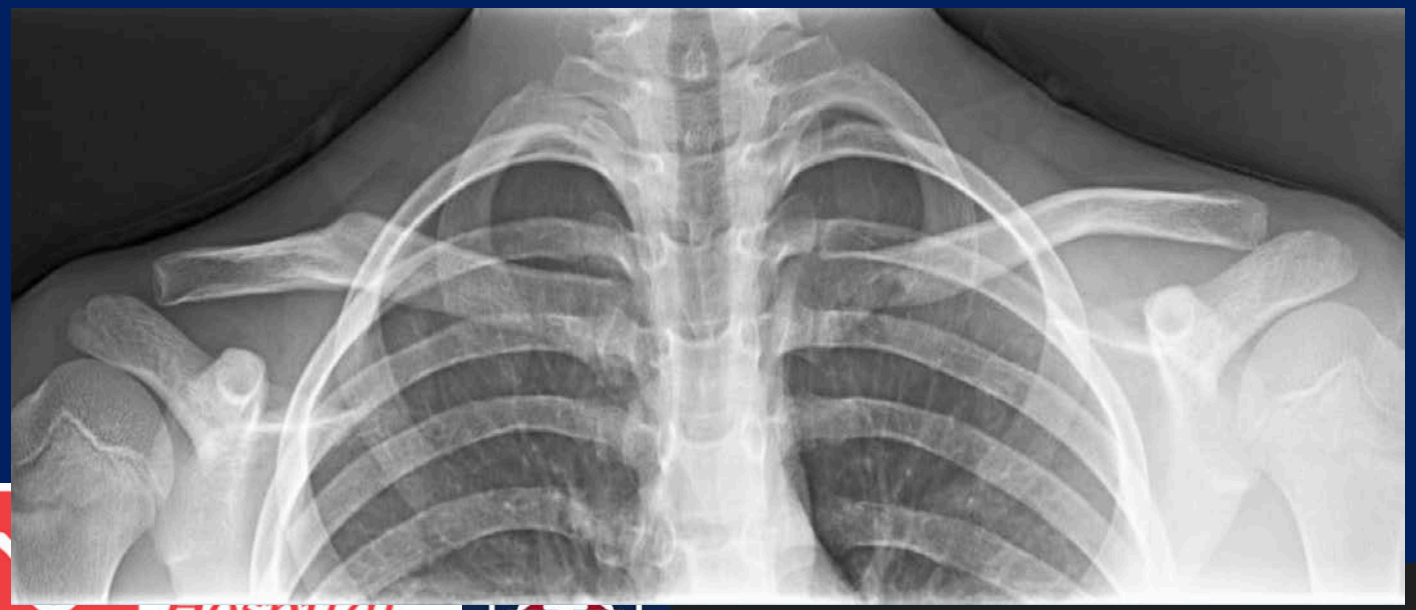
10 year old

Initial

6 years

11 year old

Initial



14 months

13 year old [5]

Initial

2.5 years

14 year old [5]

Initial

4 months

Clavicle[8]

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

Table I Patient demographic and injury data of the nonunion cohort compared with the primary fracture cohort

	Nonunion cohort (N = 25)	Primary fracture cohort (N = 545)	*P* value
Age (y)	14.5 ± 3.7	14.1 ± 2.1	.37
Gender	68% male	79% male	.21
Refracture	32%	9%	**.002**
End-to-end shortening (mm)	15.4 ± 10.4	12.4 ± (12.8)	.25
Cortex-to-cortex shortening (mm)	8.5 ± 7.6	6.9 ± 8.3	.35
Superior-to-inferior displacement (mm)	9.8 ± 9.3	8.5 ± 8.0	.537
Angulation (degrees)	16.5 ± 16.9	16.8 ± 16	.92
Comminuted	26%	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 shorting and 6 mm of cortex-to-cortex shortening was initially treated nonoperatively with a figure-of-8 brace. (**B**) The patient was subsequently lost to follow-up but presented again 21 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 returned to full sport with no limitations and no functional deficits.

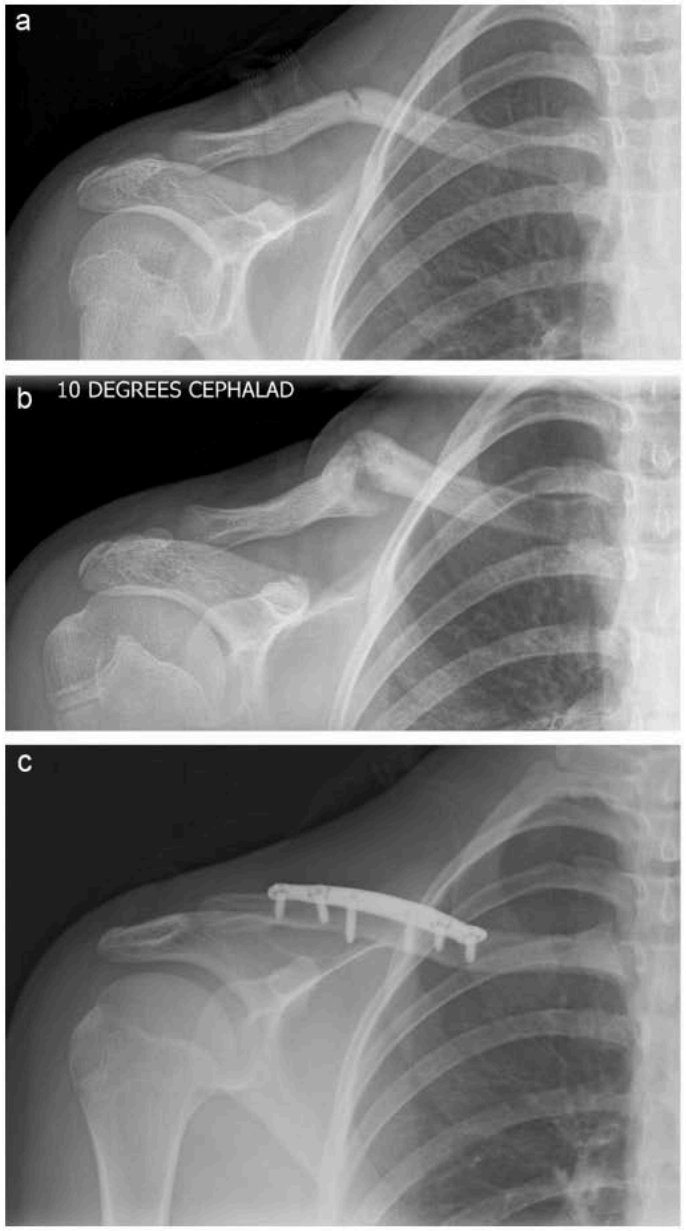

Figure 2 (**A**) A 12-year-old girl with a 33° angulated and minimally displaced clavicle fracture sustained while performing karate. (**B**) At 7 months after injury, the patient was diagnosed with a nonunion. (**C**) Final radiograph taken 18 months after nonunion repair with local bone graft demonstrating a healed clavicle.

Elbow[9-11]

- Variants in anatomy
- O
- B
- A

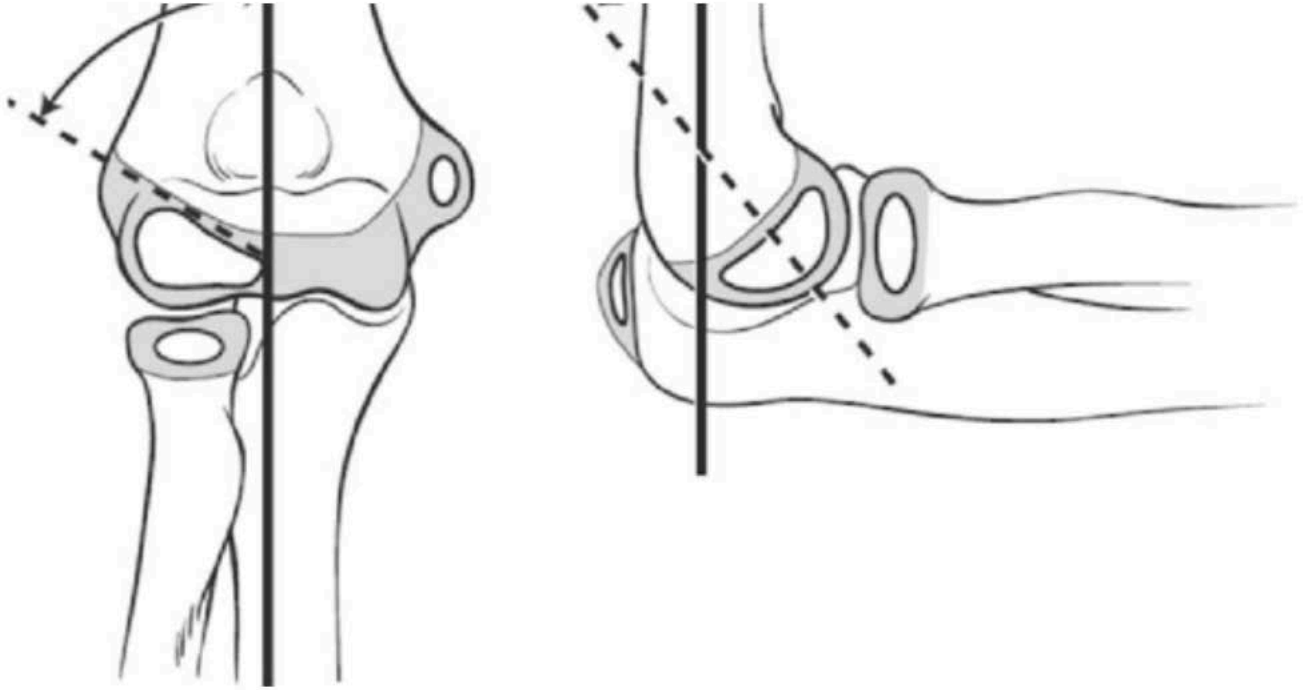

Table 1. Sum
years).

Ossification c			
C			
R			
M	5	7	5
T	8	9	7
O	8	10	9
L	11	12	11

C, capitellum; R, radial head; M, medial epicondyle; T, trochlea; O, olecranon; L, lateral condyle.

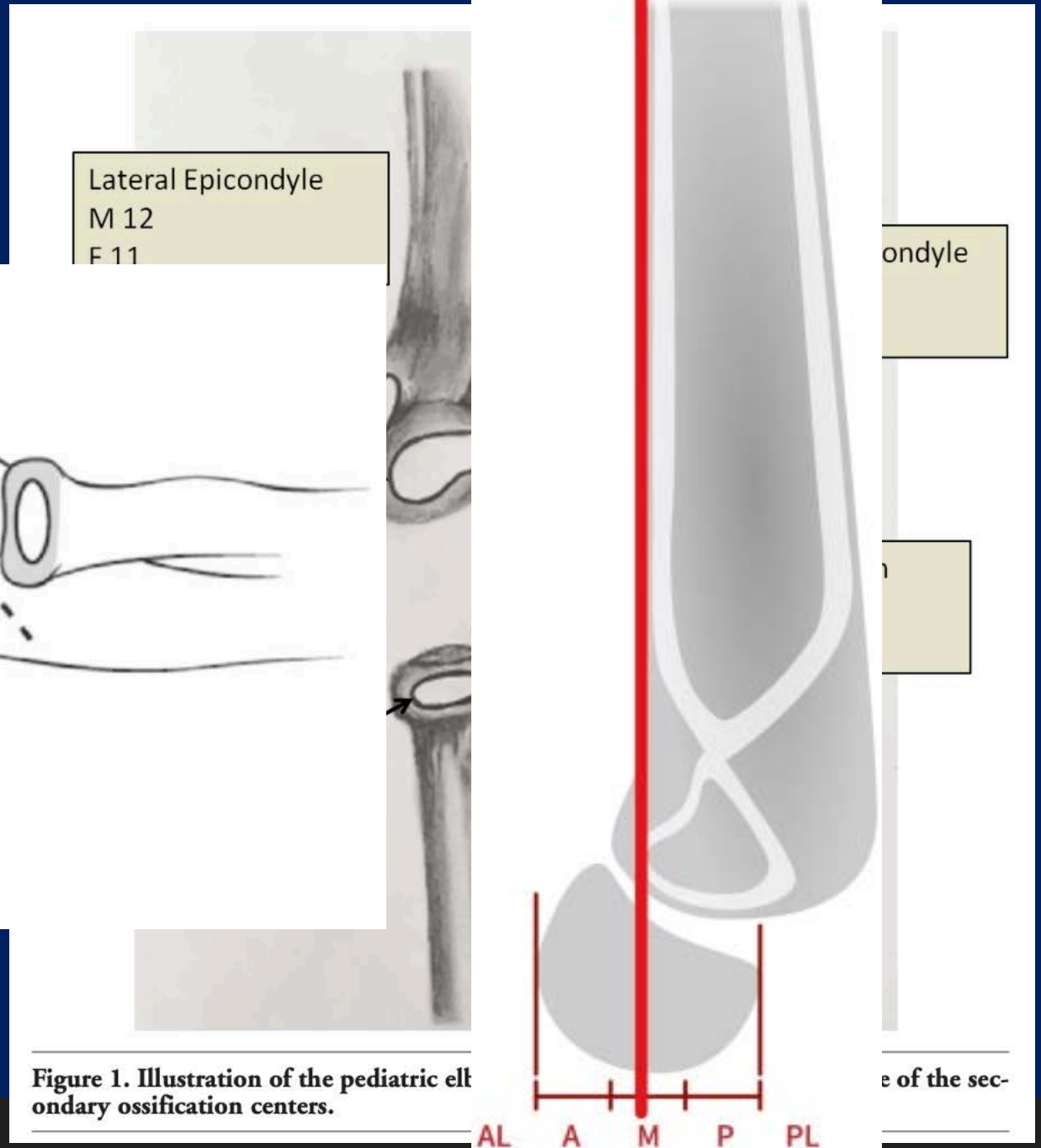

Figure 1. Illustration of the pediatric elb
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Elbow[9-11]

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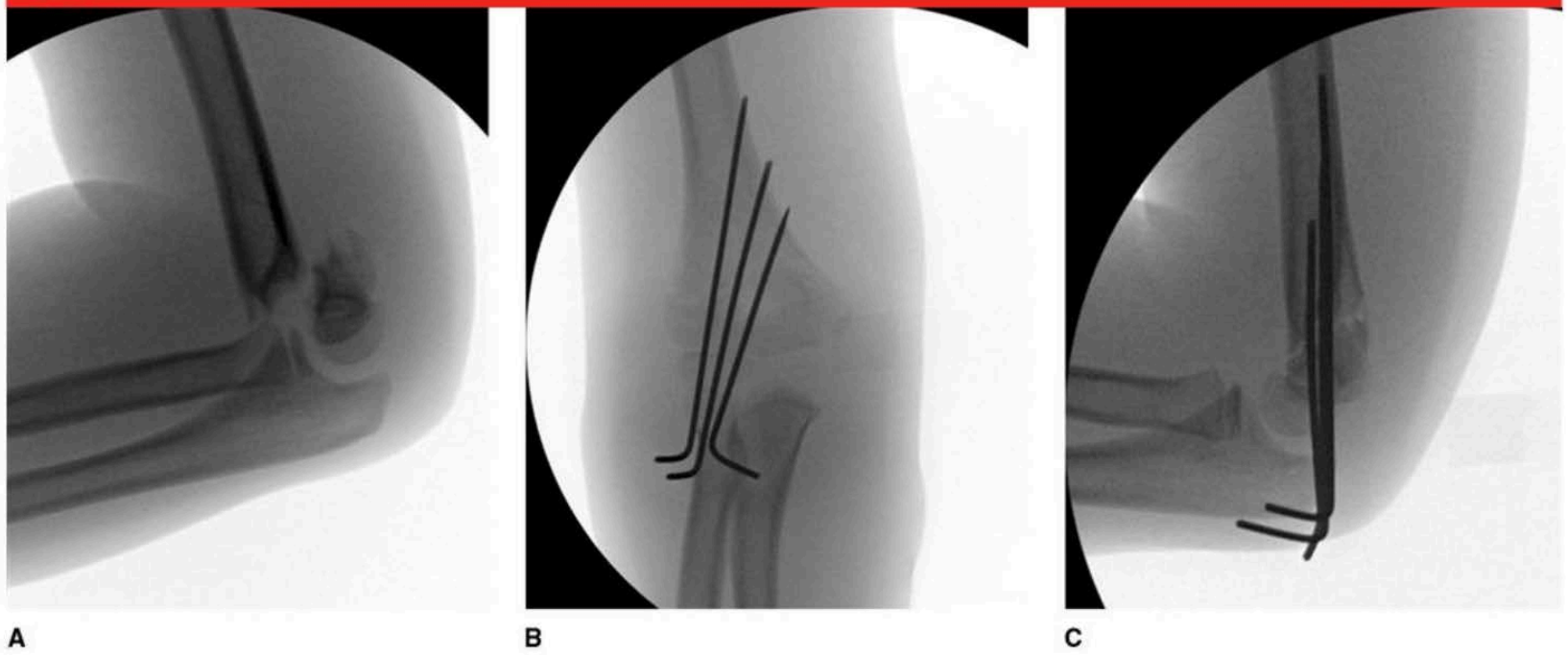
Figure 3



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[12-14]

- Lateral condyle
  - Intra articular fracture
  - Internal oblique

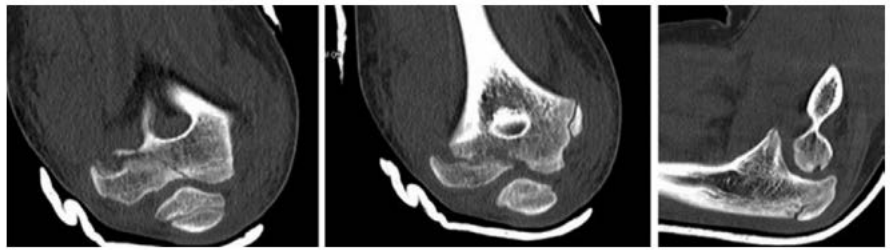

Figure 3 Postreduction CT scan of right elbow in posterior plaster splint.

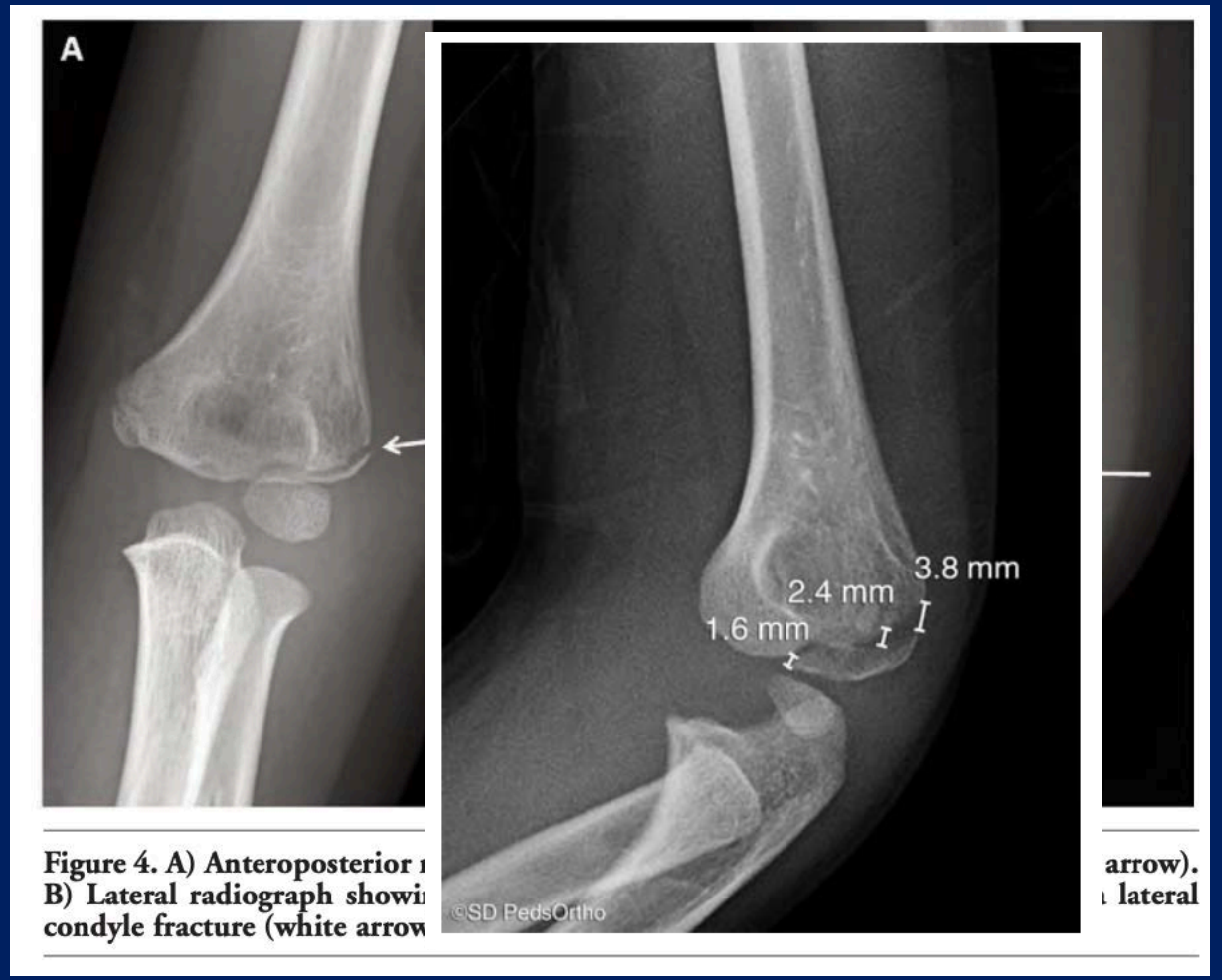

Figure 4. A) Anteroposterior r
B) Lateral radiograph showi
condyle fracture (white arrow
arrow).
lateral

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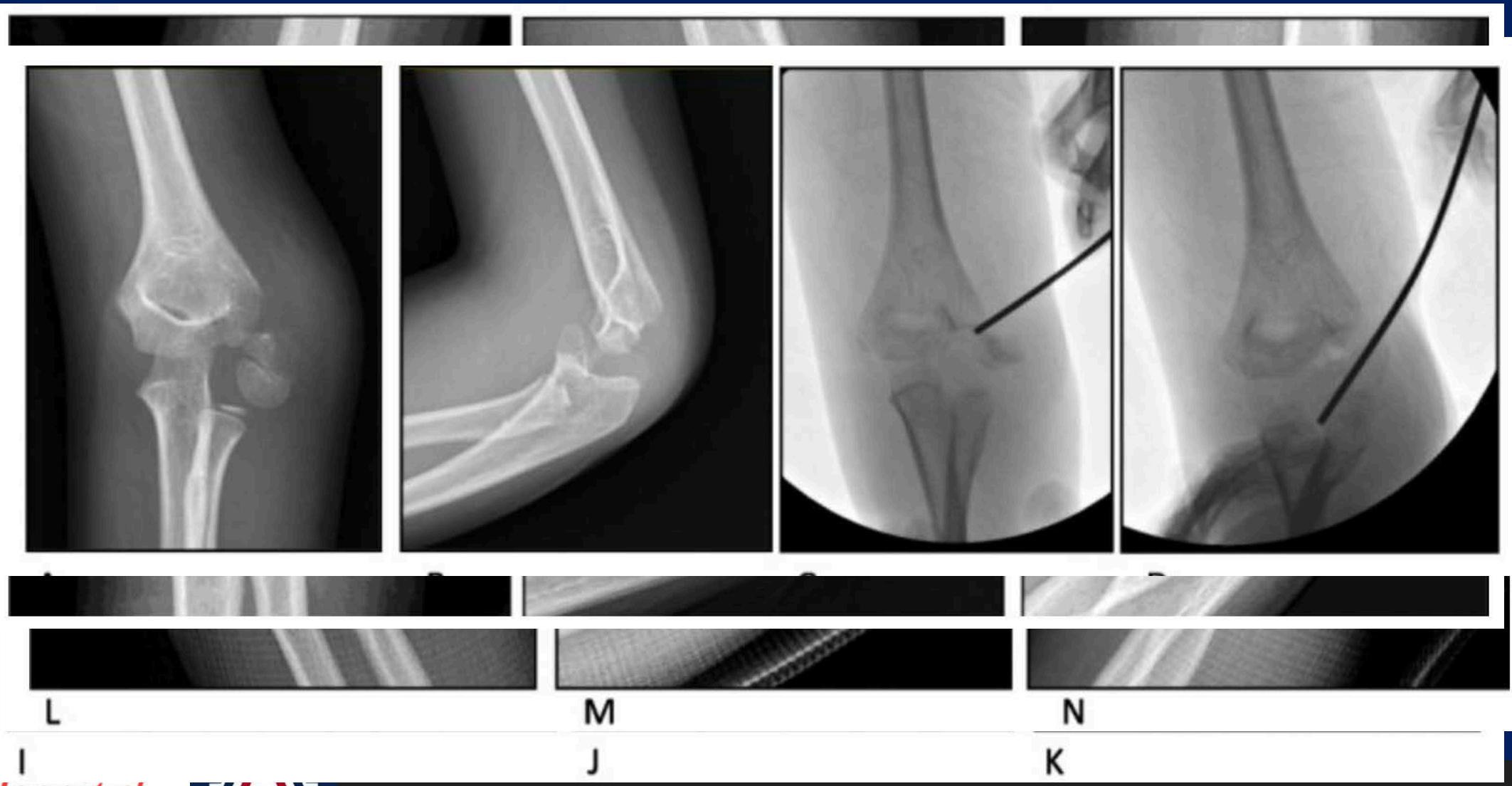
Elbow[12-14]



Hospital

Elbow[9-11]

- Medial epicondyle
  - Avulsion fracture
  - Associated with elbow dislocation
  - Evaluate for incarcerated fragment
  - Largely treated nonop

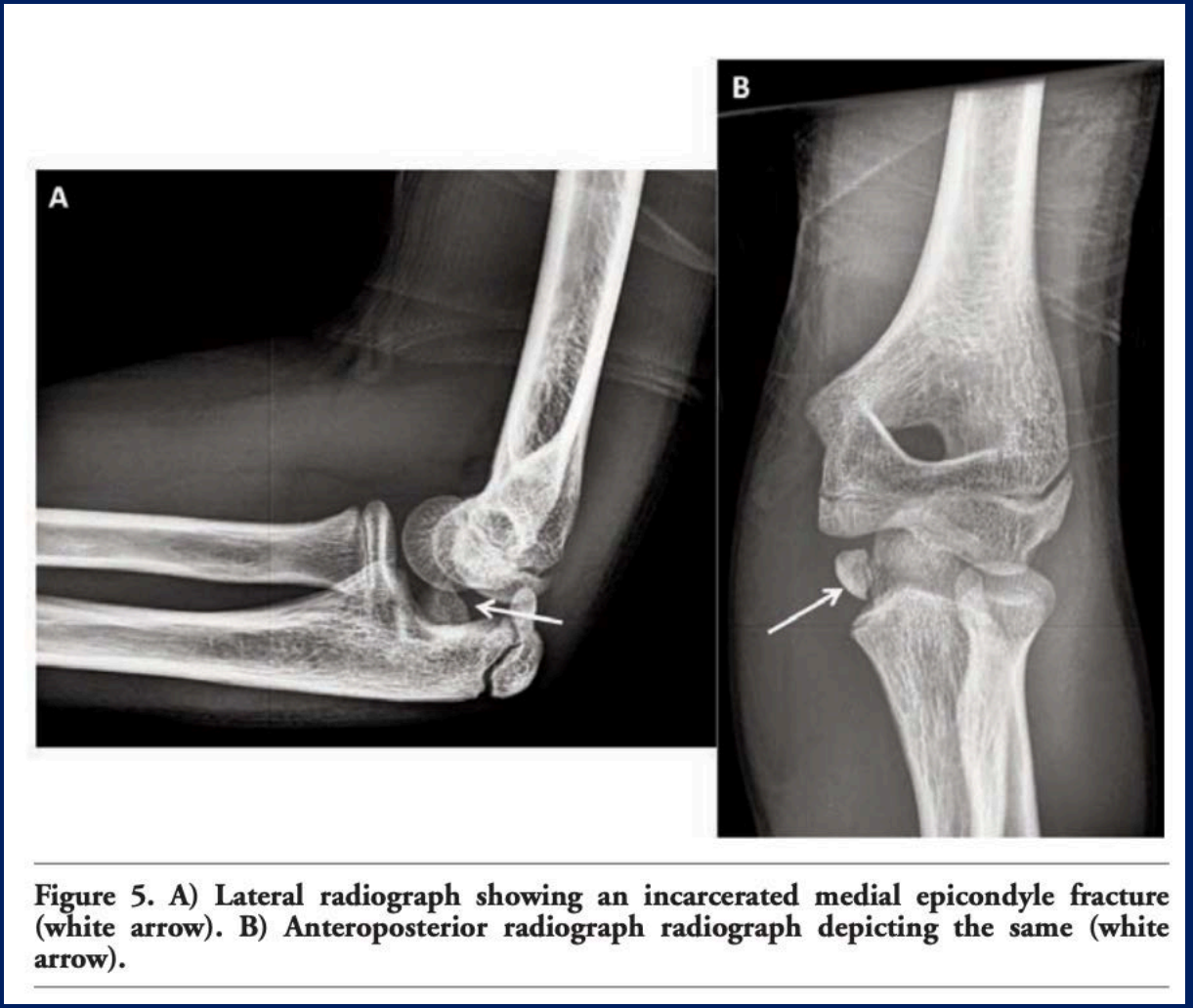


Figure 5. A) Lateral radiograph showing an incarcerated medial epicondyle fracture (white arrow). B) Anteroposterior radiograph radiograph depicting the same (white arrow).

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Monteggia[15-17]

- Monteggia
  - Fracture dislocation
  - Can be treated nonoperatively
  - Watch radiocapitellar line
  - Chronic Monteggia

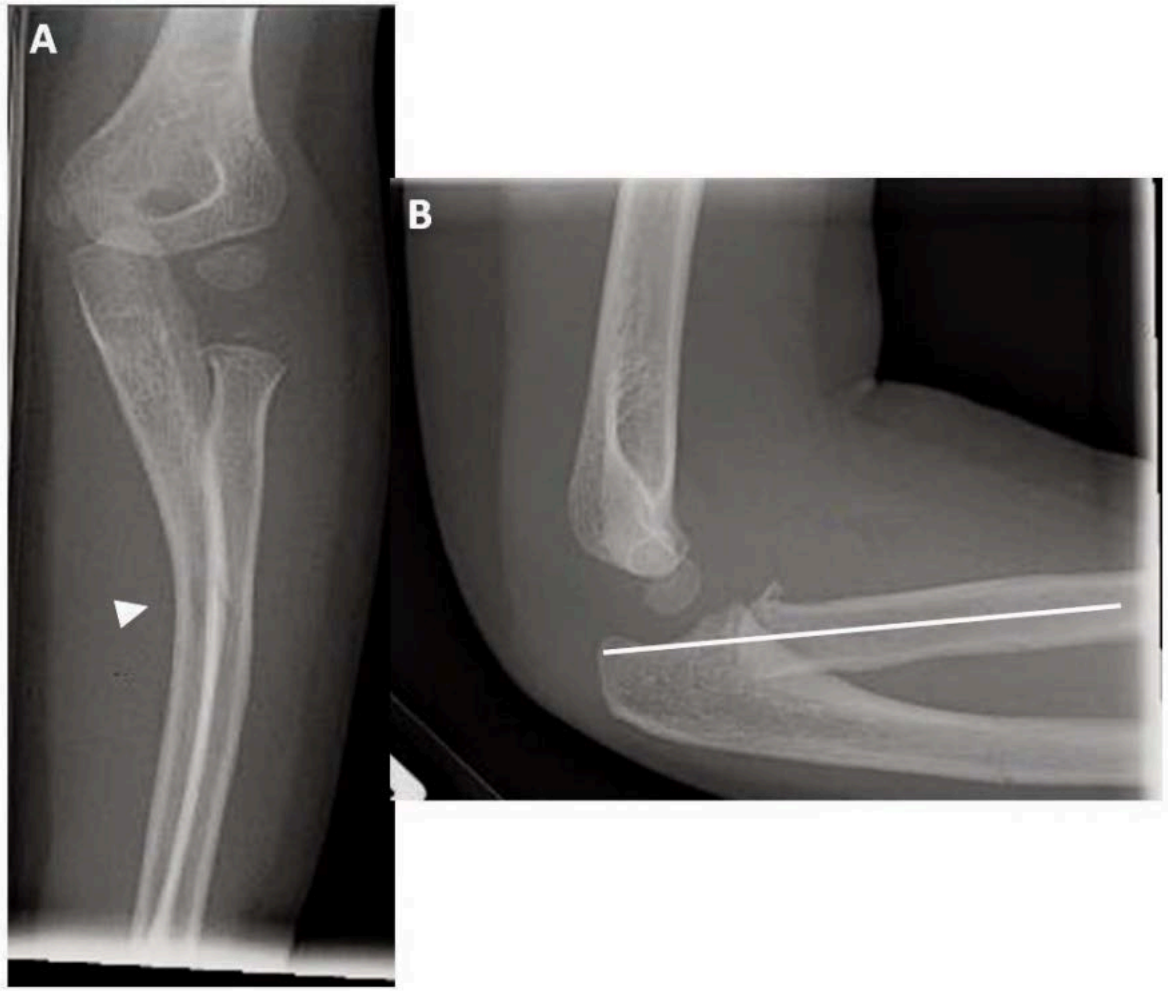

Figure 2. A) Monteggia fracture. White arrow represents ulnar bowing. The radial head is not directed at the capitellum. B) Lateral image more clearly demonstrates the malalignment of the radiocapitellar joint representing an associated posterior radiocapitellar dislocation.

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

Monteggia[15-17]

- Monteggia
  - Direction of radial head
  - Classification
  - Need for surgery

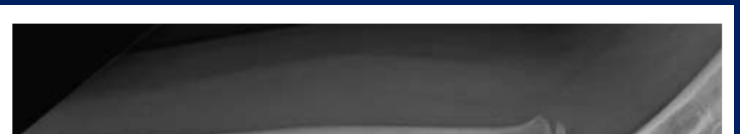

TABLE 2. Risk Factors for Failure of Nonoperative Management

	Successful Nonoperative Treatment (N = 78)	Failed Nonoperative Treatment (N = 16)	*P*
Mean age (y)	5.4 ± 1.8	5.6 ± 2.4	0.72
Sex (female) [n (%)]	31 (40)	6 (38)	0.87
Bado classification [n (%)]			**0.007**
Type I	52 (67)	7 (44)	
Type II	0 (0)	2 (12)	
Type III	18 (23)	6 (38)	
Type IV	8 (10)	1 (6)	
Ulna fracture pattern [n (%)]			0.064
Incomplete	33 (42)	2 (12)	
Plastic deformation	13 (17)	0 (0)	
Green stick	20 (25)	2 (12)	
Complete	45 (58)	14 (88)	
Length-stable	30 (38)	10 (63)	
Transverse	8 (10)	3 (19)	
Short oblique	22 (28)	7 (44)	
Length-unstable	15 (20)	4 (25)	
Long oblique	13 (17)	3 (19)	
Comminuted	2 (3)	1 (6)	
Ulna fracture location [n (%)]			0.58
Proximal	44 (56)	11 (69)	
Diaphyseal	32 (41)	5 (31)	
Distal	2 (3)	0 (0)	
Mean maximal ulna angulation (deg.)	20.8 ± 13.7	30.9 ± 18.5	**0.014**

Bold values represent a *P*-value < 0.05.

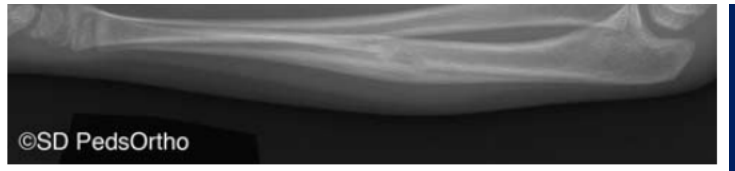

Table 1: Bado Classification of Monteggia Fracture-Dislocation

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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Forearm[1-5]

- Most common fracture type
- Great remodeling potential

- Acceptable displacement dependent on age and fracture location

Forearm[7,18,19]

- 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

Forearm[7,18,19]

- Both bone forearm fractures – cast index

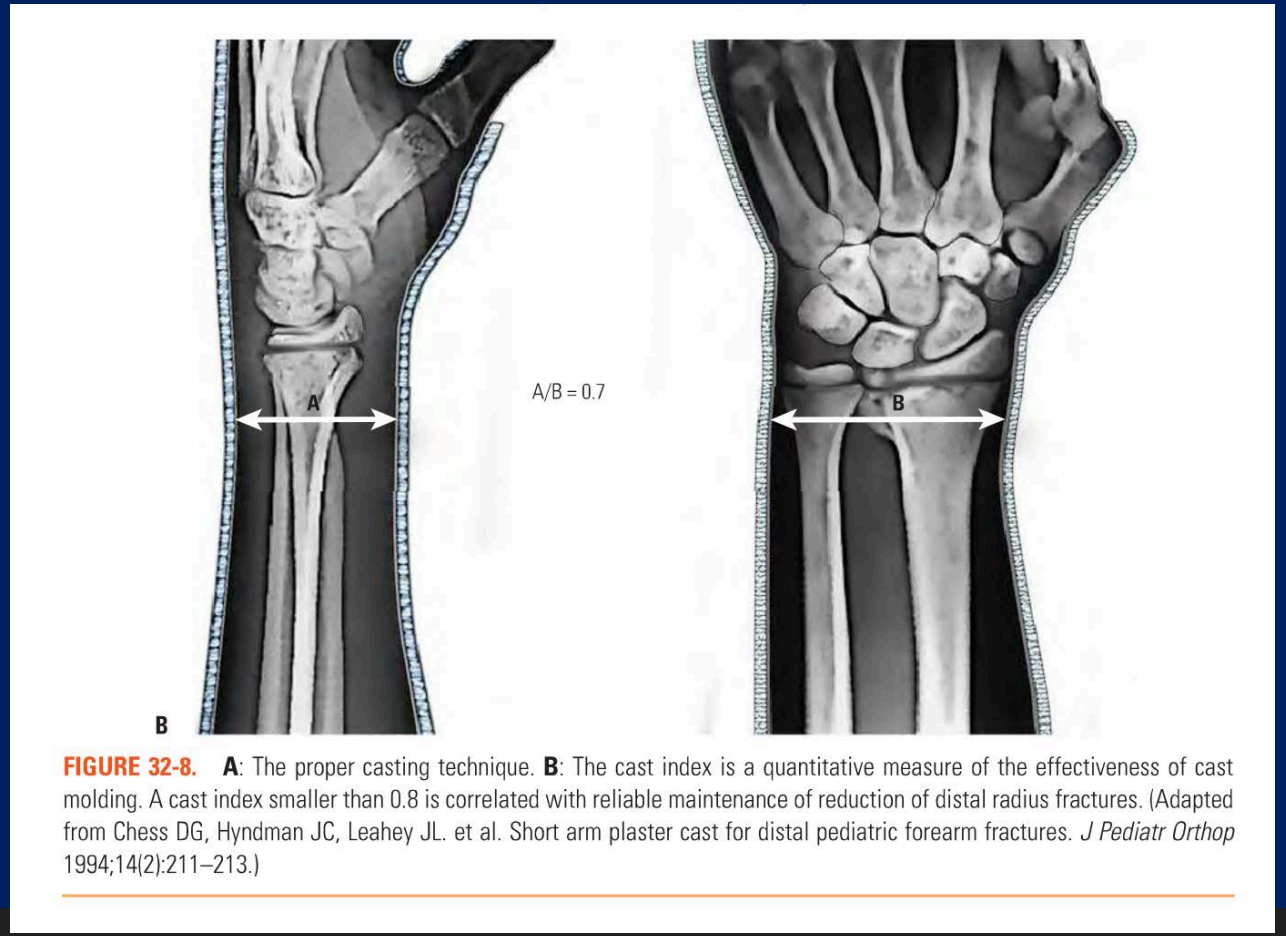

FIGURE 32-8. **A**: The proper casting technique. **B**: The cast index is a quantitative measure of the effectiveness of cast molding. A cast index smaller than 0.8 is correlated with reliable maintenance of reduction of distal radius fractures. (Adapted from Chess DG, Hyndman JC, Leahey JL. et al. Short arm plaster cast for distal pediatric forearm fractures. *J Pediatr Orthop* 1994;14(2):211–213.)

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Forearm[7,18,19]

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

	Elbow Flexion			Elbow Extension			Pronation			Supination		
Task	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 ± 3.9	143.7 ± 4.3	0.07	—	—	—	−19.4 ± 14.3	−9.6 ± 17.3	**< 0.05**	54.4 ± 9.3	51.4 ± 16.1	0.30
Hand to occiput	146.4 ± 4.6	146.1 ± 8.9	0.84	—	—	—	33.0 ± 19.3	35.8 ± 15	0.52	47.1 ± 20.5	38.9 ± 20	**< 0.05**
Hand to back	114.8 ± 10.5	125.3 ± 12.6	**< 0.001**	—	—	—	34.8 ± 22.3	43.4 ± 24.2	0.10	−5.46 ± 11.3	42.8 ± 19.5	0.44
Drinking from glass	127.3 ± 3.9	132.1 ± 6.2	**< 0.001**	61.4 ± 11.9	65.3 ± 15.5	0.21	38.9 ± 9.5	56.4 ± 11.2	**< 0.001**	21.2 ± 12.9	1.0 ± 9.2	**< 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	14.0 ± 18	**< 0.01**
Reading magazine	96.8 ± 17.1	96.9 ± 17.7	0.95	63.2 ± 17.3	68.4 ± 23.6	0.23	61.1 ± 18.9	69.4 ± 20.4	0.07	17.9 ± 16.9	0.43 ± 15.1	**< 0.001**
Standing from chair	95.5 ± 15.7	104.5 ± 11.5	**< 0.01**	35.1 ± 20.1	21.2 ± 14.1	**< 0.001**	42.6 ± 16.6	52.7 ± 13	**< 0.01**	8.9 ± 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 ± 2.2	0.08	56.4 ± 14	41.1 ± 6.6	**< 0.01**
Typing with keyboard	100.5 ± 13	95.5 ± 21.2	0.18	67.1 ± 8.8	68.9 ± 26.9	0.40	64.3 ± 14	66.5 ± 18	0.55	3.2 ± 14	−11.4 ± 13	**< 0.001**
Using computer mouse	87.4 ± 14	94.2 ± 16.9	**< 0.05**	38.5 ± 9.4	41.2 ± 20.5	0.42	52.1 ± 13	61.7 ± 14	**< 0.01**	8.7 ± 18.6	−4.9 ± 12	**< 0.001**
Texting	97.8 ± 12.7	101.2 ± 16	0.32	55.8 ± 12.3	46.0 ± 24.3	**< 0.05**	41.8 ± 16	51.1 ± 13.6	**< 0.05**	19.1 ± 15.5	10.9 ± 13.4	**< 0.05**

Bold indicates significant *P* values.

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Forearm[5]

6 year old

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Forearm[5]

7 year old

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Forearm[5]

12 year old

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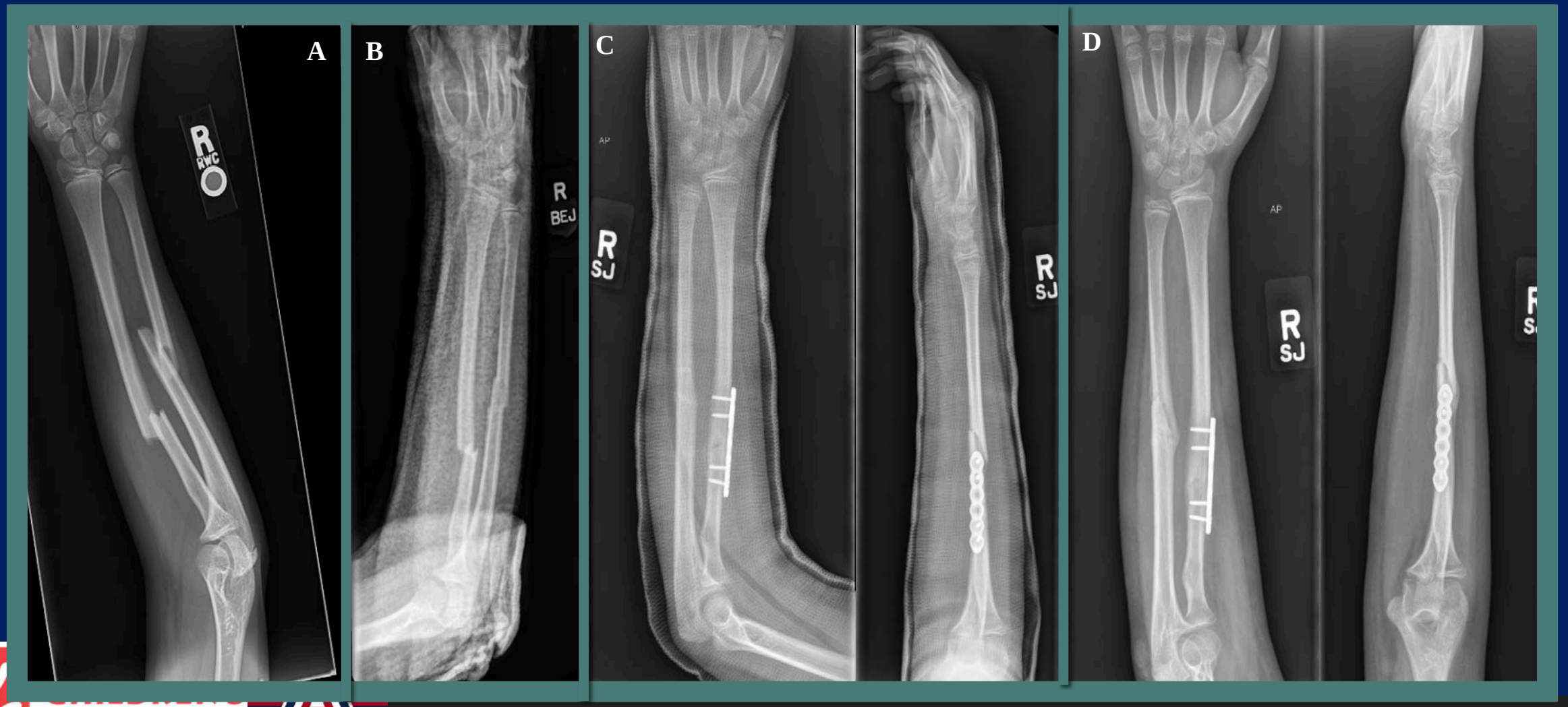
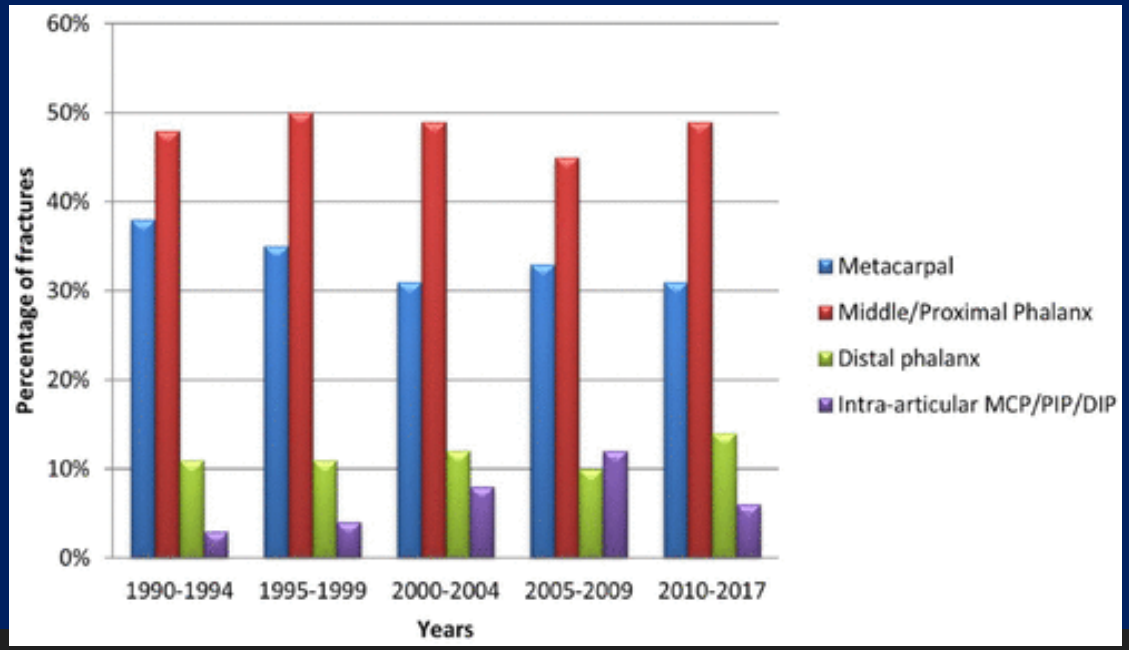
Forearm



Hand[20,21]

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



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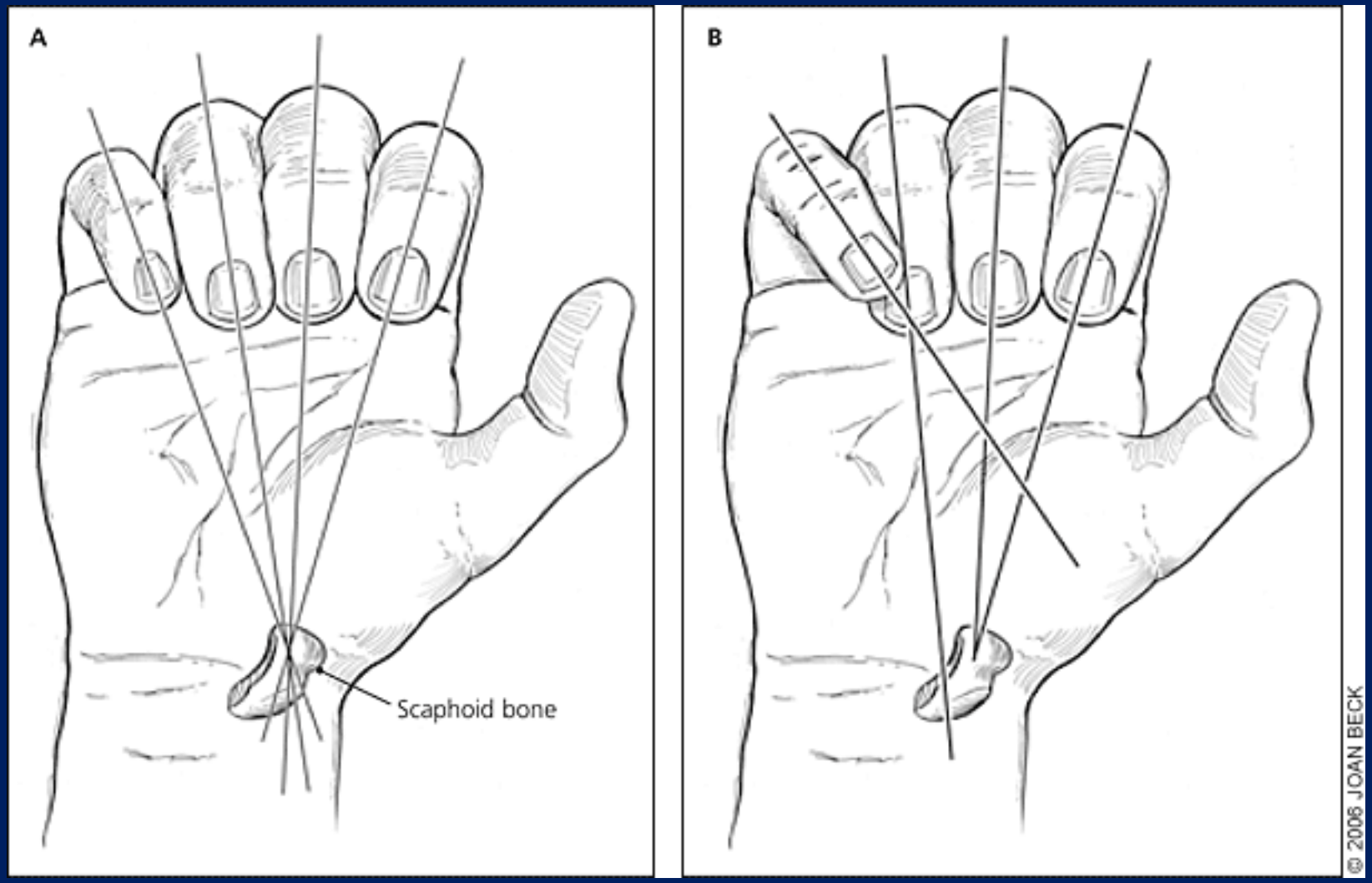
Hand[20,21]



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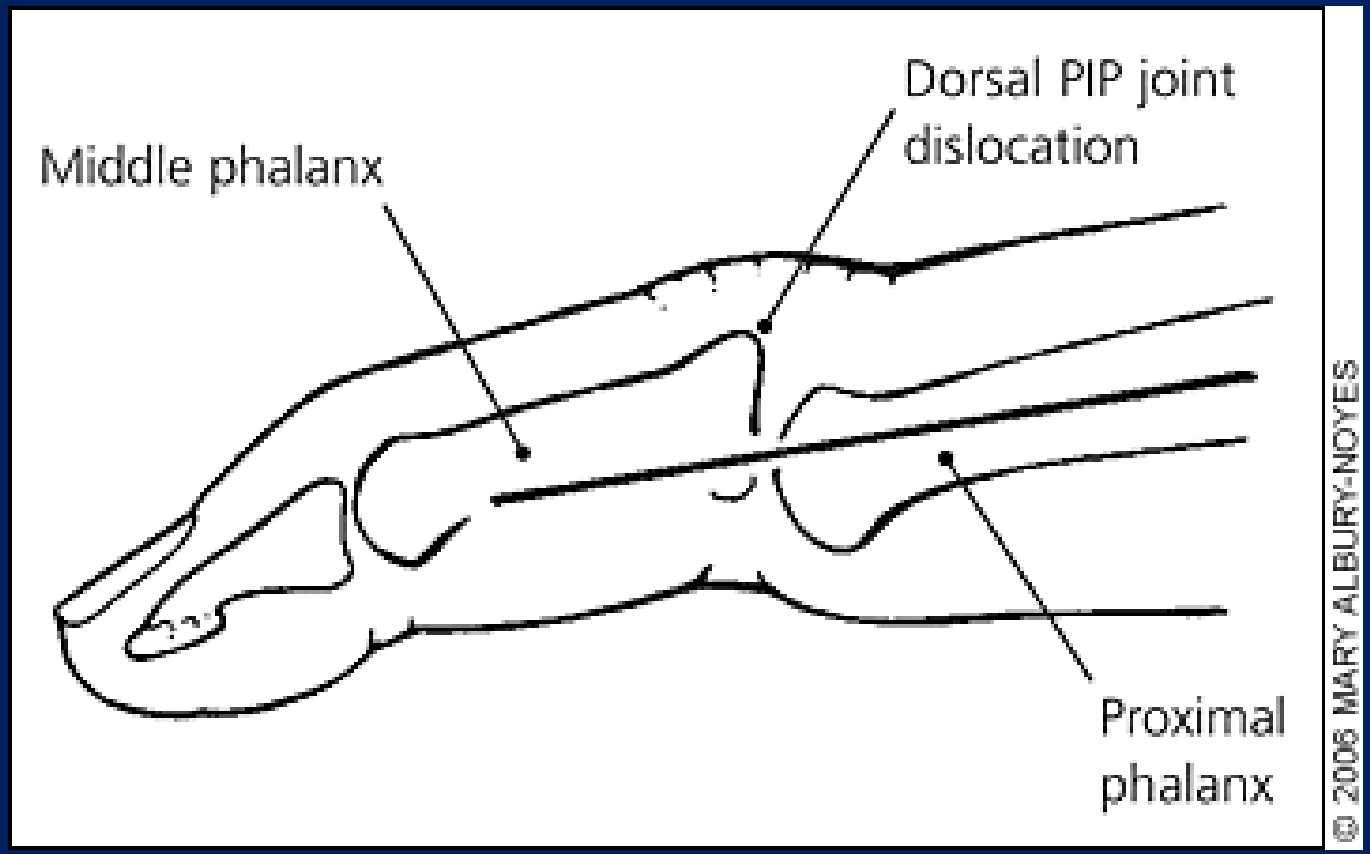
Hand[20,21]


Dorsal PIP joint dislocation
Middle phalanx
Proximal phalanx
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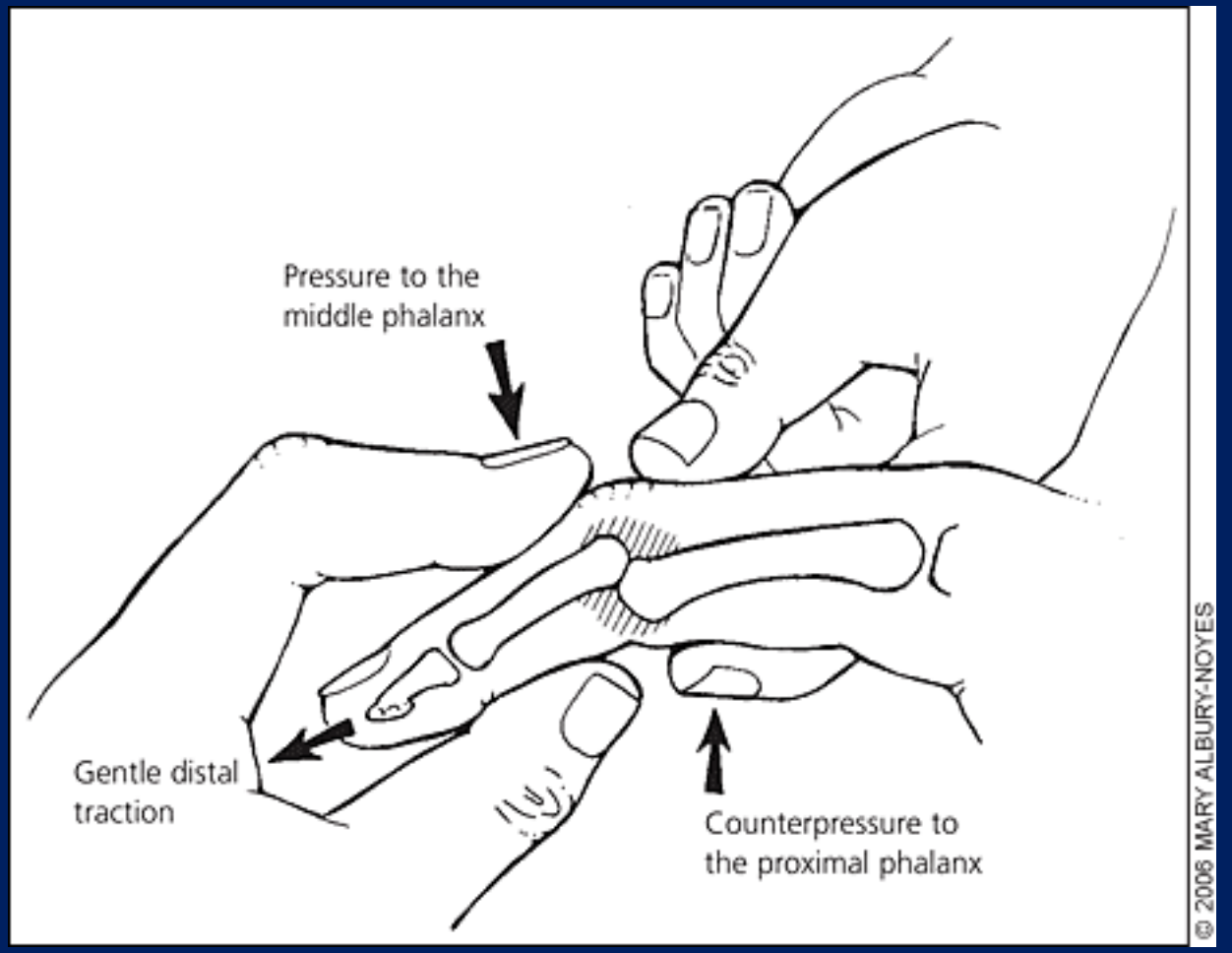
Hand[20,21]


Pressure to the middle phalanx
Gentle distal traction
Counterpressure to the proximal phalanx
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Hand[20,21]

Table 2. Fracture Management Divided by Age Group and Anatomical Site.

Fracture management			
Subgroup and anatomical localization	Closed reduction	ORIF	PP
Subgroup 0-5 years			
Extra-articular (222 fractures)			
Metacarpal (32)	28 (87%)	3 (10%)	1 (3%)
Proximal/Middle phalanx (119)	94 (79%)	13 (11%)	12 (10%)
Distal phalanx (71)	65 (92%)	5 (7%)	1 (1%)
Intra-articular fracture (12 fractures)			
MCP/PIP/DIP (12)	5 (42%)	7 (58%)	—
Subgroup 6-11 years			
Extra-articular (1308 fractures)			
Metacarpal (291)	284 (98%)	3 (1%)	4 (1%)
Proximal/Middle phalanx (863)	824 (95%)	18 (2%)	21 (3%)
Distal phalanx (154)	130 (84%)	20 (13%)	4 (3%)
Intra-articular fracture (39 fractures)			
MCP/PIP/DIP (39)	28 (72%)	11 (28%)	—
Subgroup 12-17 years			
Extra-articular (2525 fractures)			
Metacarpal (1108)	1014 (92%)	59 (5%)	35 (3%)
Proximal/ Middle phalanx (1121)	1031 (92%)	56 (5%)	34 (3%)
Distal phalanx (296)	242 (82%)	35 (12%)	19 (6%)
Intra-articular fracture (250 fractures)			
MCP/PIP/DIP (250)	185 (74%)	65 (26%)	—
Total fractures: 4356	3930 (90%)	295 (7%)	131 (3%)

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

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SOURCES

1. Landin LA. Epidemiology of children's fractures. *J Pediatr Orthop B*. 1997;6(2):79-83. doi:10.1097/01202412-199704000-00002

2. Song F, Zeng Y, Tian J, Lv Y, Feng G, Ni X. Epidemiology and the economic burden of pediatric fractures in China: A retrospective study of 14,141 fractures. *Bone*. 2021;144:115498. doi:10.1016/j.bone.2020.115498

3. Merckaert S, Chaibi E, Meriem S, Kwiatkowski B, Divjak N, Zambelli PY. Epidemiology of Pediatric Upper Extremity Fractures in a Tertiary Care Center in Switzerland. *Pediatr Emerg Care*. 2021;37(12):e825-e835. doi:10.1097/PEC.0000000000002047

4. Chaibi E, Zambelli PY, Merckaert S. Epidemiology of paediatric lower extremity fractures in a tertiary care center in Switzerland. *Eur J Trauma Emerg Surg*. Published online May 27, 2020. doi:10.1007/s00068-020-01400-6

5. Krasovic E, Bennett D. *Fracture Healing in Children*.

6. Salter-Harris classification of physeal fractures - UpToDate. Accessed February 18, 2022. https://www.uptodate.com/contents/image/print?imageKey=EM%2F54582&topicKey=EM%2F6547&source=outline_link

7. Aronsson DD, Lisle JW. *Lovell and Winter's Pediatric Orthopaedics*. Vol 1. 7th ed.; 2014.

8. Pennock AT, Edmonds EW, Bae DS, et al. Adolescent clavicle nonunions: potential risk factors and surgical management. *J Shoulder Elbow Surg*. 2018;27(1):29-35. doi:10.1016/j.jse.2017.06.040

9. Murnaghan ML, Slobogean BL, Byrne A, Tredwell SJ, Mulpuri K. The effect of surgical timing on operative duration and quality of reduction in Type III supracondylar humeral fractures in children. *J Child Orthop*. 2010;4(2):153-158. doi:10.1007/s11832-010-0240-3

10. DeFroda SF, Hansen H, Gil JA, Hawari AH, Cruz AI. Radiographic Evaluation of Common Pediatric Elbow Injuries. *Orthop Rev (Pavia)*. 2017;9(1):7030. doi:10.4081/or.2017.7030

11. Abzug JM, Herman MJ. Management of supracondylar humerus fractures in children: current concepts. *J Am Acad Orthop Surg*. 2012;20(2):69-77. doi:10.5435/JAAOS-20-02-069

12. Wiekrykas BD, Campbell N, Greenhill DA. Paediatric lateral condyle fracture with a posterolateral elbow dislocation: an atypical injury in a preadolescent. *BMJ Case Rep*. 2021;14(5):e241725. doi:10.1136/bcr-2021-241725

13. Bland DC, Pennock AT, Upasani VV, Edmonds EW. Measurement Reliability in Pediatric Lateral Condyle Fractures of the Humerus. *J Pediatr Orthop*. 2018;38(8):e429-e433. doi:10.1097/BPO.0000000000001200

14. Xie LW, Wang J, Deng ZQ, et al. Treatment of pediatric lateral condylar humerus fractures with closed reduction and percutaneous pinning. *BMC Musculoskelet Disord*. 2020;21(1):707. doi:10.1186/s12891-020-03738-9

15. Foran I, Upasni VV, Wallace CD, et al. Acute Pediatric Monteggia Fractures: A Conservative Approach to Stabilization. *Journal of Pediatric Orthopaedics*. 2017;37(6):e335. doi:10.1097/BPO.0000000000001001

16. Fowles JV, Sliman N, Kassab MT. The Monteggia lesion in children. Fracture of the ulna and dislocation of the radial head. *J Bone Joint Surg Am*. 1983;65(9):1276-1282.

17. Dormans JP, Rang M. The problem of Monteggia fracture-dislocations in children. *Orthop Clin North Am*. 1990;21(2):251-256.

18. Noonan KJ, Price CT. Forearm and distal radius fractures in children. *J Am Acad Orthop Surg*. 1998;6(3):146-156. doi:10.5435/00124635-199805000-00002

19. Valone LC, Waites C, Tartarilla AB, et al. Functional Elbow Range of Motion in Children and Adolescents. *Journal of Pediatric Orthopaedics*. 2020;40(6):304-309. doi:10.1097/BPO.0000000000001467

20. Kreutz-Rodrigues L, Gibreel W, Moran SL, Carlsen BT, Bakri K. Frequency, Pattern, and Treatment of Hand Fractures in Children and Adolescents: A 27-Year Review of 4356 Pediatric Hand Fractures. *Hand (N Y)*. 2022;17(1):92-97. doi:10.1177/1558944719900565

21. Leggit JC, Meko CJ. Acute Finger Injuries: Part II. Fractures, Dislocations, and Thumb Injuries. *AFP*. 2006;73(5):827-834.