Received: April 13, 2023
Accepted: May 10, 2023

Acad Med J 2023;3(2):180-188
UDC:616.717.5-001.5-053.2
DOI:
Surgical techniques

ANTEGRADE ELASTIC STABABLE INTRAMEDULARI NAILING IN TREATMENT OF DISTAL RADIUS DIAPHYSEAL METAPHYSEAL JUNCTION FRACTURES IN CHILDREN

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Abstract

The fractures of distal radius diaphyseal metaphyseal junction (DRDMJ) are one of the most frequent fractures in the pediatric population. In most cases, treatment of the fractures of DRDMJ is conservative. The aim of this study was to evaluate the benefits of using a new minimally invasive approach of closed reduction and internal fixation using an antegrade surgical approach and elastic stable intramedullary nail in the treatment of distal radius diaphyseal metaphyseal junction fractures in the pediatric population and to analyze the safety and efficacy of antegrade elastic stable intramedullary nail (ESIN) fixation. This study included 30 cases treated in the period from 2019 to 2021, where the use of non-surgical treatment did not work in children with distal radius diaphyseal metaphyseal junction fractures. In the surgical treatment, we used one titanium nail (2 or 2.5 mm) to achieve a correct closed reduction and internal fixation. The fracture healing was achieved in about 6 to 12 weeks after the procedure. Patients were then followed for another 6 months. In the postoperative period, there was no significant loss of reduction and no secondary displacement, nail migration, loss of fixation, non-union, or refracture. The combination of the closed reduction technique and the antegrade ESIN fixation is commonly used for the treatment of completely dislocated fractures in children. With this method we achieved minimally invasive treatment, short immobilization period, growth plate was not involved in the treatment and good outcome was accomplished.

Keywords: ESIN, pediatric, distal radius diaphyseal metaphyseal junction fracture

Introduction

The location of the distal radius is the most common site of fractures in children. Around 30% of all fractures happen due to this region[1]. The treatment of these fractures depends on the conservative approach. Typically, when referring to this fracture, we are describing the fracture that occurs at the junction betweenthe diaphysis and metaphysis of the radius[2]. The main principle in the treatment of distal radius fractures in the pediatric population is to use a non-invasive, conservative approach. In cases where the fracture is not ideal to reposition, conservative techniques such as surgical or semi-conservative ones are used instead[3].

Various techniques are applied for treatment of this fracture including crossed K-wires[4,5], open reduction and fixation with plate and screws, and pre-bending elastic stable

intramedullary nailing (ESIN)[2], if closed reduction failed or the reduction could not be sustained with cast fixation. Each technique has its own advantages and disadvantages.
In 2019 we introduced a new technique in our institution using antegrade approach and elastic stable intramedullary nail (ESIN) fixation in the treatment of displaced distal radius fractures. In this study we present our outcomes with this surgical technique.

Aims of the study

To evaluate the benefits of using a new minimally invasive approach of closed reduction and internal fixation using an antegrade surgical approach and elastic stable intramedullary nail in the treatment of distal radius fractures in the pediatric population and to analyze the safety and efficacy of antegrade elastic stable intramedullary nail (ESIN) fixation.

Material and methods

General information

The study presents the treatment of 30 children with a closed fracture of the distal radial radius with or without an accompanying ulnar fracture. The children were referred to the University Clinic for Pediatric Surgery in Skopje in the period between 2019 and 2021. The procedure was performed using a closed reduction and an internal (ESIN) fixation with titanium nail (2 or 2.5 mm). Before and after the surgery, X-rays were made and a preoperative and postoperative assessment was carried out.

Operative technique

Under general anesthesia, the patient was placed in the supine position with the upper limb positioned on a radiolucent side table (Figure 1).

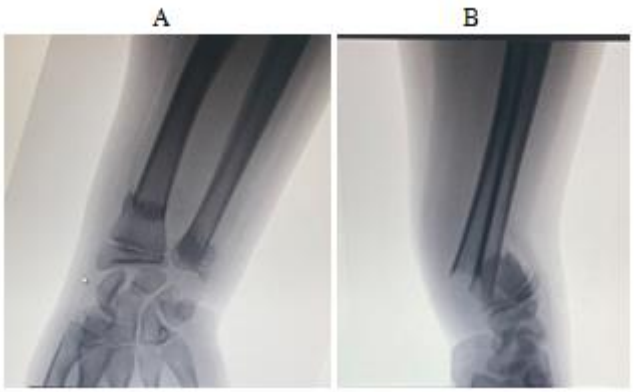

Fig. 1. AP (A) and Lateral (B), an initial X-ray of the fracture

Fig. 2. Thompson approach

The forearm was positioned with the elbow in flexion 60°-90° and forearm in a pronated position during the operation. The entrance site was dorsolateral of the proximal radius (Thompson approach) and 2-4 cm distal to the proximal articular surface of the radius (Figure 2). A skin and fascial incision was made about 1 cm and separating the muscle fibers; dissection was continued down to the bone, and the entry hole was made with an awl (Figure 3).

An ESIN was introduced in a diameter of 2.0 or 2.5 mm. The tip was then pushed into the hole with a gentle rotational movement (Fig. 3).

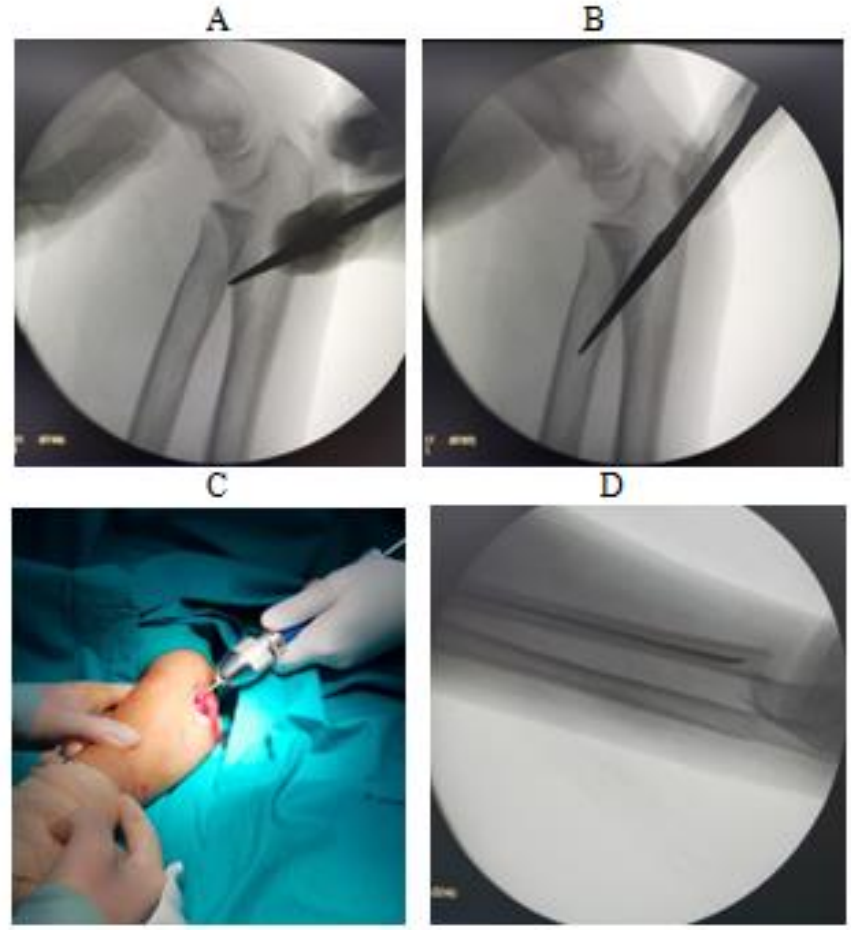

Fig. 3. (A) Making hole with an awl, (B, C) nail introduced into radius, (D) tip close to the fracture

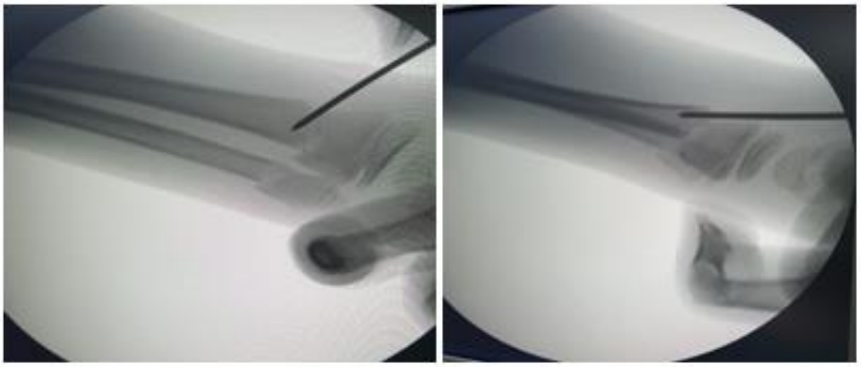

Fig. 4. Kapandji technique

The next step was to establish the length of the fracture again using C-arm fluoroscopy. If the procedure was difficult, a pin leverage technique was used with 2 to 2.5-mm-diameter K-wire. (Figure 4).

Once a satisfactory reduction had been achieved, the nail was advanced distally into the radial metaphysis (distal fragment) without penetrating the epiphysis (Figure 5). The proximal end of the pin was bent slightly and cut 1 cm from the bone and was left under the soft tissues. If there was an associated ulnar fracture that required internal fixation, a lateral and dorsal entry point on the ulna was used, approximately 1 to 2 cm from the tip of the olecranon.

Fig. 5. Final fixation

Follow-up and evaluation

A control X-ray in lateral and AP presentation were obtained before releasing the child usually three to four days postoperatively. The first X-ray control was done on the first postoperative day, then control X-rays were made according to the age of the child.

After 3 to 6 weeks, control X-rays were obtained. After the results were optimal, the extraction of the titanium nail was done when the healing was done. Control follow-up of patients was at least 6 months.

Results

This study presents our results of 30 patients with completely dislocated fractures of the distal radius treated with the minimally invasive surgical approach with closed reduction and antegrade ESIN fixation. The age of patients was 4-14 yrs., of which 20 were males, 10 females. According to the mechanism of injury – 6 patients were injured after falling from height, although majority were sport injuries, or injury during play – 24 patients (Table 1). The average age of children was 9.96 yrs. The average time of the procedure of reduction and fixation with antegrade ESIN was 16 minutes. Adjoined ulnar fractures were observed in 10 patients. The results were based on the function of the wrist (Figure 6.) The normal pronation/supination was defined as 90/0/90 degrees (A), the normal flexion/extension as 30/0/30 degrees (B), while the normal radial flexion as 20/0 degrees and the normal ulnar flexion as 0/30 degrees (C). The control group consisted of children with a healthy non-injured wrist.

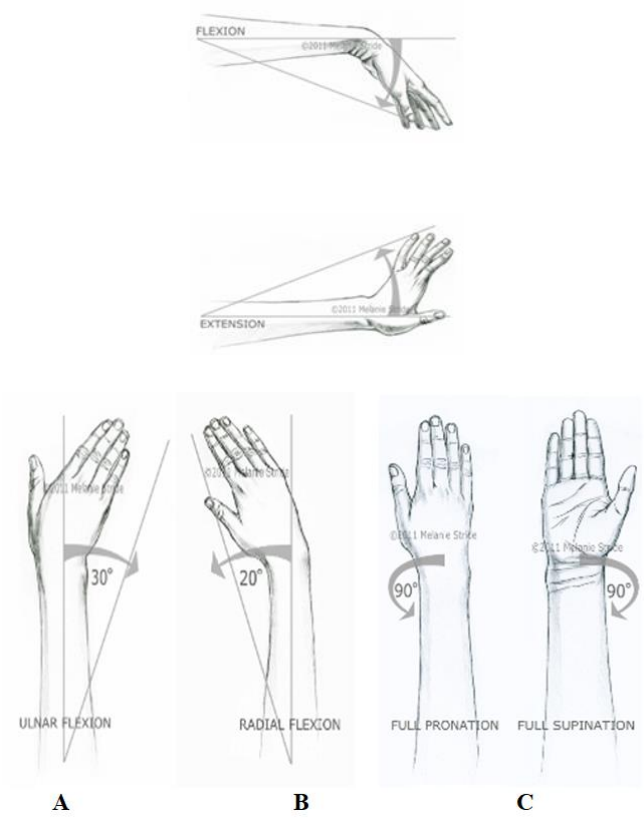

Fig. 6. Function of the wrist *The Hand: Examination and Diagnosis*, 3rd ed. Copyright © Elsevier, 1990.

The evaluation of the results was done 6 months after the intervention, and in our study we used the "Mayo wrist score" system for evaluation of the function of the wrist with analysis of several parameters: mobility, strength of grip, level of satisfaction and pain (Figure 7).

Category	Score	Findings
Pain (25 points)	25	No pain
	20	Mild pain with vigorous activities
	20	Pain only with weather changes
	15	Moderate pain with vigorous activities
	10	Mild pain with activities of daily living
	5	Moderate pain with activities of daily living
	0	Pain at rest
Satisfaction (25 points)	25	Very satisfied
	20	Moderately satisfied
	10	No satisfied, but working
	0	No satisfied, unable to work
Range of motion (25 points)	25	100% percentage of normal
	20	75~99% percentage of normal
	10	50~74% percentage of normal
	5	25~49% percentage of normal
	0	0~24% percentage of normal
Grip strength (25 points)	25	100% percentage of normal
	15	75~99% percentage of normal
	10	50~74% percentage of normal
	5	25~49% percentage of normal
	0	0~24% percentage of normal

Final result (total points)	
90~100	Excellent
80~89	Good
65~79	Fair
<65	Poor

Fig. 7. "Mayo wrist score"

With closed reduction, an anatomical or almost anatomical reduction of the fracture was achieved in all patients. Open reduction was not used. The postoperative period went

without any complications in each of the 30 patients. The X-ray signs of consolidation were seen after 4 weeks and the treatment of the fractures was fully completed 3 months after the injury, with extraction of the titanium nail after 8-16 weeks. In each patient, a full clinical and radiologic healing was obtained with a normal range of motion of the wrist. On the final X-ray, just before the extraction of the titanium nail there were no angular translation or angulations.

All fractures healed completely (Figure 8). All patients achieved full flexion and extension of the wrist (Figure 9).

Fig. 8. A postoperative anteroposterior (A) and lateral X-ray (B), showing the healed fracture of the distal radius

Fig. 9. Good flexion and extension of the wrist

The average length of time needed to achieve a full range of motion after the initial immobilization was 4 weeks (range 2-5 weeks). There was no loss of reduction or re-manipulation. No complications with the titanium nail or the cast were noted.

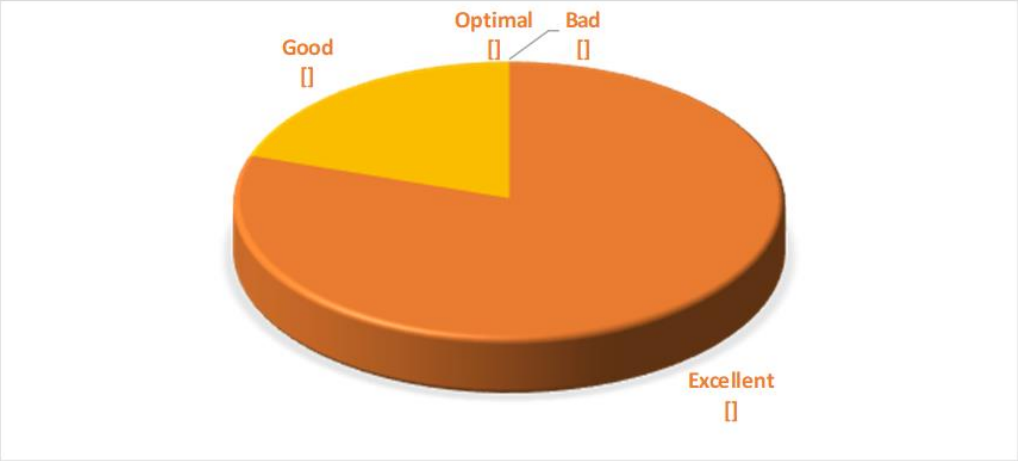

Fig. 10. Results according to the "Mayo wrist score" scoring system for evaluation

Table 1. Statistical analysis of clinical data

Age	Sex	Associated fractures	Mechanism of injury	Pin extraction in weeks	Functional results according to the Mayo wrist score
11	M	Ulna	Fall from bike	10	Excellent
10	F		Fall from rollers	11	Excellent
9	M	Ulna	Fall from sling	15	Excellent
10	F		Fall from sling	14	Excellent
12	M		Fall during football	15	Excellent
10	M		Fall from bike	13	Excellent
6	F		Fall from bike	9	Excellent
10	M	Ulna	Fall from trampoline	10	Good
4	M	Ulna	Fall from ladder	13	Excellent
7	F		Fall while skating	12	Excellent
8	F		Fall from bike	18	Good
11	M		Fall from trampoline	14	Good
12	M	Ulna	Fall from ladder	9	Excellent
11	F		Fall while skating	16	Excellent
13	M		Fall during football	11	Excellent
8	F		Fall from bike	17	Excellent
11	M	Ulna	Fall from trampoline	11	Good
9	M		Fall from ladder	13	Excellent
12	M		Fall while skating	8	Good
14	F	Ulna	Fall from trampoline	10	Excellent
11	M		Fall from ladder	15	Excellent
13	M		Fall while skating	14	Excellent
9	M		Fall from trampoline	9	Excellent
12	F	Ulna	Fall from trampoline	18	Excellent
6	M	Ulna	Fall from ladder	14	Excellent
10	M		Fall while skating	13	Excellent
9	M		Fall during football	10	Good
9	F		Fall from bike	15	Excellent
14	M		Fall from ladder	18	Excellent
8	M	Ulna	Fall from trampoline	14	Excellent

Discussion

Reduction and surgical immobilization of pediatric distal radius fractures remain a challenge. Many surgical immobilization techniques have been reported, but each type of fixation has limitations. Our study showed that the unstable rotation of the diaphyseal-metaphyseal junction can cause development of a distal radius fracture. The researchers stated that the physis did not cause the angulation deformity. A study conducted by Johari *et al*. showed that the angulation deformity was not caused by the dissolvable physis [6]. Roberts noted that the radial inclination of the distal radius was greater than that of the angulation in the sagittal plane [7]. In 1981, Morrey *et al*. suggested that a rotation of at least 100^{o} of the forearm was required to perform most daily activities [8]. The rotation of the forearm is also considered as a motion of articulation. Studies suggested that the interosseous membrane can be compressed effectively to limit the restriction of rotation. Asadollahi *et al*. found that re-displacement was easier if the angulation of a fracture was greater than 10^{o}. A higher ratio of cast fixation and closed reduction is also considered.

The higher the ratio of re-displacement, the more accurate the reduction should be [9]. It is also important to remember that the angulation should be completely corrected in rotation and in coronal plane [10]. Before the introduction of the ESIN technique, open reduction and plate fixation were the most common methods for achieving skeletal reduction. This procedure is usually preferred for children with a skeletal maturity of less than one year [11]. The strength of pronation is a risk factor for the injury to the pronator quadratus. This injury can also cause delay in the union of forearm fracture [12]. ESIN is the best choice for children with long bone fractures. It can fix the fracture by controlling the fragment away from the point of implant. An anatomical study revealed that the distance between the radial nerve and the lateral epicondyle is about 1/3 of the forearm [13]. The radial nerve was then placed obliquely to the back. The superior 1/3 point between the lateral epicondyle and radial styloid process was used as the implanting plane. ESIN can reduce fracture by penetrating into the muscle belly instead of using three points. There is no need to consider anatomical reduction in patients with metaphysis. Instead, antegrade ESIN should be considered for stabilization of the implants. It is noteworthy that ESIN is only an effective implant for the reduction of fractures. In large-scale clinical cases, 93.3% of cast fractures were treated successfully with cast fixations alone. In children with a history of overweight or obesity, the fixation and correction abilities of ESIN are not as good as those of traditional methods [14].

Conclusion

According to our results, with the use of the closed reduction and antegrade ESIN fixation, an easy and good anatomical reduction has been achieved with good postoperative results in the treatment of completely dislocated fractures in the distal radius in children. The advantages of the antegrade ESIN technique are demonstrated in treating the fracture in the diaphyseal-metaphyseal junction. It also provides a better recovery than the crossed K-wires and opened reduction and fixation with plate and screws.

Conflict of interest statement. None declared.

References

1. Randsborg PH, Gulbrandsen P, Saltyte Benth J, Sivertsen EA, Hammer OL, Fuglesang HF, *et al*. Fractures in children: epidemiology and activity-specific fracture rates. *J Bone Joint Surg Am* 2013; 95(7): e421-e427. doi: 10.2106/JBJS.L.00369.
2. Cai H, Wang Z, Cai H. Prebending of a titanium elastic intramedullary nail in the treatment of distal radius fractures in children. *Int Surg.* 2014; 99(3): 269-275. https://doi.org/10.9738/ INTSURG-D-13-00065.1.

3. Miller BS, Taylor B, Widmann RF, Bae DS, Snyder BD, Waters PM. Cast immobilization versus percutaneous pin fixation of displaced distal radius fractures in children: a prospective, randomized study. *J Pediatr Orthop* 2005; 25(4): 490-494. Available from: https://doi.org/ 10.1097/01.bpo.0000158780.52849.39.
4. Huang W, Zhang X, Zhu H, Wang X, Sun J, Shao X. A percutaneous reduction technique for irreducible and difficult variant of paediatric distal radius and ulna fractures. *Injury* 2016; 47(6): 1229-1235. Available from: https://doi.org/ 10.1016/ j.injury.2016.02.011.
5. 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(6): 395-398. doi: 10.1055/s-0030-1262843.
6. Johari AN, Sinha M. Remodeling of forearm fractures in children. *J Pediatr Orthop B* 1999; 8(2): 84-87. https://doi.org/10.1097/00009957-199904000-00003.
7. Roberts JA. Angulation of the radius in children's fractures. *J Bone Joint Surg Br* 1986; 68(5): 751-754. doi:10.1302/0301-620X.68B5.3782237.
8. Morrey BF, Askew LJ, Chao EY. A biomechanical study of normal functional elbow motion. *J Bone Joint Surg Am* 1981; 63(6): 872-877. PMID: 7240327.
9. Asadollahi S, Pourali M, Heidari K. Predictive factors for re-displacement in diaphyseal forearm fractures in children-role of radiographic indices. *Acta Orthop* 2017; 88(1): 101-108. doi: 10.1080/17453674.2016.1255784.
10. Bowman EN, Mehlman CT, Lindsell CJ, Tamai J. Nonoperative treatment of both-bone forearm shaft fractures in children: predictors of early radiographic failure. *J Pediatr Orthop* 2011; 31(1): 23-32. doi: 10.1097/BPO.0b013e318203205b.
11. Pace JL. Pediatric and Adolescent Forearm Fractures: Current Controversies and Treatment Recommendations. *J Am Acad Orthop Surg* 2016; 24(11): 780-788. doi: 10.5435/JAAOS-D-15-00151.
12. Lobo-Escolar A, Roche A, Bregante J, Gil-Alvaroba J, Sola A, Herrera A. Delayed union in pediatric forearm fractures. *J Pediatr Orthop* 2012; 32(1): 54-57. doi: 10.1097/BPO.0b013e31823832ea.
13. Ozturk A, Kutlu C, Taskara N, Kale AC, Bayraktar B, Cecen A. Anatomic and morphometric study of the arcade of Frohse in cadavers. *Surg Radiol Anat* 2005; 27(3): 171-175. doi: 10.1007/s00276-005-0321-z.
14. Zheng W, Tao Z, Chen C, Zhang C, Zhang H, Feng Z, *et al*. Comparison of three surgical fixation methods for dual-bone forearm fractures in older children: A retrospective cohort study. *Int J Surg* 2018; 51: 10-16. doi: 10.1016/j.ijsu.2018.01.005.