The Golden Ratio in Pediatric Wrist Anatomy: A Divine Symmetry

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Abstract

Introduction: The golden ratio, which equals 1.61803..., and is usually defined by the Greek letter φ (phi), has attracted broad attention for a long time. It has been found in many phenomena in the universe including, body symmetry and locomotion. Within this context, the purpose of our study was to evaluate normal morphometric measurements of the wrist in the pediatric population and to identify if phi (φ) is part of the distal radioulnar joint.

Methods: We retrospectively reviewed the hospital records of all skeletally immature patients requiring surgical intervention for distal radius fracture in our unit between January 2010 and January 2017. We define and describe a reproducible method to measure the ratio of the distal radial and ulnar physes.

Results: A total of 268 patients were included with a mean age of 9.41 (3-16) years and a mode of 7 years. Some 63.4% were boys -- 43.3% were right-sided injuries and 56.7% were left-sided injuries. The ratio between the total width of the radial and ulnar growth plates and the radial growth plate closely approximated φ; the mean of this ratio in all the patients included was 1.619684 (1.5848-1.6643). Most of the injuries happened in the summertime, between May and August.

Conclusion: We found that the golden ratio exists in our body to play its harmony in the pediatric wrist joint. We believe that with the support of further studies, the golden ratio might yield diagnostic and prognostic implications in the treatment of distal radius/ulnar fractures or abnormalities in this population.

Categories: Pediatrics, Orthopedics, Anatomy
Keywords: anatomy at the wrist, articular anatomy, body symmetry, distal end radius, golden ratio

Introduction

The golden ratio commonly appears in mathematics, architecture, art, and other areas, and equates approximately to 1.618 [1]. In mathematics, the golden ratio is calculated by dividing a segment in two, such that the proportion between the segment and its longer part will be equal to the proportion between the longer and shorter part [2].

The first known written definition can be found in Euclid's Elements book [3]. At the beginning of the 12th century, the mathematician Mark Barr introduced the symbol phi (φ) for the golden ratio. It was the first letter of the name Phidias, a famous 5th century BC Greek sculptor, architect, and painter who used the golden ratio to form the basis of his sculptures [1].

Since ancient Greek times, it is believed that the golden ratio can be found in nature and human body anthropometry, despite the paucity of scientific literature on the topic. In our study, we focus on the association of the number φ with the pediatric distal radial and ulnar anatomy. Distal radius fractures are common within the pediatric population, accounting for up to 20%-30% of all injuries [4-5]. The distal radial metaphysis is the most common site of these fractures [4].

According to AO (Arbeitsgemeinschaft für Osteosynthesefragen) pediatric comprehensive classification of long bone fractures, we can identify the metaphysis by a square whose side is the same length as the widest part of the growth plate. In the case of bone pairs such as radius/ulna and tibia/fibula, then both bones should be included in the square [6].

Our hypothesis was that the ratio between the total width of the radial and ulnar growth plates to the radial growth plate will be the same as the ratio of the radial growth plate to the ulnar growth plate and should, therefore, approximate the golden ratio.

Materials And Methods

Methods

In this retrospective observational study, we included all skeletally immature patients assessed radiologically, who sustained a distal radius fracture and underwent a procedure in operating theaters between January 2010 and July 2017. Patients with partially or fully closed growth plates were excluded (Figures *1-3*).
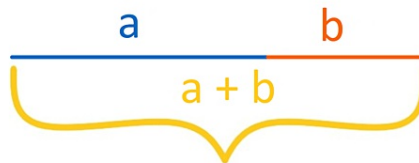

FIGURE 1: Golden ratio – line segments.

$$\frac{a + b}{a} = \frac{a}{b} = \Phi = 1.618...$$

FIGURE 2: Golden ratio proportion -- algebraic form.
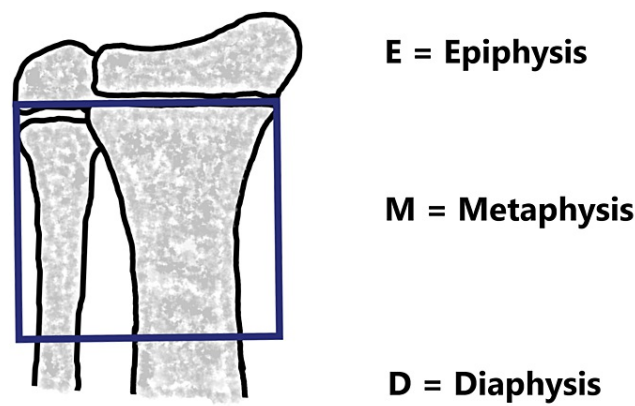
E = Epiphysis

M = Metaphysis

D = Diaphysis

FIGURE 3: Diagrammatic measurement of metaphysis.

Distal radius and ulnar physis calculation

We developed a reproducible method to measure the ratio of the distal radial and ulnar physes. All measurements were done in a true posteroanterior (PA) radiograph of the distal radius. First, we measured the widest mediolateral dimension of the ulnar physis (Figure 4). Subsequently, we measured the widest mediolateral dimension of the radial physis (Figure 5).

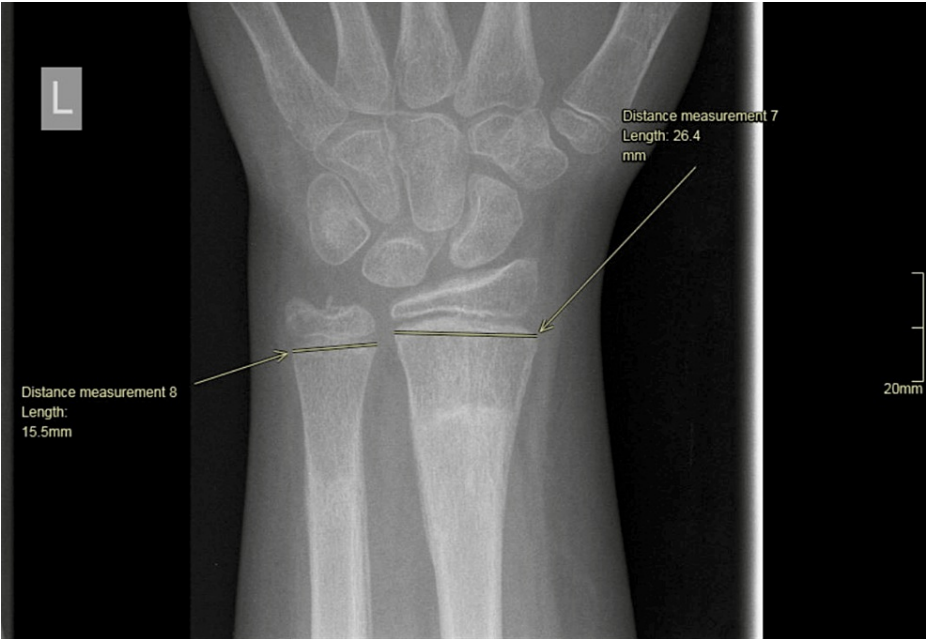**FIGURE 4: Measurement of the widest dimension of the ulnar physis.**

FIGURE 5: Measurement of the widest dimension of the radial physis.

We then drew a circle centered on the ulnar side of the ulnar physis, the circle's radius being the ulnar physis (Figure 6).
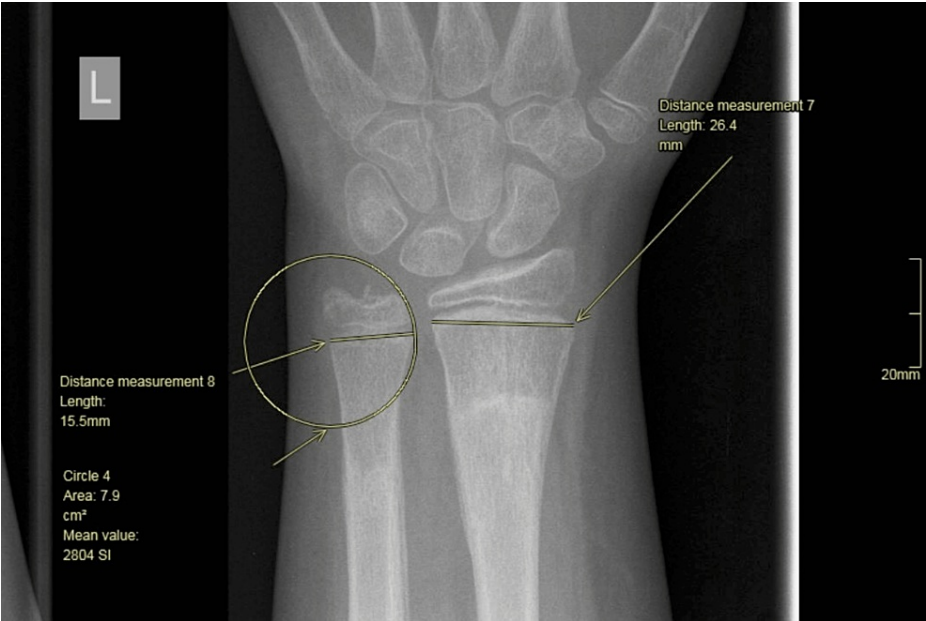

FIGURE 6: Drawing of a circle centered on the ulnar side of the ulnar physis (circle radius is the width of the ulnar physis).

We then drew a circle centred over the radial aspect of the radial physis and with the radius of the circle equal to the radial physeal length (Figure 7).
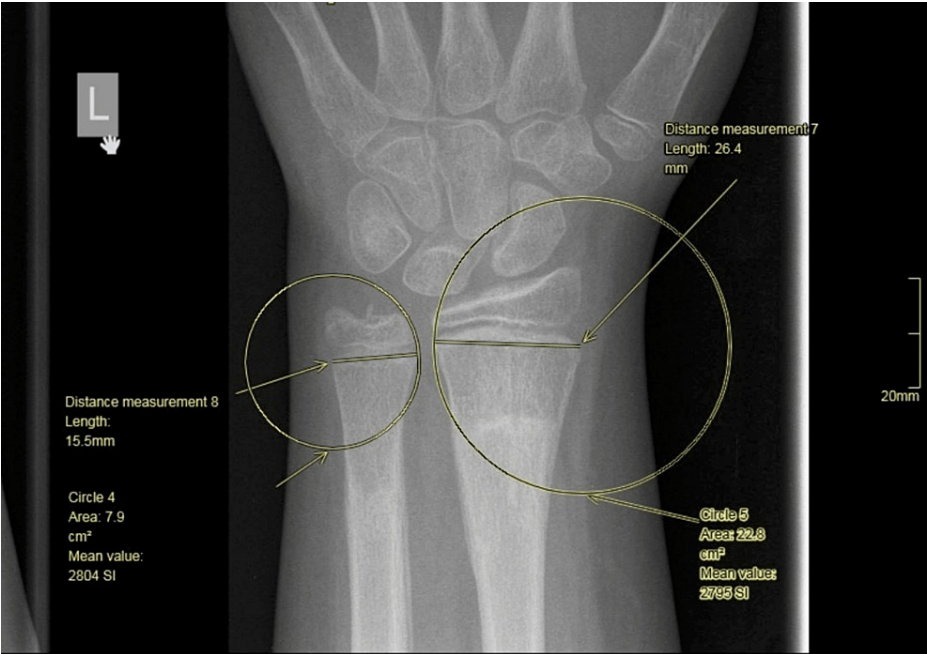
FIGURE 7: Drawing of a circle centered on the radial aspect of the radius physis (circle radius is the width of the radial physis).

Then we drew a line between the two centers of these circles and we measured the part of the line which was outside of the circles. We divided this line by 2, as this is the space of the distal radioulnar joint that participated equally into the wrist joint. Following these drawings, we calculated the proportion with the equation $\frac{CD+BD/2}{AB+BD/2}$ (Figures *8-9*).
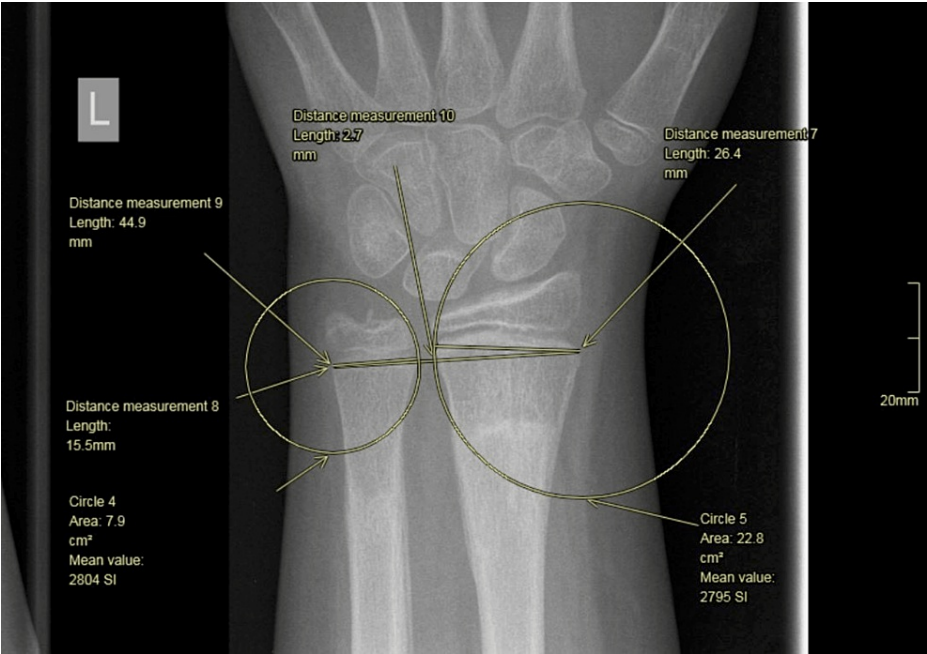

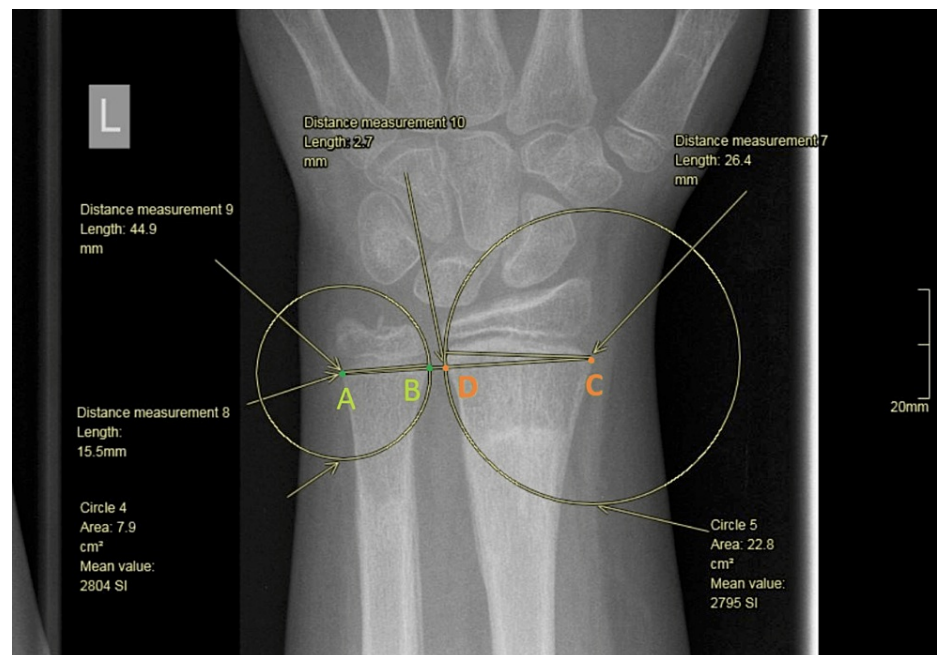**FIGURE 8: Line drawn between the centers of the two circles.**

FIGURE 9: AB distance corresponds to the ulnar physis. DC corresponds to the physis of the radius. BD corresponds to the radioulnar joint.

Results

Some 268 patients were included in this study -- 63.4% were boys and 36.6% were girls. Ages ranged from 3 to 16 years old with a mean of 9.41, a median of 9, and a standard deviation of 3.246. Some 116 (43.3%) fractures were on the right side and 152 (56.7%) were on the left. No bilateral injuries were observed.

When we used our equation $\frac{CD+BD/2}{AB+BD/2}$ to calculate the proportion of the radial and ulna physis, we found that the result is approximately equal to the number φ. The mean of all our patients was 1.619684 (1.5848-1.6643) and the standard deviation was 0.0179473. The frequency of each age group with an average of phi is shown in Table *1*.

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Age	Frequency	Average measurements
3	5	1.618912731
4	8	1.615254249
5	20	1.621134699
6	26	1.617770116
7	34	1.621147302
8	24	1.620943379
9	18	1.611171123
10	26	1.623010678
11	24	1.629361125
12	29	1.621080288
13	17	1.616227367
14	25	1.615250012
15	8	1.610687803
16	4	1.626401356
Total	268	1.619168016

TABLE 1: Average measurement of our equation in relationship to age.

Discussion

The golden ratio φ is a proportion that has been found with many natural phenomena, as well as in different fields in medicine: cardiovascular pathophysiology [7-9], respiratory medicine [10], ENT surgery [11], dental surgery [12-13], plastic surgery [14-16], and many other fields [17-18]. To the best of our knowledge, this is the first study to assess the geometry of the wrist joint in relation to the golden ratio.

In our study, we determined that the golden ratio is part of the anatomy of the wrist joint. Our measurements showed that the ratio between the total width of radial and ulnar growth plates to radial growth plate was almost equal with the number φ= 1.61803.

We believe that this observation of wrist joint anatomy could be an important factor to guide the management of distal radial fractures, as this topic remains controversial. Until now, there are no objective criteria to assess when to perform manipulation under anesthesia (MUA) or Kirschner wires (K-wires) fixation for a distal radius fracture [19-20]. The number φ as a guide for the normal radio-ulnar ratio could be an additional radiological tool in the arsenal of the orthopedic surgeon deciding treatment strategies for these injuries.

More specifically, it is still debated which deformities of the distal radial metaphysis can be accepted for either MUA or fixation with K-wire [21-22]. There are few studies that define a diametaphyseal transitional zone. These characterize the diametaphyseal transitional zone as the area which remains when the square over the radial physis has been subtracted from the metaphysis [23-24]. This definition can be a useful factor to determine the required surgical technique [23, 25]. The radio-ulnar ratio described in our study is similar in concept to the transitional zone and we believe its clinical relevance in management decision-making can be linked to the findings of transitional zone studies. However, this specific point is outside of the scope of this anatomical study and would require further research, also needed to investigate the mathematical regularity which can be found in the human body, as we feel that the ratio φ can be a useful guide in deciding the appropriate surgical technique for distal radius fractures.

Limitations

We acknowledge that our study has some limitations. We only included the pediatric population that had sustained distal radius fracture. Nonetheless, the measurements were completed when the normal anatomy was restored, therefore, our findings can be applied to the general pediatric population of skeletally immature patients with open physes (typically up to 14 years old for girls and 16 years old for boys).

Conclusions

In conclusion, the golden ratio resides in our body to play its harmony in the wrist joint. Understanding the role of the golden ratio or proportion might yield diagnostic and prognostic implications in the treatment of distal radius/ulnar fractures or abnormalities.

Additional Information

Disclosures

Human subjects: Consent was obtained or waived by all participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. de Campos D, Da Costa Oliveira M: Michelangelo Buonarroti's code in the frescoes of the Sistine chapel - an allusion to gematria of the Hebrew/Greek alphabet and the Golden Ratio. Clin Anat. 2018, 31:948-955. 10.1002/ca.23251
2. Iosa M, Morone G, Paolucci S: Phi in physiology, psychology and biomechanics: the golden ratio between myth and science. Biosystems. 2018, 165:31-39. 10.1016/j.biosystems.2018.01.001
3. Simson ER: The Elements of Euclid 1793 . Wingrove, U.S. Department of Education, USA; 1793.
4. Hove LM, Brudvik C: Displaced paediatric fractures of the distal radius . Arch Orthop Trauma Surg. 2008, 128:55-60. 10.1007/s00402-007-0473-x
5. Pretell Mazzini J, Beck N, Brewer J, Baldwin K, Sankar W, Flynn J: Distal metaphyseal radius fractures in children following closed reduction and casting: can loss of reduction be predicted?. Int Orthop. 2012, 36:1435-1440. 10.1007/s00264-012-1493-x
6. Slongo TF, Audigé L: Fracture and dislocation classification compendium for children: the AO pediatric comprehensive classification of long bone fractures (PCCF). J Orthop Trauma. 2007, 21:S135-S160. 10.1097/00005131-200711101-00020
7. Ozturk S, Yalta K, Yetkin E: Golden ratio: a subtle regulator in our body and cardiovascular system? . Int J Cardiol. 2016, 223:143-145. 10.1016/j.ijcard.2016.08.147
8. Yalta K, Ozturk S, Yetkin E: Golden Ratio and the heart: a review of divine aesthetics . Int J Cardiol. 2016, 214:107-112. 10.1016/j.ijcard.2016.03.166
9. Iosa M: Golden ratio and the heart, God and the science . Int J Cardiol. 2016, 222:762-763. 10.1016/j.ijcard.2016.07.287
10. Yetkin E, Çuğlan B, Turhan H, Ozturk S: Does Golden Ratio reside in pulmonary circulation?. Chest. 2019, 156:629-630. 10.1016/j.chest.2019.04.112
11. Petekkaya E, Ulusoy M, Bagheri H, Şanlı Ş, Ceylan MS, Dokur M, Karadağ M: Evaluation of the Golden Ratio in nasal conchae for surgical anatomy. Ear Nose Throat J. 2021, 100:NP57-NP61. 10.1177/0145561319862786
12. Mamidi D, Vasa AA, Sahana S, Done V, Pavanilakshmi S: The assessment of Golden proportion in primary dentition. Contemp Clin Dent. 2020, 11:34-38. 10.4103/ccd.ccd_320_18
13. Anand R, Sarode SC, Sarode GS, Patil S: Human permanent teeth are divided into two parts at the cemento-enamel junction in the divine Golden Ratio. Indian J Dent Res. 2017, 28:609-612. 10.4103/ijdr.IJDR_525_16
14. Hwang K, Park CY: The divine proportion: origins and usage in plastic surgery . Plast Reconstr Surg Glob Open. 2021, 9:e3419. 10.1097/GOX.0000000000003419
15. Bozola AR: Abdominoplasty: same classification and a new treatment concept 20 years later . Aesthetic Plast Surg. 2010, 34:181-192. 10.1007/s00266-009-9407-z
16. Pereira Filho O, BIns Ely J, Lee KH, Paulo EM, Granemann AS: Multiplanar assembly mammaplasty based on the divine proportion. Plast Reconstr Surg Glob Open. 2019, 7:e1979. 10.1097/GOX.0000000000001979
17. Mazzeffi MA, Faraoni D, Tanaka KA: Reassessing RECESS: in pursuit of the Golden Ratio of hemostatic components to red blood cells. Anesth Analg. 2017, 124:1760-1761. 10.1213/ANE.0000000000002123
18. Ulcay T, Kamaşak B, Görgülü Ö, Uzun A, Aycan K: A golden ratio for foramen magnum: an anatomical pilot study. Folia Morphol (Warsz). 2022, 81:220-226. 10.5603/FM.a2021.0018
19. Pavone V, Vescio A, Lucenti L, Chisari E, Canavese F, Testa G: Analysis of loss of reduction as risk factor for additional secondary displacement in children with displaced distal radius fractures treated conservatively. Orthop Traumatol Surg Res. 2020, 106:193-198. 10.1016/j.otsr.2019.10.013
20. Rai P, Haque A, Abraham A: A systematic review of displaced paediatric distal radius fracture management: plaster cast versus Kirschner wiring. J Clin Orthop Trauma. 2020, 11:275-280. 10.1016/j.jcot.2019.03.021
21. van Delft EA, Vermeulen J, Schep NW, van Stralen KJ, van der Bij GJ: Prevention of secondary displacement and reoperation of distal metaphyseal forearm fractures in children. J Clin Orthop Trauma. 2020, 11:S817-S822. 10.1016/j.jcot.2020.07.016
22. Zeng ZK, Liang WD, Sun YQ, et al.: Is percutaneous pinning needed for the treatment of displaced distal radius metaphyseal fractures in children?: a systematic review. Medicine (Baltimore). 2018, 97:e12142. 10.1097/MD.0000000000012142
23. Lieber J, Schmid E, Schmittenbecher PP: Unstable diametaphyseal forearm fractures: transepiphyseal intramedullary Kirschner-wire fixation as a treatment option in children. Eur J Pediatr Surg. 2010, 20:395-398. 10.1055/s-0030-1262843
24. Lieber J, Sommerfeldt DW: [Diametaphyseal forearm fracture in childhood. Pitfalls and recommendations

for treatment]. Unfallchirurg. 2011, 114:292-299. 10.1007/s00113-011-1962-5

25. Jozsa G, Devecseri G, Vajda P, Juhasz Z, Varga M, Juhasz T: Distance of the fracture from the radiocarpal surface in childhood: does it determine surgical technique? A retrospective clinical study: a STROBE compliant observational study. Medicine (Baltimore). 2020, 99:e17763. 10.1097/MD.0000000000017763

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