Distance of the fracture from the radiocarpal surface in childhood: does it determine surgical technique? A retrospective clinical study

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Abstract
Unstable distal metaphyseal and dia-metaphyseal fractures of the radius may have treated with a variety of operative techniques, Kirschner wires (K-wires), dorsally inserted titanium elastic stable intramedullary nailing (DESIN), and short titanium elastic stable intramedullary nailing (SESIN) in children.

The aim of this study was to evaluate the differences in clinical and radiographic outcomes between these methods.

Between January 2009 and December 2017 196 children were treated for forearm fractures in the distal third of the distal radius. Gender of the patients, different types of surgical techniques, number of postoperative X-rays, date of metal removal and degree of axis deviation after the metal removal were studied. Distance of the fracture line from the radiocarpal surface, the width of the distal epiphysis of the ulna and radius, and the cumulative width of the distal epiphysis of the ulna and radius were analyzed.

Out of the 196 children, stabilization of the fracture was achieved by K-wire in 139, by DESIN in 44, and by SESIN in 13 patients. The average time of metal removal was significantly shorter (3.8 months), following stabilization with K-wire. In children treated with K-wire, axial deviation of <5° was seen in 118 patients, 5° to 10° deviation in 15 patients, while deviation was above 10° in 6 children. In the DESIN group, <5° axial deviation was found in 37 patients and 5° to 10° in 7 patients. In all 13 children treated with SESIN, axial deviation was measured to be <5°. The fracture distance from the radiocarpal surface was on average 23.7 and 45.6 mm in the children treated with K-wire and DESIN, respectively.

Fracture distance from the radiocarpal surface might determine the type of surgical technique required. If the distance of the fracture line is less than the width of the distal radius, osteosynthesis with K-wire is recommended, while if the distance of the fracture is more than the cumulative width of the radius and the ulna, then DESIN may provide better results. The use of SESIN may be indicated when the area of the growth plate is injured.

Abbreviations: DESIN = dorsally inserted titanium elastic stable intramedullary nailing, ESIN = elastic stable intramedullary nailing, K-wire = Kirschner wire, SESIN = short titanium elastic stable intramedullary nailing.

Keywords: dia-metaphyseal fracture, ESIN, K-wire, pediatric trauma, short double elastic nailing

1. Introduction
Displaced fractures of the distal forearm are the most common injuries in childhood. Traditionally, these fractures have been treated by closed reduction and casting, but, due to the intrinsic instability of these fractures in the cast, many authors prefer surgical treatment to prevent redisplacement. Unstable distal forearm fractures are usually treated by closed reduction and minimal invasive fixation. Operative osteosynthesis technique of pediatric wrist fractures is optimally minimally invasive, spare the physis and maintain an acceptable and painless reduction. Unstable, angulated fractures of the distal radius can be treated by several methods: with insertion of Kirschner wires (K-wires), with dorsally inserted titanium elastic stable intramedullary nails (DESIN), or with short titanium elastic stable intramedullary nailing (SESIN). Preliminary result was described by Sinikumpu et al about absorbable elastic nailing of the forearm fractures. This procedure combined with long-arm casting is feasible in treating the pediatric forearm fractures. The technique may bring benefits to handling these challenging fractures. The disadvantages of metallic implants may be
In this study we compared three different surgical techniques for surgical stabilization of unstable fractures of the distal forearm in children and evaluated the differences in clinical and radiographic outcomes between these methods. We retrospectively analyzed the clinical and radiographic outcomes of 76 children with distal forearm fractures, who were treated by different surgical techniques. The patients were divided into three groups: group A (n=24) treated with closed reduction and cast immobilization, group B (n=26) treated with ESIN (extra-articular stable intramedullary nailing), and group C (n=26) treated with DESIN (double elastic stable intramedullary nailing).

2. Patients and methods

The study was conducted at the Department of Paediatrics, Medical School, University of Pécs, Hungary. One surgeon performed all the surgical procedures. The inclusion criteria were closed fractures of the distal part of the radius, surgery was recommended because the fracture involved the distal radial physis. The exclusion criteria were open fractures, physeal injuries, and pathological fractures. The study was approved by the ethical committee of our institution.

The surgical intervention was performed under general anesthesia. The nails were inserted proximal to the metaphysis and distal to the epiphysis. The nails were inserted through the skin, and the entry point was marked on the dorsal side of the radius just proximal to the growth plate. The nails were cut down to bone and an awl was used to make the entry point. The nails were cut short, just below the level of the skin, and the hardware removal was performed under general anesthesia. The patients were instructed to avoid injury to the distal part of the radius for 4 weeks following surgery.

The functional outcome was assessed by the parents of each child before the final follow-up. The radiographs were assessed for comparing two or more independent samples of equal or different variances. The possible association between the fracture distance from the articular surface and the choice of surgical method was considered.

The surgical gold standard for the treatment of distal forearm fractures is closed reduction and K-wire fixation. The surgical technique may increase the risk of radial nerve injury. K-wire related complications are well known in the literature: migration of the pins, superficial infections, damage of the radial or ulnar articular surface and the choice of surgical method.

In this study we compared three different surgical techniques for surgical stabilization of unstable fractures of the distal forearm in children and evaluated the differences in clinical and radiographic outcomes between these methods. The optimal treatment for the dia-metaphyseal transition zone is usually the distal radial cast for 4 weeks following surgery, because the soft-tissue swelling and the risk of radial nerve injury is reduced. In addition, the cast immobilization is easy to apply and does not require any special equipment.

Although there are many various percutaneous Muller and K-manually techniques, the most commonly used treatment option is the Muller and Kapandji percutaneous pinning method. This technique does not require the open reduction of the fracture, but it increases the risk of radial nerve injury.

Internal fixation with classic K-wire intramedullary nailing (ESIN) has increased in popularity. It can improve the quality of a closed reduction and also can increase the quality of a closed reduction. The optimal treatment for the dia-metaphyseal transition zone is usually the distal radial cast for 4 weeks following surgery, because the soft-tissue swelling and the risk of radial nerve injury is reduced. In addition, the cast immobilization is easy to apply and does not require any special equipment.

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different sample sizes. We studied the age and gender distribution in the groups.

3. Results

We included 196 children. We applied K-wire stabilization in 139 of 196 children (70.0%), DESIN in 44 of 196 children (22.4%), and SESIN in 13 of 196 children (6.6%). With regards to gender distribution, out of the 139 K-wire treated children, 98 were boys and 41 were girls, out of the 44 patients of the DESIN group, 30 were boys and 14 were girls. The ratio was little bit higher in group of SESIN, 10 were boys and 3 were girls. This gender ratio is similar to international and European incidence rates, in which boys are more likely (two times) to be injured. The mean age of the studied children was 10.7\textsuperscript{±}1.25 years. All groups were the same data and we could be able to compare.

Casts were used in all patients treated by K-wire fixation. A short removable splint was applied for 1 week in children treated with SESIN. Cast immobilization was not applied for patient treated with SESIN. Control X-ray images were obtained on average in 4.3, 2.6, and in 3.4 times per patient after K-wire, DESIN and SESIN treatment, respectively. The average time until metal removal was significantly shorter (3.8 months), following stabilization with K-wires when compared to the other groups. The time until implant removal was equal in patients treated by different types of elastic nailing, (average 6 months). In children treated with K-wire, axial deviation of <5° was seen in 118 patients, 5° to 10° deviation in 15 patients, while deviation was

![Figure 1](image1.jpg)

**Figure 1.** Definition of the large square (a) was based on the cumulative width of the distal epiphysis of the radius and URD, and small square (b) was based on the RD. Definition of the transition zone (c). RD=radius width, URD=ulna radius width.

![Figure 2](image2.jpg)

**Figure 2.** Schematic picture (antero-posterior and lateral view) of the Müller’s percutaneous pinning (a) and Kapandji’s Kirschner wire fixation (b).
above 10° in six children. One patient required further reconstruction, due to residual deformity. In the DESIN group, <5° axial deviation was found in 37 patients and 5° to 10° in seven patients. In all 13 children treated with SESIN, axial deviation was measured to be <5° (Fig. 5). The fracture distance from the radiocarpal surface was on average 23.7 mm in the children treated with K-wire, 45.6 mm treated with DESIN and 32.7 mm treated with SESIN, respectively (Fig. 6). Based on

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**Figure 3.** Lateral and anteroposterior radiographs representing the dorsally inserted ESIN (DESIN) technique. DESIN = dorsally inserted titanium elastic stable intramedullary nailing, ESIN = elastic stable intramedullary nailing.

**Figure 4.** Lateral and anteroposterior radiographs show the SESIN method. SESIN = short titanium elastic stable intramedullary nailing.

**Figure 5.** Diagram shows the degree of axis deviation of the radius after implant removal (n=196). K-wire = Kirschner wire, DESIN = dorsally inserted titanium elastic stable intramedullary nailing, SESIN = short titanium elastic stable intramedullary nailing.
Kruskal–Wallis test we found that strong correlation of the chosen fixation method between distal epiphysis of the radius, and the cumulative diameter of the distal epiphysis of the ulna and distance of the fracture line from the radiocarpal surface. In our clinic based on retrospective study results the distance of the fracture line determine the operative technique.

### 4. Discussion

The current study was designed to evaluate the differences in clinical and radiographic outcomes of dia-metaphyseal fractures of the radius in children between three different (K-wire, DESIN, SESIN) methods of stabilization. Percutaneous pin fixation is most commonly used for unstable distal radial, or distal forearm fractures in pediatric patients. This method has several advantages: it is minimally invasive, has short operative time, implant removal is not technically demanding and it does not require any special instrumentation. K-wire fixation has some complications as well: migration of the wires, damage to the growth plate, skin irritation and infection. It is recommended to combine K-wire fixation with application of a short, or long cast after the reduction and fixation.

Dorsal insertion nailing, DESIN is also an accepted method of fixation for the distal dia-metaphyseal fractures of the radius. Generally it is difficult to bend the nail before the nail tip has been advanced into the proximal radius, which is the key point of this method. If the fracture is located too close to the physis the risk of the dorsal cortical damage is relatively high. It is very important to verify the optimal level of the fracture when the DESIN technique is indicated. This type of minimally invasive technique usually does not require cast immobilization.

SESIN technique is a novel method for fixation of the unstable distal dia-metaphyseal radial fracture in children. SESIN procedure has a risk of complications such as: injury of the superficial (sensory) branch of the radial nerve, iatrogenic injury of extensor pollicis longus tendon, and injury of the physis if the insertion points are incorrect. The authors suggested this technique for the dia-metaphyseal fracture because of the fixation in this zone is difficult, usually too distal to treat by DESIN, and too proximal to fix with a K-wire. We conclude that SESIN is an effective, safe and stable form of stabilization for unstable fractures of the distal third of the radius. A number of different treatment options have been published previously in the literature. Some of them suggest the transepiphysial fixation. The main complication of these procedures are iatrogenic physeal injury and subsequent physeal arrest and deformity. Almost all the previous studies described technical problems and high rates of different complications. Two articles published excellent results after treatment of this type of fracture. One of these technique does not respect the phys, The SESIN technique respects the phys. In this study we focused on the distance of the fracture from the articular surface, which may determine the surgical procedure applied. We were unable to find any previous studies, which focused on the measurement of the fracture distance from the articular surface. Based on our results we found that the fracture distance determines the operative method. If the fracture distance is shorter than the width of the distal epiphysis of the radius the recommended treatment is K-wire fixation based on our retrospective study. If the fracture distance is higher than the cumulative width of the distal epiphysis of the ulna and radius the optimal treatment is DESIN according to our results. In the study period SESIN technique was used just in the distal dia-metaphyseal radial fractures. The limitations of our study are that it was retrospective and conducted in one center. The patients were non-comparative and not randomized. If the level of the fracture distance was measured between the distal radius epiphysis width and cumulative width of the radius and ulna, stabilization was performed with the presented three different methods. K-wire fixation is a gold standard method for the distal metaphyseal radial fracture, some authors suggest treating the transition zone fractures this way as well. Based in our results the SESIN is a safe and physis-sparing procedure for stabilizing the unstable dia-metaphyseal radius fracture. We have not observed any complication for the method in our series. We did not apply SESIN used in any other level fractures, just in the transition zone. Based in our results the fracture distance determined the operative technique. In our department K-wire fixation was indicated, when the fracture distance was shorter than the width of the distal radius. DESIN procedure was chosen when the fracture distance was higher than the cumulative diameter of the radius and ulna. Transition zone fractures were treated differently depending on the surgeon, but the SESIN technique was used predominantly in the fractures of transition zone. There were significant differences between the axial deviations at the time interval until implant removal. The highest incidence of axial deviation was measured in patients treated by K-wiring. The shortest time of the implant removal was measured in K-wire treated group. No further differences were found in our series.

### Author contributions

Conceptualization: Gergo Jozsa.  
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