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Medullary Fixation Using K-Wires for Forearm Fracture in Children

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ABSTRACT

Forearm fractures in children are the most common longbone fractures, comprising about 13% of all pediatric fractures.Diaphyseal forearm fractures are known to remodel poorly, with a high incidence of mal-union. Anatomical reduction may therefore be of greater importance in young age as they can tolerate a lesser degree of mal-union. The proportion of pediatric forearm fractures treated with internal fixation has increased. Traditionally, internal fixation of unstable pediatric forearm fractures has been achieved by open reduction and rigid internal fixation with plate and screws (ORIF) with good results. Intramedullary nails (IMN) are load shearing devices that do not induce significant stress shielding. This loading of the fracture site has been demonstrated to enhance fracture union and callus maturation. IMN are inserted with a small exposure and provides many biological and mechanical advantages. Thus, the main purpose of treatments in the long term is to achieve full recovery of the range of motion in the forearm and minimize complications.The aim of this study to review management of Forearm Fracture in Children UsingMedullary Fixation Using K-Wires.

Keywords: Forearm Bones Fracture; Children; Medullary Fixation; K-Wires

INTRODUCTION

The forearm is a complex anatomical structure between the elbow and the wrist that serves an important function of the upper extremity. The forearm consists of two parallel bones, the radius and the ulna. There is an interosseous membrane (IOM) between the shafts of the radius and ulna **(1)**. Forearm rotation is dependent on normal anatomic contour of the radial bow so it is to be maintained by treatment if a fracture occurs**(2,3)**. Two important bony landmarks of the radius are the radial styloid and the bicipital tuberosity. The radial styloid is a lateral, distal prominence, and the bicipital tuberosity is an antero-medial prominence **(4)**.

The proximal radial epiphysis may not ossify until a child is 5–7 years old and usually unites between 12 and 15 years of age**(5)**. It generally ossifies symmetrically. Because of the epiphyseal tilt, however, ossification may be asymmetric and may resemble a triangle rather than an ellipse in certain positions. An angular shape may also indicate a problem of abnormal radio- humeral joint stress, such as radioulnarsynostosis or Panner's disease**(6)**.

The forearm is both a mechanical axis and a joint. It functions as a lever that delivers momentum and enables rotational movements of the hand regardless of the flexion-extension position of the elbow **(7)**.Rotation of the forearm is dependent on the bowed shape of the radius which changes its axial rotation at the proximal end, swinging the distal end around the distal part of the ulna **(8)**. The proximal head of the radius pivots within the annular ligament **(9)**.The swinging radius needs enough intra-osseal space. If the distance between the two forearm bones is narrowed, rotation may be limited**(10)**.

The rotational axis in the forearm runs through the Centre of the proximal radial head in the elbow distally to the Centre of fovea of the ulnar head at the wrist **(11)**. Hence the functional axis is oblique to the longitudinal anatomic axes of both the radius and ulna **(12)**. Intact geometry of the forearm bones is important for their function **(13)**. Pronation motion is around 80 degrees and supination around 90 degrees in children and adolescents **(14)**.The range of motion of the left and right sides are very similar but not identical **(15)**. Rotation is an important motion for various activities of daily living such as feeding and personal hygiene **(16-18).**

Epidemiology of pediatric forearm fractures

Forearm fractures in children are the most common long bone fractures, comprising about 13% of all pediatric fractures **(19)**. Epidemiologic studies have shown that 18% of children will experience a fracture by the age of 9, with children between the ages of 5 and 14 having the highest fracture incidence. Due to the high incidence of fractures in children, it is important to treat them adequately and to recognize the potential psychosocial impact, a fracture can have on a child, possibly limiting physical activity and affecting their grades in school **(20)**. The distal aspect of the radius and ulna is the most common site of fracture in the forearm. These fractures have been reported to be three times more common in boys; however, the increased participation in athletics by girls at a young age may be changing this ratio. Although these fractures occur at any age, they are most frequent during the adolescent growth spurt **(21)**.

Thirty-seven percent of children’s fractures are caused by injuries sustained around the home, 20% are sport and recreation injuries, 5–20% occur at school and less than 5% are due to motor vehicle accidents. Not all fractures are due to accidents. In children under three years of age, child abuse is a frequent cause **(22)**. Fractures are twice as frequent on the left side, compared with the right. That may be a result of spontaneous use of the left, non-dominant hand in protecting the body in fall **(23)**.

Factors affecting pediatric forearm fractures

There are biological factors that affect the strength of children’s bones. In early adolescence, during the growth spurt, a transient decrease in bone strength occurs **(24)**.. Bone strength is directly dependent on nutrition and inefficient nutrition affects mineralization **(25)**. Children with bone fractures show lower total bone mass than uninjured children **(26)**.

Vitamin D is obligatory for bone growth and development prenatally and in the early childhood **(27)**. Low vitamin D levels are associated with decreased mineral content of the bone. Calcium and phosphate are necessary for bone mineralization. Milk avoidance is related to an elevated risk of childhood fractures **(28,29)**.So,theincrease in forearm fractures could be due to lower bone mineralization

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resulting from physical inactivity, poor nutrition, and vitamin D deficiency **(30)**.

Remodeling of pediatric forearm fractures

There are special characteristics of an immature forearm in its response to trauma. Remaining bone growth in children reflects great osteogenic potential and remodeling capacity **(31)**. Remodeling continues after the fracture has healed until the physes close. This makes it important to determine the stage of growth plate closure when considering an acceptable fracture position **(32)**.

Remodeling at the fracture site occurs by resorption of the bone on the convex side and generation of new bone on the concave side. This is explained by increased pressure (compression) on the concave side that stimulates new bone formation by means of intramembranous apposition**(33,34)**.In addition, remodeling can occur at the physis by altering the direction of bone growth in order to become perpendicular to the forces that act through them **(35)**.

Signs and Symptoms:

The diagnosis of forearm fractures is usually self-evident from the history and the obvious deformity**(36)**.A child with a forearm fracture typically presents after a traumatic injury complaining of pain, swelling, and, if the fracture is displaced, a visible deformity of the involved extremity. Occasionally, pain with bearing weight on the involved extremity and painful range of motion, particularly pronation and supination, are the chief complaints, especially with nondisplaced fractures or incomplete fractures with minimal swelling**(37-40)**.

While most forearm fractures present as isolated injuries, it is critical that a careful history is taken and a primary physical assessment including vital signs and the cardiovascular parameters is performed for patients who sustain these injuries from higher-energy mechanisms, such as a fall from a height or a motor vehicle accident **(41,42)**.

Radiological assessment Imaging

High-quality anteroposterior (AP) and lateral radiographs of the entire forearm, including the elbow and wrist, are necessary to evaluate potential forearm fractures effectively**(43)**. Malrotation in complete fractures can be difficult to detect and assess so both the wrist and elbow should be captured in the same film in order to make it possible to evaluate rotational deformity **(44)**. A mismatch of the cortices on both sides of the fractured bone is indicative of rotational deformity **(45)**.

Rotation in the fracture line is also evaluated by comparing the bicipital tuberosity and the radial styloid, which normally lie 180º from each other Also Disruption of radial bowing is radiographically determined by antro-posterior projection **(46)**. If the bow is straightened, the bone will also present lengthening that may restrict movements**(47)**.

Treatment of forearm fractures

Treatment of forearm shaft fractures aims to achieve and maintain acceptable reduction until bone union occurs **(48)**. Because of the unique feature of the forearm

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as a joint, and unlike other diaphyseal fractures, fractures of the radius and the ulna must be approached like other articular fractures **(49)**. It is not only a question of fracture healing but also of function of a broken joint and possible stiffness after injury **(50)**. Spontaneous remodeling of the long bones can be considered as a part of treatment: however, the capacity of remodeling should not be overestimated as the angular deformation will correct spontaneously not more than 1° in a year until skeletal maturity **(32)**.

Conservative treatment:

Greenstick fractures are usually treated with a closed reduction and well molded cast placed. In order to reduce these fractures, the force opposite to the mechanism of injury is applied. As greenstick fractures result predominantly from torsional forces that occur as the arm is axially loaded, reduction is often easily achieved by merely applying gentle traction and rotating the distal forearm and thumb toward the apex of the deformity, often referred to as the “rule of thumbs.” Therefore, apex volar fractures are reduced by pronating the forearm while apex dorsal fractures are reduced by forearm supination**(51,52).**

A topic of controversy when treating these fractures is whether or not the fracture should be completed. Advocates for completing the fracture argue that this will help prevent re-angulation or diminish the risk of re-fracture **(53)**. In contrast, many believe that the intact cortex helps maintain the alignment of the fracture after reduction. After reduction, the arm is immobilized in a well-molded long-arm cast in neutral rotation with the elbow flexed 90º**(54)**.

Complete Fractures

Complete fractures in different regions of the shaft of the forearm behave differently from a clinical perspective and have classically been divided into distal-, middle-, and proximal-third fractures. Single-bone complete fractures usually are caused by direct trauma (nightstick fracture) and are difficult to reduce. Blount described a reduction technique that may be effective for reduction of a displaced single-bone shaft fracture. The intact bone is used as a lever to re-establish the length of the fractured bone, and then transverse forces are applied to realign the bone ends. Both-bone complete fractures (often with bayonet shortening) are common and are best treated with finger-trap or arm traction applied over 5 to 10 minutes. This stretches out the soft tissue envelope and aids in both reduction and cast or splint application. Traction allows complete fractures to “seek their own level of rotation” and allows correction of rotational malalignment**(53-55)**.

Acceptable Reduction

For children under the age of 8 years, up to 20 º of diaphyseal angulation may remodel while angulation of as little as 10 º may not in those older than 10 years of age **(52)**. To confound the issue, residual radiographic angulation does not always have a direct correlation with functional outcomes and patient satisfaction. Shortening

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is well tolerated in patients younger than 10 years of age, with up to one centimeter being acceptable after failed closed reduction **(54)**.The recommended acceptable forearm reduction parameters for children younger than 10 years of age include residual angulation of the radius or ulna measuring 20 º or less. There are two exceptions: radius fractures in the proximal third and radius fractures with apex ulnar angulation. Those are at risk of rotation loss even in this young age group. Complete translation, bayonet apposition with shortening of 1 cm or less, and malrotation less than 30 º are other acceptable parameters of reduction **(48,55)**.

Children who are 10 years of age and older have less capacity for fracture remodeling. Greater than 10 º of angulation of either bone in any plane, greater than 50 % translation, shortening or bayonet apposition, and greater than 30 º of malrotation are unacceptable reduction parameters. Individuals with less than 2 years of growth remaining have minimal remodeling capability; therefore, near anatomic alignment must be obtained for acceptable reduction **(54,55)**.

Operative Treatment

Surgical treatment for radial and ulnar shaft fractures usually is reserved for open fractures, those associated with compartmental syndrome, floating elbow injuries, and fractures that develop unacceptable displacement during non-operative management **(56)**.

Residual angulation after closed reduction is much better tolerated by younger children than older adolescents and adults because of the increased remodeling potential in the younger age patients**(57)**. As a consequence, adolescents are more likely to benefit from surgical treatment of their forearm fractures more than are younger children. Although internal fixation is the standard for displaced forearm fractures in adults**(58)**.

Success of non-operative methods and the complications associated with internal fixation have tempered enthusiasm for its application to pediatric forearm fractures, Compared to closed treatment methods, healing is slower after open reduction and internal fixation, no matter what type of implant is used. In rare situations, external fixation has been used for pediatric forearm fractures fixation **(53,59)**.

The primary reduction strategy is very different for greenstick fractures (rotation) compared to that for complete fractures (vertical traction). Certain comminuted fractures (e.g., comminution of both bones) may preclude reduction and casting and require surgical fixation**(23,31)**.

Practical classification:

The typical buckle fracture “speed bump” may accompany either plastic deformation or greenstick fractures. Thus, there are two bones, three levels, and four common fracture patterns**(34,45,53)** as follow:

1- Fracture displacement:can occur as angulation, rotation, shortening, or translation.
2- Angulation: Is important in treatment decision-making and can be measured with

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reasonable reliability.

3- Rotation: is a simple concept, but it is difficult to assess clinically. The best that usually can be done is to roughly estimate rotation within a 45-degree margin of error. Based on available clinical studies, it appears that less than 1 cm of shortening should be accepted in either single-bone or both-bone fracture patterns.

4- Shortening: It has also been suggested that the shortening that accompanies displaced fractures may help preserve future motion through interosseous membrane relaxation.

5- Translation: completely (100%) translated fractures of the middle third and distal third of the forearm have been shown to reliably remodel [6, 57]. Certain situations may raise concern regarding complete translation, such as isolated middle-third radial fractures with medial (ulnar) displacement that significantly narrows the interosseous space and translation in children who have less than two full years of growth remaining, because remodeling of the translated fracture site is less predictable than in younger children.

Management of Open Fractures of Diaphyseal Radius and Ulna Fractures

Open fractures of the shafts of the radius and ulna one of the most common open fractures in children Although the infection rate is extremely low for open fractures, even grade I open forearm fractures in children have been associated with serious complications such as gas gangrene.Early irrigation and debridement are indicated for open forearm fractures, and care should be taken to inspect and properly clean the bone ends**(60)**.

Open fractures tend to be more unstable than closed fractures (because of soft tissue stripping and comminution) and more commonly require internal fixation. Internal fixation also may facilitate soft tissue management and healing**(55-60)**.

Even grade I open forearm fractures in children can be complicated by gas gangrene or osteomyelitis, and therapeutic amputation has been reported.Open fracture grade does not appear to correlate with the infection rate in childhood forearm fractures, with most of the serious forearm infections reported in the literature occurring after grade I fractures**(61,62)**.

Functional assessment for intramedullary k wires in forearm fractures

Outcome Grading System developed by Martus et al was used to assess overall functional outcome. This outcome grading system for surgical management of pediatric forearm fractures incorporates a modification of the validated Clavien-Dindo classification of surgical complications and the minimum forearm rotation required for activities of daily living (ADL) in normal subjects**(63,64)**.

CONCLUSION

Intramedullary nails IMN is a sufficient and effective option in treating both bones forearm displaced unstable fractures in the pediatric age group, with excellent

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functional outcome and union rates and without any failures, avoiding the complication of large wound infection.

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REFERENCES:

1. **Firl, M., &Wünsch, L. (2004).** Measurement of bowing of the radius. The Journal of bone and joint surgery. British volume, 86(7), 1047-1049.

2. **Heare, A., Goral, D., Belton, M., Beebe, C., Trizno, A., &Stoneback, J. (2017)**. Intramedullary implant choice and cost in the treatment of pediatric diaphyseal forearm fractures. Journal of Orthopaedic Trauma, 31(10), e334-e338.

3. **Mehlman, CT and Wall, EJ and Beaty, JH and KasserJ(2006**). Injuries to the shafts of the radius and ulna.p.; 399--840.

4. **Bair, M. M., &Gondal, A. Z. (2019).** Anatomy, Shoulder and Upper Limb, Forearm Radius. In StatPearls [Internet]. StatPearls Publishing**.**

5. **Kuhn, S., Burkhart, K. J., Schneider, J., Muelbert, B. K., Hartmann, F., Mueller, L. P., &Rommens, P. M. (2012).** The anatomy of the proximal radius: implications on fracture implant design. Journal of shoulder and elbow surgery, 21(9), 1247-1254.

6. **Chen, J., Alk, D., Eventov, I., &Wientroub, S. (1987).** Development of the olecranon bursa An anatomic cadaver study. ActaorthopaedicaScandinavica, 58(4), 408-409.

7. **Evans, E. M. (1945**). Rotational deformity in the treatment of fractures of both bones of the forearm. JBJS, 27(3), 373-379.

8. **Hotchkiss, R. N., An, K. N., Sowa, D. T., Basta, S., &Weiland, A. J. (1989).** An anatomic and mechanical study of the interosseous membrane of the forearm: pathomechanics of proximal migration of the radius. The Journal of hand surgery, 14(2), 256-261.

9. **Ogden, J. A., Beall, J. K., Conlogue, G. J., & Light, T. R. (1981).** Radiology of postnatal skeletal development. IV. Distal radius and ulna. Skeletal Radiology, 6(4), 255-266

10. **Ogden, J. A. (1990).** Transphyseal linear ossific striations of the distal radius and ulna. Skeletal radiology, 19(3), 173-180.

11. **O'Shaughnessy, M., Shapiro, L. M., Schultz, B., Retzky, J., Finlay, A. K., & Yao, J. (2020).** Morphology at the Distal Radioulnar Joint: Identifying the Prevalence of Reverse Obliquity. Journal of Wrist Surgery, 9(05), 417-424.

12. **Gutowski, C. J., Darvish, K., Ilyas, A. M., & Jones, C. M. (2017).** Interosseous ligament and transverse forearm stability: a biomechanical cadaver study. The Journal of hand surgery, 42(2), 87-95.

13. **` Pereira, B. P., Thambyah, A., & Lee, T. (2012**). Limited forearm motion compensated by thoracohumeral kinematics when performing tasks requiring pronation and supination. Journal of applied biomechanics, 28(2), 127-

138.

14. **Sinikumpu J.** Forearm shaft fractures in children**. 2013.**

15. **Armstrong PF, Joughin VE, Clarke HM & Willis RB. (2003)** Fractures of the forearm, wrist, and hand. In: Green NE &Swiontkowski MF (Eds) Skeletal Trauma in Children. Philadelphia, Saunders Elsevier Science: 166–255.

16. **Sinikumpu JJ, Serlo W. (2013)** Forearm shaft fractures in children. University of Oulu

17. **Tatebe, M., Shinohara, T., Okui, N., Yamamoto, M., Kurimoto, S., & Hirata, H. (2012).** Tilt of the radius from forearm rotational axis reliably predicts rotational improvement after corrective osteotomy for malunited forearm fractures. Nagoya Journal of Medical Science, 74(1-2), 167.

18. **Myers, G. J. C., Gibbons, P. J., &Glithero, P. R. (2004).** Nancy nailing of diaphyseal forearm fractures: single bone fixation for fractures of both bones. The Journal of bone and joint surgery. British volume, 86(4), 581-584.

19. **Naranje, S. M., Erali, R. A., Warner, W. C., Sawyer, J. R., & Kelly, D. M. (2016).** Epidemiology of pediatric fractures presenting to emergency departments in the United States. Journal of Pediatric Orthopaedics, 36(4), e45-e48.

20. **Nellans, K. W., Kowalski, E., & Chung, K. C. (2012).** The epidemiology of distal radius fractures. Hand clinics, 28(2), 113-125.

21. **Valerio, G., Gallè, F., Mancusi, C., Di Onofrio, V., Colapietro, M., Guida, P., &Liguori, G. (2010).** Pattern of fractures across pediatric age groups: analysis of individual and lifestyle factors. BMC Public Health, 10(1), 656.

22. **Mathison, D. J., &Agrawal, D. (2010).** An update on the epidemiology of pediatric fractures. Pediatric emergency care, 26(8), 594-603.

23. **Farr, J. N., &Dimitri, P. (2017).** The impact of fat and obesity on bone microarchitecture and strength in children. Calcified tissue international, 100(5), 500-513.

24. **Goulding, A. (2007, March**). Childhood fractures: time to implement strategies to reduce these events. In International Congress Series (Vol. 1297, pp. 3-14). Elsevier.

25. **Viljakainen, H. T., Korhonen, T., Hytinantti, T., Laitinen, E. K. A., Andersson, S., Mäkitie, O., &Lamberg-Allardt, C. (2011).** Maternal vitamin D status affects bone growth in early childhood—a prospective cohort study. Osteoporosis international, 22(3), 883-891.

26. **Högler, W. (2015).** Complications of vitamin D deficiency from the foetus to the infant: One cause, one prevention, but who's responsibility?. Best Practice & Research Clinical Endocrinology & Metabolism, 29(3), 385-398.

27. **Bouillon, R., Marcocci, C., Carmeliet, G., Bikle, D., White, J. H., Dawson-Hughes, B., &Bilezikian, J. (2019).** Skeletal and extraskeletal actions of vitamin D: current evidence and outstanding questions. Endocrine reviews,

40(4), 1109-1151.

28. **Ryan, L. M., Teach, S. J., Searcy, K., Singer, S. A., Wood, R., Wright, J. L., & Chamberlain, J. M. (2010).** Epidemiology of pediatric forearm fractures in Washington, DC. Journal of Trauma and Acute Care Surgery, 69(4), S200-S205.

29. **Frick, S. L., & Jones, E. T. (2014).** Skeletal growth, development, and healing as related to pediatric trauma. Green's skeletal trauma in children, 1-15.

30. **Brinker MR,(2013).** Review of orthopaedic trauma. Lippincott Williams & Wilkins; Apr 29. PP123-146.

31. **Wilkins, K. E. (1980).** The uniqueness of the young athlete: musculoskeletal injuries. The American journal of sports medicine, 8(5), 377-382.

32. **Hardy M, Feehan LM. (2020)** Fracture Healing: An Evolving Perspective. Rehabilitation of the Hand and Upper Extremity 14:264.

33. **Ulstrup, A. K. (2008).** Biomechanical concepts of fracture healing in weight-bearing long bones.ActaOrthopaedicaBelgica, 74(3), 291.

34. **Lascombes, P., Haumont, T., &Journeau, P. (2006).**Use and abuse of flexible intramedullary nailing in children and adolescents. Journal of Pediatric Orthopaedics, 26(6), 827-834.

35. **Price CT &Mencio GA (2001)** Injuries to the shafts of the radius and ulna. Rockwood and Wilkins' fractures in children, 5th edn.Lippincott Williams & Williams, Philadelphia: 455–460.

36. **Rosendahl K, Chateil JF, Johnson K.p (2015)**Paediatric Musculoskeletal Trauma and the Radiology of Non-accidental Injury and Paediatric Fractures. Grainger & Allison's Diagnostic Radiology: Paediatric Imaging.24:168.

37. **Holdsworth, B. J., & Sloan, J. P. (1982**). Proximal forearm fractures in children: residual disability. Injury, 14(2), 174-179.

38. **Sinikumpu, J. J., &Serlo, W. (2015).** The shaft fractures of the radius and ulna in children: current concepts. Journal of Pediatric Orthopaedics B, 24(3), 200-206.

39. **Wilkins, K. E. (2005).** Nonoperative management of pediatric upper extremity fractures or 'Don't throw away the cast'. Techniques in Orthopaedics, 20(2), 115-141.

40. **Ring, D., Jupiter, J. B., & Waters, P. M. (1998).**Monteggia fractures in children and adults. JAAOS-Journal of the American Academy of Orthopaedic Surgeons, 6(4), 215-224.

41. **Foran, I., Upasani, V. V., Wallace, C. D., Britt, E., Bastrom, T. P., Bomar, J. D., &Pennock, A. T. (2017**). Acute pediatric Monteggia fractures: a conservative approach to stabilization. Journal of Pediatric Orthopaedics, 37(6), e335-e341.

42. **McCombe D.(2015)** Hand Injuries in Children. InDisorders of the Hand (pp. 285-309). Springer, London.

43. Rowlands R, Rippey J, Tie S, Flynn J. (2017) Bedside ultrasound vs X-ray for the diagnosis of forearm fractures in children. The Journal of emergency medicine. 52(2):208-15.

44. Eckert K, Ackermann O, Schweiger B, Radeloff E, Liedgens P. (2012) Sonographic diagnosis of metaphyseal forearm fractures in children: a safe and applicable alternative to standard x-rays. Pediatric emergency care. 28(9):851-4.

45. Yasin MN, Talwalkar SC, Henderson JJ, et al. (2008) Segmental radius and ulna fractures with scaphocapitate fractures and bilateral multiple epiphyseal fractures. Am J Orthop. 37:214–217.

46. Yuan PS, Pring ME, Gaynor TP, Mubarak SJ, Newton PO. (2004) Compartment syndrome following intramedullary fixation of pediatric forearm fractures. J PediatrOrthop. (4):370–5.

47. Flynn, J. M., Jones, K. J., Garner, M. R., & Goebel, J. (2010). Eleven years' experience in the operative management of pediatric forearm fractures. Journal of Pediatric Orthopaedics, 30(4), 313-319.

48. Bae, D. S., Kadiyala, R. K., & Waters, P. M. (2001). Acute compartment syndrome in children: contemporary diagnosis, treatment, and outcome. Journal of Pediatric Orthopaedics, 21(5), 680-688.

49. Noonan K, McCarthy J. (2010) Compartment syndromes in the pediatric patient. J PediatrOrthop. 30(8):96-101.

50. Corsino, C.B. and Sieg, R.N.(2019) Distal radius fractures JAMA Network Open , Orthopedics.

51. Landfried, M. J., Stenclik, M., & Susi, J. G. (1991). Variant of Galeazzi fracture-dislocation in children. Journal of Pediatric Orthopaedics, 11(3), 332-335**.**

52. Sinikumpu, J. J., Pokka, T., &Serlo, W. (2013). The changing pattern of pediatric both-bone forearm shaft fractures among 86,000 children from 1997 to 2009. European journal of pediatric surgery, 23(04), 289-296.

53. Patel A, Li L, Anand A. (2014) Systematic review: functional outcomes and complications of intramedullary nailing versus plate fixation for both-bone diaphyseal forearm fractures in children. Injury.;45(8):1135-43 .

54. Ploegmakers, J. J., &Verheyen, C. C. (2006). Acceptance of angulation in the non-operative treatment of paediatric forearm fractures. Journal of Pediatric Orthopaedics B, 15(6), 428-432.

55. Flynn JM, Skaggs DL, Waters PM(2019). Nonoperative Treatment of Diaphyseal Radius and Ulna Fractures .Rockwood&Wilkins 'fractures in children ninth edition. 429- -433.

56. Webb, G. R., Galpin, R. D., & Armstrong, D. G. (2006). Comparison of short and long arm plaster casts for displaced fractures in the distal third of the forearm in children. JBJS, 88(1), 9-17.

57. Bellemans, M., &Lamoureux, J. (1995). Indications for immediate percutaneous intramedullary nailing of complete diaphyseal forearm shaft

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fractures in children: Enclouagecentro-médullaire. Actaorthopaedicabelgica, 61, 169-172.

58. **Hasler CC, Von Laer L, Hell AK.(2005)** Open reduction, ulnar osteotomy and external fixation for chronic anterior dislocation of the head of the radius. The Journal of bone and joint surgery.British volume.;87(1):88-94.

59. **Chen, C., Xie, L., Zheng, W., Chen, H., &Cai, L. (2019).** Evaluating the safety and feasibility of a new surgical treatment for forearm fractures in older children: study protocol for a randomised controlled trial. Trials, 20(1), 320.

60. **Soeur, R. (1946).** Intramedullary pinning of diaphyseal fractures. JBJS, 28(2), 309-331.

61. **Green, S. A., & Dahl, M. T. (2018).** Surgical Principles of Intramedullary Lengthening.In Intramedullary Limb Lengthening (pp. 51-92). Springer, Cham.

62. **Parikh SN, Brody AS, Crawford AH. (2004)** Use of a picture archiving and communication system (PACS) and computed plain radiography in preoperative planning. Am J Orthop.;33:62–64.

63. **Lee, S., Nicol, R. O., & Stott, N. S. (2002**). Intramedullary fixation for pediatric unstable forearm fractures. Clinical Orthopaedics and Related Research®, 402, 245-250.

64. **Blackman, A. J., Wall, L. B., Keeler, K. A., Schoenecker, P. L., Luhmann, S. J., O'Donnell, J. C., & Gordon, J. E. (2014).** Acute compartment syndrome after intramedullary nailing of isolated radius and ulna fractures in children. Journal of Pediatric Orthopaedics, 34(1), 50-54.