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Current Concept Review

Management of Malunions and Nonunions Following Elbow Trauma

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Abstract

Fractures in children are common in pediatric orthopaedic practice with the majority having positive outcomes with standard treatment. However, complications can develop and clinicians should be aware of common sequelae of pediatric elbow trauma and understand their prevention and treatment. The focus of this article is to provide an overview of common sequelae following pediatric elbow trauma including malunions of supracondylar humerus fractures and nonunion of lateral condyle, radial neck, and medial epicondyle fractures.

Key Concepts

- Coronal malunions of supracondylar humerus fracture have been largely recognized as cosmetic deformities but do demonstrate a propensity for late lateral condyle fracture and ulnar nerve dysfunction. Corrective osteotomy is the preferred surgical treatment, taking care to orient the osteotomy obliquely to the distal humerus to prevent excessive lateral prominence.
- Sagittal plane malunions of supracondylar humerus fractures have the capacity to remodel in patients 5 years and younger but are nearly nonexistent in patients over 8 years.
- Lateral condyle nonunion is best prevented by initial treatment based on initial fracture displacement. Established nonunions can be successfully treated with surgical intervention based upon the patient's skeletal maturity, size and location of osseous fragment, and associated deformity.
- Radial neck nonunion is a rare complication but one that is particularly challenging for surgical treatment. Non-surgical treatment measures are the preferred treatment approach with surgical treatment reserved for severe cases.

- Nonunion of the medial epicondyle is a frequent occurrence following nonsurgical treatment of medial epicondyle fracture but is symptomatic in only 21% of cases. For large osseous fragments, open reduction with nonunion repair and screw fixation is preferred while fragment excision and suture anchor repair are reserved for small fragments or revision cases with deficit bone.

Introduction

Fractures are a common entity in pediatric patients with upwards of 34% of all children sustaining a fracture before the age of 17, with the majority of these affecting the upper extremity.[1] Fractures about the elbow account for approximately 12% of all pediatric fractures, third only to distal radius and fractures of the hand.[2] Management of these injuries varies based upon the anatomic region affected, the patient's age, and injury characteristics. While the majority of these fractures result in uneventful healing, complications do arise, particularly with untreated or undertreated injuries.

We present a review of common pediatric upper extremity fracture patterns, highlighting commonly encountered complications, emphasizing risk factors for complication development while supplying providers with information regarding patient and family counseling regarding the potential for adverse outcomes as well as provide strategies for risk mitigation.

Supracondylar Humerus Fractures

Coronal Plane Malunion

Coronal plane malunion following a supracondylar humerus most commonly presents as cubitus varus deformity (Figure 1). Although the exact incidence of this complication is unclear, it is a complication that has decreased in frequency since the adoption of K-wire fixation of supracondylar humerus fractures.[3] Cubitus varus deformity is recognized by its characteristic frontal plane deformity and decreased Baumann's angle, which most commonly results from medial column comminution or malalignment rather than growth arrest or asymmetric growth of the distal humerus.[4] For this reason, medial column comminution is recognized as an indication for operative treatment due to the high

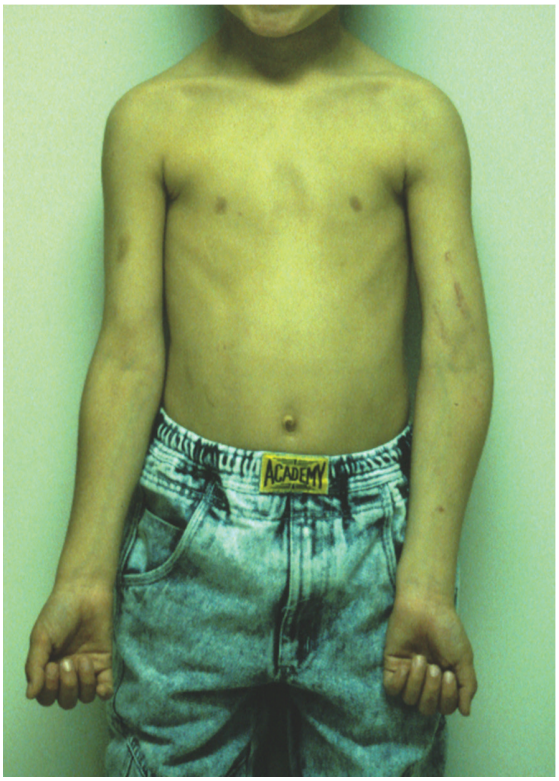

Figure 1. *Clinical picture demonstrating a child with cubitus varus deformity.*

risk of medial collapse with subsequent cubitus varus deformity.[5] Although cubitus varus deformity has been historically recognized as a cosmetic deformity, there are important consequences that can arise long-term. Varus malalignment of the distal humerus has been associated with a predisposition for lateral condyle fracture[6] as well as being associated with the development of tardy ulnar nerve palsies.[7]

Proper treatment begins first with recognition of risk factors for deformity development. Acute fractures with medial comminution are preferentially treated with closed reduction and percutaneous pinning (CRPP) to obtain and maintain coronal plane alignment. When

Figure 2. *Postoperative AP radiographs following closed wedge osteotomy demonstrating excessive lateral humeral prominence.*

patients present the development of cubitus varus late following fracture, many techniques have been reported for deformity correction. In these instances, we prefer to wait for surgical correction until after fracture healing and remodeling have occurred to avoid operating through early callus. Of the available techniques, the lateral closing wedge osteotomy is the simplest with demonstrated effectiveness in correcting the underlying deformity.[8,9] However, it is important to orient the osteotomy oblique to the distal humerus articular surface to prevent excessive lateral humeral prominence (Figure 2).[10] Additionally, if patients present with ulnar nerve symptoms, an in-situ decompression of the ulnar nerve at the cubital tunnel should also be incorporated[11] (See Video Additional Links).

Sagittal Plane Malunion

Sagittal plane malalignment of pediatric supracondylar humerus fractures is an important topic that is often overshadowed by coronal plane deformities despite having direct implications on post-injury range of motion. The incidence of sagittal plane malalignment has been reported between 10-13.4%.[12,13] The implications of this deformity on range of motion vary by severity of the injury and the patient's age at the time of injury.[12,13] Limited elbow flexion is the most common complaint, presenting in as many as 50% of cases sagittal plane malalignment;[13] however, with mild to moderate cases, asymmetry ≥5 degrees is infrequently encountered.[12] Additionally, the importance of patient age at the time of injury is important, as children <5 years of age have been shown to remodel 100% of initial displacement of the center of the capitellum at an average of 21 months follow-up, whereas children >8 years demonstrate minimal remodeling potential.[14]

For children presenting with sagittal plane malalignment following supracondylar humerus fractures, the authors preferred approach following counseling of the patients and family is a period of observation. For younger patients, follow-up radiographs are obtained a year following injury to assess for deformity remodeling with detailed active and passive range of motion assessments. Given the low incidence of functional limitations following these injuries,[12,15] observation is usually sufficient. However, for patients with symptomatic deformities and in older and adolescent children with functional range of motion deficits, corrective osteotomy can be performed to restore sagittal alignment.

Lateral Condyle Fracture Nonunion

Nonunion of lateral condylar fractures, defined as a lack of osseous union 12 weeks following injury, is often the result of untreated or missed fracture displacement during nonoperative treatment. Nonunion is a more common complication of lateral condyle fractures than of other pediatric elbow fractures, affecting upwards of 15% of injuries.[16] Significant initial fracture displacement[16] has been recognized as an important risk factor for nonunion development, and operative management is generally recommended for fractures with more than 2 mm of displacement.[17]

In the setting of an unstable lateral condyle fracture, the fragment typically migrates proximally, which can result in cubitus valgus deformity and possible ulnar nerve palsy.[18] The Flynn criteria, consisting of a large metaphyseal fragment, <1 cm of displacement from the articular surface, and an open, viable condylar physis,[19] are useful for determining which patients are appropriate for operative treatment. Regardless of the symptomatology, operative treatment is generally recommended for an established nonunion to minimize the risk of progressive deformity, decreased range of motion, and potential for ulnar nerve dysfunction[20] as well as to minimize the risk of functional impairment.[21]

The operative management of an established nonunion varies according to the extent of displacement, viability of the condylar physis, valgus deformity, and ulnar nerve dysfunction. The presence of an open condylar physis is a positive prognostic factor for achieving osseous union following nonunion repair.[19] In cases of minimal displacement without cubitus valgus deformity or ulnar nerve dysfunction, percutaneous stabilization has been reported as a viable treatment option for skeletally immature patients presenting within 6 months of injury.[22] For skeletally mature patients or for immature patients presenting late (>4-6 months following injury), open reduction with internal fixation and local bone grafting is the preferred treatment approach (Figure 3). Although acute fixation of these fractures is often performed with K-wire fixation, we prefer screw fixation for a nonunion to allow for enhanced stability, compression, and to mitigate potential pin site complications.

In cases with concomitant valgus deformity who are skeletally mature, corrective supracondylar osteotomy with rigid internal fixation is the preferred treatment approach. For patients with ulnar nerve dysfunction, an anterior ulnar nerve transposition is generally

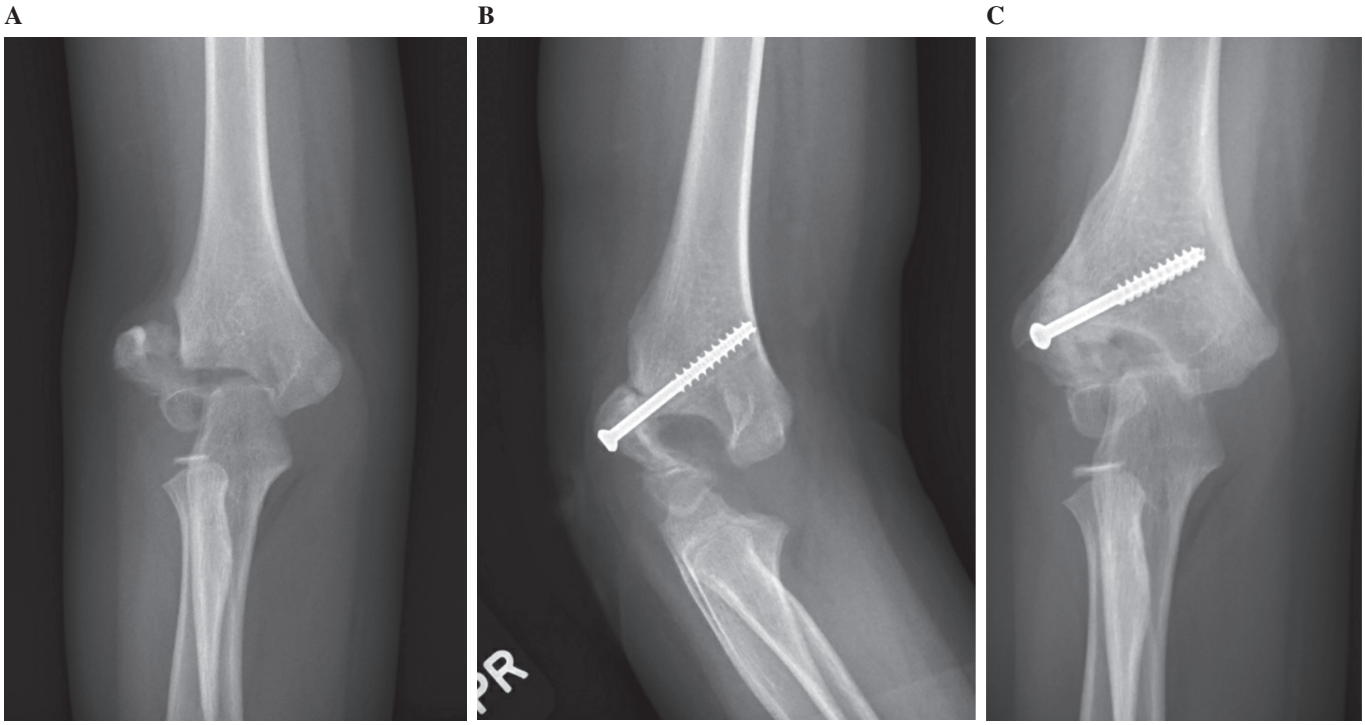

Figure 3. *AP radiographs of the right elbow (A) in an 8-year-old patient with an established lateral condyle nonunion, who presented with elbow discomfort and limited motion 4 months after sustaining a fall after climbing a tree at their home. The patient underwent local bone grafting with in-situ fixation with a cannulated screw and K-wire augmentation. At the 3-month postoperative visit, AP radiograph demonstrated a persistent nonunion (B). He subsequently underwent a formal nonunion repair with bone grafting and revision screw fixation, achieving osseous union (C).*

recommended, although Ibrahim and Ismail[23] reported that isolated deformity correction and fixation was successful in managing skeletally mature patients with associated ulnar nerve dysfunction.

Radial Neck Nonunion

Fractures to the radial neck and head represent approximately 14% of all pediatric elbow fractures.[24] Radial head fractures have a separate complication profile beyond the scope of this article. Good results are generally observed with simple immobilization if a radial neck fracture is angulated less than 30 degrees and has less than 50% translation.[25] Greater fracture displacement and the need for more invasive treatment are associated with an increased rate of complications.[25] Inadequate fixation technique can also increase probability of nonunion.[26] Radial neck nonunions are rare; a nonunion rate of 0% was reported in a review of 78 patients by Basmajian et al.[27] and 0.7% in a review of 151 surgically treated patients by Zimmerman et al.[28]

A review of 11 radial neck nonunions found that nine presented with pain and five with valgus deformity.[29] Additional presentation findings are decreased motion, particularly lack of supination, as well as functional limitations.[24] After the initial diagnosis is confirmed on plain films, a trial of conservative treatment with range of motion exercises is recommended.[30,31] For highly symptomatic patients who fail conservative management, surgical intervention may be warranted, which consists of open reduction internal fixation with or without bone grafting. Fixation methods may include radial intramedullary pinning, oblique K-wire fixation, or plate osteosynthesis.[26,29] Pursuing these methods yielded union in all 11 patients reviewed by Fernandez et al.[29] However, healing of the nonunion does not guarantee improvement of clinical symptoms.[26] If the radial head shows significant deformity, a radial head resection may be required to improve motion, but this can result in elbow instability.[29,32] Figure 4 A-G shows an example of radial neck nonunion treated conservatively which resulted in acceptable function with no pain but with cubitus valgus with limited pronation and supination. These authors find nonoperative treatment preferable with consideration of surgical intervention only in severe cases.

Medial Epicondyle Nonunion

Fractures of the medial epicondyle account for upwards of 20% of all pediatric elbow fractures[33,34] and remain a controversial topic for treatment recommendations. However, what is not controversial is the increased risk of developing a nonunion with conservative management, with a reported nonunion rate of 50% as compared with 7% with operative treatment as reported in a systematic review by Kamath et al.[35] The nonunion rate has been reported as high as 90% following conservative management[36] but with only 21% of these patients developing symptoms such as pain, weakness, decreased range of motion, joint instability, and ulnar nerve dysfunction.[37]

In patients with an asymptomatic nonunion, clinical observation is the most appropriate management approach, with surgical intervention being reserved for symptomatic nonunions. Treatment options include fragment fixation[37,38] and fragment excision with suture anchor repair of the flexor pronator mass and medial elbow ligamentous complex.[39,40] For children with an ample-sized osseous fragment, open reduction with takedown of the nonunion site with screw fixation is our preferred approach (Figure 5 A-B). When necessary, local bone graft can be harvested from the olecranon to place at the nonunion site prior to screw fixation. When the osseous fragment is small, fragmented, or in cases of failed internal fixation, excision of fragment with suture anchor repair of the medial structures is recommended (Figure 6 A-B).

Summary

In summary, although complications following pediatric elbow fractures are not infrequent, proper recognition of risk factors with treatment tailored to each individual patient can mitigate complication development. When present, each elbow should be thoroughly evaluated with

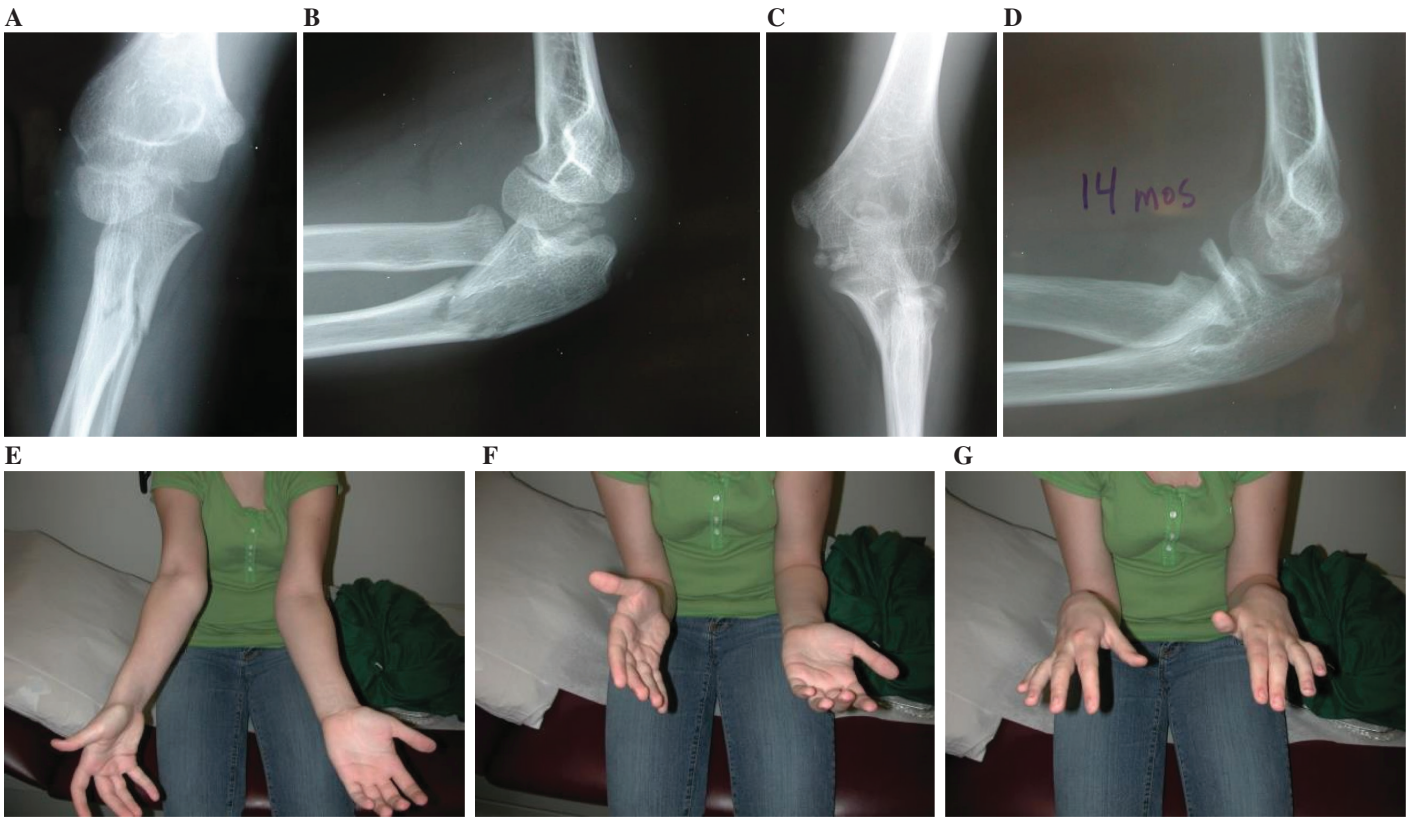

Figure 4. *AP (A) and lateral (B) radiograph of the right elbow in a 9-year-old female with acute radial neck fracture and proximal ulna fracture treated with immobilization. AP (C) and lateral (D) radiographs at 14-months follow-up demonstrating healed ulna fracture and radial neck nonunion which was treated conservatively. Patient 16 years of age with residual cubitus valgus (E), limited supination (F), and limited pronation (G) with no pain.*

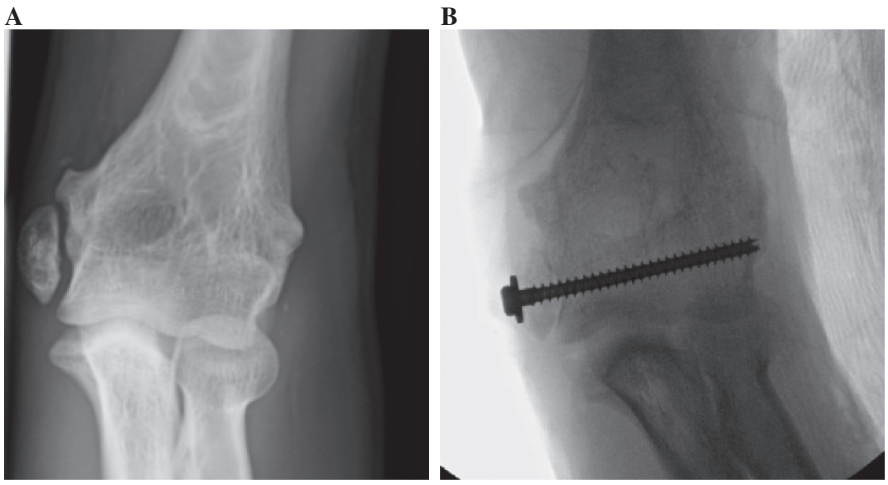

Figure 5. *A 16-year-old male wrestler presents with right elbow pain and instability 3 years after sustaining an elbow dislocation with associated medial epicondyle fracture, demonstrating a nonunion of the medial epicondyle (A). He underwent an open reduction with takedown of the nonunion site and local bone grafting from the olecranon with lag screw fixation.*

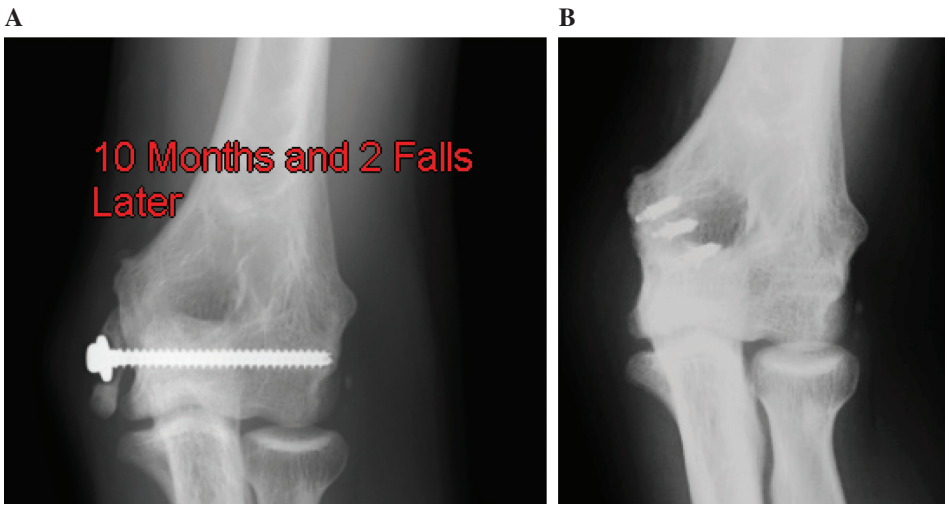

Figure 6. *The patient from figure 5 presented 10 months following surgery with pain and medial prominence following return to wrestling. Radiographs demonstrate fragmentation and displacement of the medial epicondyle (A). He underwent a removal of hardware with excision of the osseous fragment and repair of flexor pronator mass and medial ligamentous structures to the distal humerus via multiple suture anchors (B).*

treatment predicated on the patient's symptomatology and expectations. Through these highlighted examples, we provide pediatric orthopaedic providers with a detailed overview, highlighting risk factors and treatment strategies to ensure optimal treatment for each of our patients.

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Additional Links

- Oblique Lateral Closing-Wedge Osteotomy for Cubitus Varus in Skeletally Immature Patients, *The Journal of Bone and Joint Surgery*. Dustin A. Greenhill, MD; Scott H. Kozin, MD; Michael Kwon, MD; Martin J. Herman, MD.
- POSNA Pediatric Trauma Virtual Symposia, 2022 POSNA Annual Meeting, POSNA Trauma, Prevention, and Disaster Response Committee.

Disclaimer

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References

1. Hedström EM, Svensson O, Bergström U, et al. Epidemiology of fractures in children and adolescents. *Acta Orthop*. 2010;81(1):148-153.
2. Landin LA. Epidemiology of children's fractures. *J Pediatr Orthop B*. 1997;6(2):79-83.
3. Pirone AM, Graham HK, Krajbich JI. Management of displaced extension-type supracondylar fractures of the humerus in children. *J Bone Joint Surg Am*. 1988;70(5):641-650.
4. Voss FR, Kasser JR, Trepman E, et al. Uniplanar supracondylar humeral osteotomy with preset Kirschner wires for posttraumatic cubitus varus. *J Pediatr Orthop*. 1994;14(4):471-478.
5. De Boeck H, De Smet P, Penders W, et al. Supracondylar elbow fractures with impaction of the medial condyle in children. *J Pediatr Orthop*. 1995;15(4):444-448.
6. Miura Y, Shimura H, Fujita K, et al. Understanding the susceptibility to lateral condyle fracture by analyzing unaffected Baumann's angle in children with distal humeral fracture. *J Orthop Sci*. 2022;27(1):211-214.
7. Abe M, Ishizu T, Shirai H, et al. Tardy ulnar nerve palsy caused by cubitus varus deformity. *J Hand Surg Am*. 1995;20(1):5-9.
8. Cho CH, Song KS, Min BW, et al. Long-term results of remodeling of lateral condylar prominence after lateral closed-wedge osteotomy for cubitus varus. *J Shoulder Elbow Surg*. 2009;18(3):478-483.
9. Lee SC, Shim JS, Sul EJ, et al. Remodeling after lateral closing-wedge osteotomy in children with cubitus varus. *Orthopedics*. 2012;35(6):e823-e828.
10. Greenhill DA, Kozin SH, Kwon M, et al. Oblique lateral closing-wedge osteotomy for cubitus varus in skeletally immature patients. *JBJS Essent Surg Tech*. 2019;9(4):e40.1-8.
11. Rubin G, Orbach H, Bor N, et al. Tardy ulnar nerve palsy. *J Am Acad Orthop Surg*. 2019;27(19):717-725.

12. Silva M, Day MJ, Aceves-Martin B, et al. Sagittal plane residual deformity in pediatric type II supracondylar humerus fractures. *J Pediatr Orthop*. 2020;40(7):e547-e553.
13. Simanovsky N, Lamdan R, Mosheiff R, et al. Underreduced supracondylar fracture of the humerus in children: clinical significance at skeletal maturity. *J Pediatr Orthop*. 2007;27(7):733-738.
14. Gamble JG, Vorhies JS. Remodeling of sagittal plane malunion after pediatric supracondylar humerus fractures. *J Pediatr Orthop*. 2020;40(10):e903-e909.
15. Moraleda L, Valencia M, Barco R, et al. Natural history of unreduced Gartland type-II supracondylar fractures of the humerus in children: a two to thirteen-year follow-up study. *J Bone Joint Surg Am*. 2013;95(1):28-34.
16. Launay F, Leet AI, Jacopin S, et al. Lateral humeral condyle fractures in children: a comparison of two approaches to treatment. *J Pediatr Orthop*. 2004;24(4):385-391.
17. Tejwani N, Phillips D, Goldstein RY. Management of lateral humeral condylar fracture in children. *J Am Acad Orthop Surg*. 2011;19(6):350-358.
18. Abed Y, Nour K, Kandil YR, et al. Triple management of cubitus valgus deformity complicating neglected nonunion of fractures of lateral humeral condyle in children: a case series. *Int Orthop*. 2018;42(2):375-384.
19. Flynn JC, Richards JF, Jr., Saltzman RI. Prevention and treatment of non-union of slightly displaced fractures of the lateral humeral condyle in children. An end-result study. *J Bone Joint Surg Am*. 1975;57(8):1087-1092.
20. Shimada K, Masada K, Tada K, et al. Osteosynthesis for the treatment of non-union of the lateral humeral condyle in children. *J Bone Joint Surg Am*. 1997;79(2):234-240.
21. Eamsobhana P, Kaewpornsawan K. Should we repair nonunion of the lateral humeral condyle in children? *Int Orthop*. 2015;39(8):1579-1585.
22. Knight DM, Alves C, Alman B, et al. Percutaneous screw fixation promotes healing of lateral condyle nonunion in children. *J Pediatr Orthop*. 2014;34(2):155-160.
23. Ibrahim MA, Ismail M. Corrective osteotomy and in situ fusion for late-presenting nonunion of lateral condyle fractures of the humerus in adults. *J Shoulder Elbow Surg*. 2019;28(3):520-524.
24. Macken AA, Eygendaal D, van Bergen CJ. Diagnosis, treatment and complications of radial head and neck fractures in the pediatric patient. *World J Orthop*. 2022;13(3):238-249.
25. Kumar S, Mishra A, Odak S, et al. Treatment principles, prognostic factors and controversies in radial neck fractures in children: a systematic review. *J Clin Orthop Trauma*. 2020;11(Suppl 4):S456-s63.
26. Waters PM, Stewart SL. Radial neck fracture nonunion in children. *J Pediatr Orthop*. 2001;21(5):570-576.
27. Basmajian HG, Choi PD, Huh K, et al. Radial neck fractures in children: experience from two level-1 trauma centers. *J Pediatr Orthop B*. 2014;23(4):369-374.
28. Zimmerman RM, Kalish LA, Hresko MT, et al. Surgical management of pediatric radial neck fractures. *J Bone Joint Surg Am*. 2013;95(20):1825-1832.
29. Fernandez Fernandez F, Weiß B, Zwingmann J, et al. Nonunion of the radial neck in children: a rare but severe complication after fractures of the radial neck. *Eur J Trauma Emerg Surg*. 2021;47(2):283-292.
30. Vocke AK, Von Laer L. Displaced fractures of the radial neck in children: long-term results and prognosis of conservative treatment. *J Pediatr Orthop B*. 1998;7(3):217-222.
31. Tan BH, Mahadev A. Radial neck fractures in children. *J Orthop Surg (Hong Kong)*. 2011;19(2):209-212.
32. Wegmann H, Heider S, Novak M, et al. Outcome following excision of the radial head in children with open physes for impaired elbow motion. *J Shoulder Elbow Surg*. 2019;28(3):525-529.
33. Waters PMSDLFJMC-BCM. Rockwood and Wilkins' fractures in children. Philadelphia: Wolters Kluwer; 2020.
34. Stans T. Dislocation of the elbow and medial epicondylar humerus fractures. In: Waters PM, Skaggs DL, Flynn JM, eds. Rockwood and Wilkins Fractures in Children. 9th ed. Philadelphia, PA: Wolters Kluwer; 2020.
35. Kamath AF, Baldwin K, Horneff J, et al. Operative versus non-operative management of pediatric medial epicondyle fractures: a systematic review. *J Child Orthop*. 2009;3(5):345-357.
36. Farsetti P, Potenza V, Caterini R, et al. Long-term results of treatment of fractures of the medial humeral epicondyle in children. *J Bone Joint Surg Am*. 2001;83(9):1299-1305.
37. Smith JT, McFeely ED, Bae DS, et al. Operative fixation of medial humeral epicondyle fracture nonunion in children. *J Pediatr Orthop*. 2010;30(7):644-648.
38. Chorney M, Sylvestre D, Seeley M. Medial epicondyle nonunions in children: case report with overview and management. *J Am Acad Orthop Surg Glob Res Rev*. 2019;3(2):e046.
39. Gilchrist AD, McKee MD. Valgus instability of the elbow due to medial epicondyle nonunion: treatment by fragment excision and ligament repair--a report of 5 cases. *J Shoulder Elbow Surg*. 2002;11(5):493-497.
40. Rogers M, Scillia AJ, Cain EL. Fragment excision with flexor-pronator mass repair for chronic medial humeral epicondyle nonunions. *Orthopedics*. 2021;44(3):e337-e342.