Retrospective Study

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# Results of Antegrade Intramedullary Elastic Wires for Severely Displaced Distal Radial Fractures in Children

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## Abstract

**Objective:** The objective of this study is to present a new method of Antegrade elastic wires, which is a minimally invasive surgical approach to treat displaced fractures in the distal radial metaphyseal and dia-metaphyseal fractures in children.

**Materials and Methods:** We conducted a retrospective analysis of 18 patients who received antegrade elastic wires treatment for distal radial fractures from January 2019 to January 2023. The surgical indications encompassed closed, significantly displaced, and unstable fractures located in the metaphysis or diaphyseo-metaphyseal region of the radius. The fractures were stabilized using two prebent short elastic nails that were introduced from the diaphysis to the metaphysis. In instances when an ulnar fracture was present, a traditional anterograde nailing procedure was also carried out. A long or short arm plaster cast was administered for a duration of 3 weeks.

**Results:** The group consisted of 15 boys and 3 girls, with an average age of 10.8 years (ranging from 7 to 16 years). The right hand was implicated in 12 instances, whereas the left hand was implicated in 6 instances. The mean duration of follow-up was 7.8 months, with a range of 4 to 28 months. Out of the 18 patients, 2 individuals experienced skin irritations, which were resolved after the removal of the radial nails. All patients had complete restoration of their range of motion and experienced successful bone healing without any problems.

**Conclusions:** An antegrade elastic wire fixation is a very efficient, secure, and readily replicable technique for treating unstable fractures of the distal radius, while also preventing harm to the physeal plate. It successfully attains favorable functional and radiological outcomes and allows early mobilization.

**Keywords:** Distal radius, Metaphyseal fracture, dia-metaphyseal fractures, Elastic wires, Antegrade.

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## Introduction

Paediatric metaphyseal radial fractures that are substantially displaced and have a complete rupture of the periosteum are typically classified as unstable fractures. Distal radial metaphyseo-diaphyseal fractures are commonly managed with closed reduction, yielding satisfactory outcomes [1]. Distal paediatric forearm fractures that are severely displaced and unstable pose challenges in maintaining stability with a cast following closed reduction. Therefore, surgical fixation is recommended for selected cases [2, 3]. Although children had significant potential for remodeling, a study found that 15-29% of patients treated with closed methods saw a decrease in rotational capacity in the forearm [4]. Patients who are at high risk of reduction loss following closed therapy should have a fixation with percutaneous Kirschner wire (K-wire) to prevent forearm rotational loss [5, 6].

The current available procedures and adaptations of Kirschner wiring or traditional elastic stable intramedullary nailing (ESIN) exhibit a similar rate of problems.

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**Figure 1A:** Antegrade entry of ulna nail. Antegrade entry of radial nails

Growth disruption is an infrequent, yet highly significant consequence of transepiphyseal wire implantation [7]. The spacious canal at the intersection between the metaphysis and diaphysis is frequently responsible for insufficient alignment or the reversal of alignment achieved when using the percutaneous K-wire approach through the epiphysis for stabilization. In their study, Marcell Varga et al [8] outlined a technique called the epiphyseal sparing method. This method involves inserting two short and prebent, retrograde elastic titanium nails from the proximal metaphysis to the distal radial diaphysis. By using this technique, a highly secure stabilization can be accomplished without the requirement of a protracted period of cast immobilization. The nails are positioned in a way that avoids crossing the physeal plates, therefore preventing the occurrence of postoperative physeal arrest [8].

The previously mentioned techniques for retrograde K wire fixation are also associated with a significant risk of superficial radial nerve damage and pin tract infection, which should not be underestimated [9, 10]. Plate osteosynthesis, a well-established but intrusive procedure, is commonly used in adult

**Figure 2:** Displaced metaphyseal fracture radius and ulna fracture

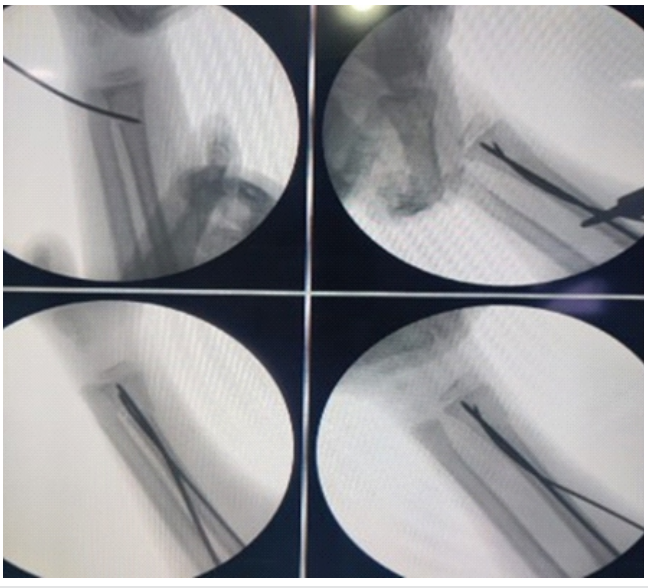

**Figure 1B:** Intrafocal reduction and placement of wires in metaphyseal fractures

trauma surgery. However, it is excessive and unnecessary for pediatric patients due to the possibility for problems of infection and scarring [11]. In light of these concerns, we sought a resolution to circumvent these challenges using the antegrade approach of inserting wires from the diaphysis towards the metaphysis. This technique, which spares the physis, effectively avoids these problems. We would like to present our innovative approach of antegrade ESIN for surgically treating highly displaced fractures in the distal metaphyseal region of pediatric patients.

## Patients and methods

We conducted a retrospective assessment of 18 patients who underwent surgical procedures for substantially displaced fractures of the distal forearm or diametaphyseal fractures of the radius and ulna between January 2019 to January 2023. There were 13 individuals who had only radial fractures, and an

**Figure 2:** Immediate post op x-ray.

**Figure 2:** Fixation of radius and ulna. Union and follow up x-ray after 2 years.

**Figure 2:** Clinical photographs showing pronation and supination

additional 5 children who had both radial and ulnar fractures. The group consisted of 15 boys and 3 girls, with an average age of 10.8 years (ranging from 7 to 16 years). There were 12 instances where the right hand was implicated and 6 instances where the left hand was implicated. All patients underwent treatment with antegrade short double prebent intramedullary nails for the radius and a single intramedullary nail for the ulna, following the usual antegrade method. Surgical intervention is recommended for cases of closed fractures with significant displacement, regardless of whether there is an accompanying ulna fracture. We omitted cases with open fractures, physeal injuries, and pathological fractures. The study received clearance from the Institutional Ethics Committee. (Table 1)

**Table 1: Patient demographic data**

| | |
|---|---|
| Number of Patients | 18 |
| Male | 15 |
| Female | 3 |
| Average Age (range) @ time of surgery | 10.8 years [range 7 -16 years |
| Number of Patients with Fracture in the Dominant Hand | 12 |
| Associated ulna fracture | 5 |

**Surgical procedure**

Under short GA or regional block, anaesthesia was used for the procedure in each patient. The patient was placed in a supine posture with the elbow flexed to 90°, the forearm pronated, the wrist in a neutral position, and the shoulder abducted to 90°. Under image intensifier guidance, closed reduction of the fracture was performed after standard skin preparation. Fluoroscopic confirmation was obtained for both the quality and acceptable reduction requirements in each case. If acceptable closed reduction was not possible a 2 mm K wire was passed from the dorsal to the volar aspect at the fracture site by percutaneous manoeuvre the fracture is reduced by intra-

**Figure 3A:** Displaced distal forearm fracture

**Figure 3B:** Immediate post op x-ray. Fixation of radius and ulna.

**Figure 3C:** Union and follow up x-ray after 2 years.

**Figure 3D:** Clinical photographs showing pronation and supination

focal manipulation of K wire. Ulna fixation was fixed first to gain length in applicable cases by the antegrade method. The insertion of the nail is done through in proximal ulna lateral taking care not to injure the epiphysis.

Over the dorsal-radial surface of the radius bone, a 2 cm longitudinal incision was made approximately at the proximal 2/3 rd and distal 1/3 rd junction of the radius bone. To access the cortex of the radius dorsal to the pronator muscle, the area between the extensor carpi radialis brevis muscle and the extensor digitorum muscle proximal to the abductor pollicis longus muscle was developed. Two holes were drilled into the radius at two separate locations—ulnar and radial—using a 2 mm drill bit typically at a distance of 4-5 mm from each other, depending on the patient's radius measurement. To obtain access through the cortical shell, the drill was first started perpendicular to the bone and then directed obliquely at an angle of roughly 40° to 45°, to prevent

**Figure 4B:** Immediate post op x-ray. Fixation of radius and closed reduction of ulna


**Figure 4A:** Distal Metaphysio diaphyseal forearm fracture

the opposing cortex from penetrating, much care was used. Using a T-handle drill, 1.8 or 2 mm pre-bent stainless steel elastic wires with blunt points were then manually inserted through these holes and into the IM canal. The tip of the wire is slightly bent for easy negotiation through the oblique hole, this also helps in manipulating wires across the fracture site by simple rotational adjustments. While maintaining the closed reduction, the wires were aimed distally until they were positioned across the fracture site into the metaphyseal bone.

**Figure 4C:** Union and follow up x-ray after one year

**Figure 4D:** Clinical photographs showing pronation and supination

Because of their elastic nature, the wires curved smoothly as they were introduced into the IM canal, taking on the shape of the radial canal in the process. It was made sure that at least two wires were supporting the broken segment at the mid-metaphyseal level sparing the epiphysis. Before the incision was closed, the proximal ends of the wires were bent and cut close to the bone. (Fig. 1 A, and B)

**Postoperative care**

During the initial 3 weeks, a below-elbow cast was used for a fracture in the radius alone, whereas an above-elbow cast was used for a fracture in both the radius and ulna. The level of anatomical alignment and the advancement of healing were verified using plain radiographs taken at the first, third week, six weeks, and three months after the surgery. Engaging in sports and strenuous physical activity is prohibited for 12 weeks, however complete range of motion can be initiated within a few days. The mean duration of follow-up was 7.8 months, with a range of 4 to 28 months. It is recommended to remove the nails 8-9 months following the surgery, either under general anesthesia or under local anesthesia with sedation. (Fig. 2, 3, and 4)

**Results**

The mean duration of operation was 25 minutes, with a range of 15 to 45 minutes. The mean duration of follow-up was 7.8 months, with a range of 4 to 28 months. No instances of infection, tendon, nerve, or growth plate injury were detected during the follow-up period. Out of the patients' follow-up x-rays, 16 cases were determined to be anatomically correct. The x-rays taken 6 months after the operation revealed exceptional healing and restructuring of the fracture site, with no indication of any growth abnormalities at the distal radius. Out of the 18 patients, 2 experienced skin irritations, which were cured with removal of the radial nail. All patients achieved complete restoration of their range of motion without experiencing any problems. As per the grading system developed by Price et al. [12], all patients were assessed as excellent during the last follow-up, and no poor outcomes were seen in this study. (Table 2)

**Table 2: Clinical outcome**

| Outcome | Symptoms | Loss of forearm rotation | No. of case |
|---|---|---|---|
| Excellent | No complaints with strenuous activity | < 15 degrees | 16 |
| Good | Mild complaints with strenuous activity | 15 – 30 degrees | 2 |
| Fair | Mild complaints with daily activities | 31- 90 degrees | 0 |
| Poor | All other results | ➢ 90 degrees | 0 |

**Discussion**

The majority of the distal radius and ulna fractures are typically managed with closed reduction and casting, yielding satisfactory outcomes. Anatomical reduction is not always necessary for treating these types of fractures, as the distal radius can reconstruct itself [13]. Severe dislocations that exceed an angle of 30-40° and occur in older children (boys older than 12 years and girls older than 10 years) require reduction within the range of the body's ability to remodel. Additionally, it is important to acknowledge the anxiety that parents or caregivers may feel when they do not see a perfectly aligned X-ray after surgery or the removal of a cast. Hence, a select group of patients suffering from an unstable pediatric distal radial fracture, with or without involvement of the distal ulna, undergo treatment with closed reduction and percutaneous pinning, yielding good outcomes [14]. Although retrograde percutaneous pinning is a straightforward and efficient technique for stabilizing unstable distal radial fractures, it also has several possible downsides and implications. The problems associated with Kirschner wire usage are widely recognized and include pin migration, superficial infections, growth plate destruction, skin irritation, and inadequate biomechanical capacity to sustain reduction without casting [15]. Lieber et al. employed trans epiphyseal pinning in these instances and observed that the occurrence of iatrogenic physeal injury is minimal. However, it is important to note that a potential complication of any trans epiphyseal stabilization is the development of physeal arrest and progressive deformity.

Fractures occurring in the region where the metaphysis and diametaphyseal junction meet pose a unique challenge. These fractures are typically placed too far from the center to be effectively treated using the standard method of Kirschner wire fixation. Marcell Varga and his colleagues propose the use of a specifically designed, pre-bent, short elastic nail that avoids damage to the growth plate, to resolve this issue. In a study involving 24 patients with paediatric distal radial fractures, all fractures were successfully treated using short

double elastic nailing in metaphyseal or diametaphyseal fractures of the radius. The patients regained full range of motion, with only 3 cases experiencing skin irritations that were resolved after removing the radial nail.

Implant prominence was observed in our initial cases (2 cases) due to the wires not being cut flat to the bone, as we discovered during a retrospective review. Therefore, we recommend trimming the nails so that they are level with the bone. This will prevent skin irritation, migration, and pin tract infection. However, there is a possibility that the wire may become embedded in the bone if the implant is not removed in a timely manner. The postoperative radiological results in all patients demonstrated good outcomes, with each case showing either total or almost anatomical reduction. There were no instances of reduction loss or displacement seen, indicating that antegrade double elastic nailing provides improved stability compared to percutaneous pinning.

The technique of Antegrade elastic stable intramedullary nail fixation for distal radius fractures at the intersection of the diaphysis and metaphysis in children was described by Mengmeng Du et al [19]. An entry site is established on the posterolateral aspect of the proximal radius, located 2-4 cm distal to the articular surface of the radius. This entry point is used to insert the ESIN (Elastic Stable Intramedullary Nailing) device for immobilizing the fractures. A set of thirty patients achieved outstanding outcomes using a novel surgical technique targeting the proximal "safe zone" of the posterior interosseous nerve (PIN). We believe that this antegrade nailing technique has technical challenges and poses a risk of harm to the posterior interosseous nerve (PIN). We documented the use of antegrade intramedullary fixation with short nails as a strategy to treat distal radius fractures in adults. This approach yielded satisfactory clinical and radiological results (20). Therefore, we decided to expand the application of our method to pediatric distal radius fractures as an initial research. Our technology involves the utilization of 2 mm elastic nails that conform to the geometry of the medullary cavity. These nails provide 3-point fixation in both the diaphysis and metaphysis, targeting various corners. These nails exert the most significant tensile force in the wide area between the shaft and the metaphysis of the radius bone. We conducted an analysis of patient characteristics, complications, duration till removal, and the duration of the surgical procedure for hardware removal. The use of a short nail for the radius in the stable intramedullary nail (ESIN) fixation can yield comparable outcomes to those described by Mengmeng et al. in their series.

The use of the dorsolateral insertion point significantly reduces the risk of physeal damage and harm to the superficial branch of the radial nerve. These problems, which are frequently encountered with the currently stated and used procedure, should not be underestimated or considered insignificant [21]. The benefits of our technique include prompt mobilization using a compact splint and the prevention of potential growth plate damage. We believe that our technique offers a less intrusive and easily replicable alternative surgical approach, in comparison to percutaneous pinning in metaphyseal fractures and plate or trans epiphyseal osteosynthesis in situations of diaphyseo-metaphyseal displacement fractures of the radius forearm.

We acknowledge several limitations of our study, the most significant being its small sample size, limited to a single center. Additionally, we did not include a matched control group to compare with other methods or conservative measures. Additional prospective and biomechanical investigations are necessary to validate our preliminary findings.

**Conclusion**

An antegrade wiring reported in this research study yields outstanding functional and radiological results, accompanied by manageable problems. Short elastic intramedullary wire fixation is a feasible alternative approach that preserves the epiphysis in surgically indicated fractures.

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**Declaration of patient consent :** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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