Research Square

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Stable Elastic Nail Application with Poller K-wire for Pediatric Irreducible Distal Radius Metaphyseal-Diaphyseal Junction Fractures: A New Operative Technique

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Abstract

Background

Surgical treatment of irreducible distal radius diaphyseal- metaphyseal junction fractures involves difficulties as the fracture remains too proximal for K-wire fixation and too distal for the elastic stable intramedullary nail. Our study aims to present the clinical results of applying an elastic stable intramedullary nail with a poller K-wire to achieve both reduction and stable fixation.

Patients and Methods

A retrospective analysis was performed on 26 patients who underwent ESIN with a poller K-wire for distal radius diaphyseal-metaphyseal region fracture. Reduction parameters such as residual angulation and alignment were evaluated on postoperative follow-up radiographs. Changes in angular and alignment parameters on follow-up radiographs were recorded. Wrist and forearm functions at the last follow-up were evaluated.

Result

There were 17 male and nine female patients with an average age of 10.9. The residual angulation in sagittal and coronal planes on immediate postoperative radiographs was 3° and 4°, respectively. The mean translation rate on immediate postoperative radiographs was 5% and 6% in the sagittal and coronal planes, respectively. No change was observed in translation rates in the last follow-ups, with an average of 1° of change in the coronal plane and 2° in the sagittal plane. No tendon injury or neurovascular injury was observed in any of the patients.

Conclusion

In the surgical treatment of pediatric distal radius diaphyseal metaphyseal junctional fractures, applying elastic stable intramedullary nailing with poller K-wire is an effective, safe, and novel method for achieving reduction and stable fixation.

1. Introduction

Distal radius fractures are the most common fractures in the pediatric population [1]. It accounts for 35% of all pediatric fractures [2]. Although pediatric distal radius fractures can be successfully treated conservatively, reduction losses of 21–39% can be observed in the treatment with a plaster cast [3].

Reduction losses are frequently observed in distal radius diaphyseal metaphyseal junctional (DRDMJ) fractures, primarily due to the limited contact surface of the fracture [4]. There has yet to be a consensus regarding the treatment protocol for DRDMJ fractures [5]. In DRDMJ fractures, surgery is recommended in cases where satisfactory alignment cannot be achieved with closed reduction and cast immobilization or there is reduction loss in clinical follow-ups [4, 6, 7].

In the surgical treatment of pediatric distal radius fractures, despite achieving successful outcomes with closed reduction and K-wire fixation, these techniques prove inadequate for fractures occurring at the diaphysis-metaphysis junction (DMJ). Reduction losses can be observed [8]. Due to the limited length of the distal segment in pediatric distal radius fractures, retrograde elastic stable intramedullary nailing (ESIN) application leads to displacement at the fracture site [8]. Lieber et al. [9] emphasized that DRDM fractures are too proximal for fixation with a K-wire and too distal for fixation with an ESIN. Reduction losses are observed after inadequate fixation of DMJ fractures [10]. The narrowness of the DRDM region makes K-wire applications more complicated than the metaphyseal region. As a result of the application of the K-wire's higher insertion angle and applying the K-wire closer to the fracture line, the fixation strength decreases. In diaphyseal radius fractures, the deforming effect of ESIN decreases depending on the application since it bends very distal to the fracture line, and ESIN is already directed towards the intramedullary area. In DRDMJ fractures, on the other hand, the stress caused by the bending of the ESIN is close to the fracture line, leading to angulation. When the dorsal entry point is preferred for the ESIN in DRDMJ fractures, the tensile forces due to bending of the ESIN cause flexion of the fracture line in the sagittal plane. When a more radial entry point is preferred, it causes coronal plane deformities. Many intramedullary surgical techniques have been described due to inadequate K-wire fixation and displacement due to ESIN applications [4, 9, 11]. It can lead to severe but rare complications such as growth plate disorder and iatrogenic fracture associated with these surgical techniques. Considering skeletal maturity, open reduction and internal fixation (OR-IF) are becoming popular in current practice in older pediatric cases [12]. In our clinical practice, although we prefer OR-IF in patients over 14 years of age or who have completed skeletal maturity, we use more minimally invasive intramedullary fixation methods in cases that have not completed skeletal maturity.

In this article, the focus is on the implementation of ESIN's poller K-wire technique to prevent fracture displacement and achieve stable fixation during clinical follow-ups. Our study aims to report this novel technique's effectiveness and clinical outcomes, which we have defined for DRDMJ fractures.

2. Patients and Methods

2.1 Study Population

Pediatric DRDMJ fractures aged 9–14 years with limited remodeling capacity and incomplete skeletal maturity were included in the study. The study did not include patients under nine with higher remodeling capacity and broader acceptable reduction parameters [13, 14]. The study did not include cases over 14 years of age treated with OR-IF, considering it an adult forearm fracture. Between 2019–2022 1240 pediatric distal radius fractures were admitted to our clinic. Considering the fracture distribution according to the anatomical location, the fracture location was in the DRDM junction in 87 patients. In 51 patients, reduction parameters (< 25° of angulation on the lateral radiograph, < 10° of angulation on the posteroanterior radiograph, < 25% apposition of the fracture on the lateral or posteroanterior radiograph) [15] were achieved with closed reduction and cast immobilization treatment at the first admission. Plate and screw fixation was performed in 4 patients since they had comminuted fractures, and it was thought

that adequate alignment could not be obtained with ESIN. External fixation was applied in 2 patients due to farm injuries and contaminated open fractures. In 4 patients, adequate alignment and reduction were achieved in fluoroscopic controls with only ESIN application. All cases who underwent ESIN with a poller k-wire due to DRDM junctional fracture were included in the study.

2.2 Study Design and Participants

Diaphyseal metaphyseal junction fractures previously described by Lieber et al. [9] were included in the study. While defining the DRDMJ, the width of the distal radius physis (wDRP) and the distal radio-ulnar joint (wDRUJ) were measured. The fractures between one wDRP and one wDRUJ distance from the physis were described as DRDMJ fractures (Fig. 1). In our study, we retrospectively evaluated patients who underwent ESIN with a poller K-wire in DRDMJ fractures between 2020–2022. All patients underwent surgery within two days. A single trauma-specialized orthopedic surgeon performed all surgeries under general anesthesia. Preoperative radiographs of the patients were not included in the evaluation because the reduction could not be obtained, and the fracture was unstable.

Post-operative radiographs of all patients were evaluated to review the measurement of angulations in the frontal and sagittal planes and the translation ratio at the fracture site. On postoperative radiographs, sagittal and coronal angulations were defined as the angle formed between the radial shaft and a line drawn to the physis [16]. Accompanying ulna fracture on preoperative radiographs was also evaluated. Coronal and sagittal plane angulations and translation rates at the fracture were recorded on the radiographs obtained immediately after the operation. Clinical follow-ups were performed in two weeks, four weeks, six weeks, three months, six months, and one year after surgery. Coronal and sagittal angulation and translation rates were evaluated in the radiographs obtained in the sixth week, as defined before. Fracture union and complications data were analyzed in clinical follow-ups. Poller K-wires were removed after fracture union was observed. Poller K-wires were removed after adequate union at four weeks. Plaster treatment was terminated at 4–6 weeks. ESINs were removed 3 to 6 months after the operation under general anesthesia.

At the final follow-up in the 12 months, the wrist's range of motion and rotation of the forearm were assessed. The wrist joint function of the affected side was compared with that of the healthy side. To evaluate the forearm functions of the patients at the last follow-up, Price et al. grading system was used [17].

2.3 Inclusion Criteria

- Children aged 9–14 years,
- Failed closed reduction,
- No previous history of fracture,
- Fractures treated with a method ESIN with Poller K-wire
- DRDMJ fractures accompanied by ulna fracture
- DRDMJ fractures

2.4 Exclusion Criteria

- Open or pathological fracture,
- Accompanying physis injury,
- Open fracture,
- Previous history of fracture at the forearm,
- Less than 12 months of follow-up.

2.5 Examined Variables

- Immediate postoperative radiographic evaluation,
- 6th week control radiographic evaluation.
- Last follow-up radiographic evaluation.

2.6 Surgical Technique

The operation was performed under general anesthesia while the patient was supine, with the arm placed on the radiolucent side table. Each stage of the ESIN application was performed with the guidance of fluoroscopy. Before starting the application, ESINs of 2 or 2.5 mm were selected according to the diameter of the narrowest part of the radius medullary cavity with fluoroscopic control. In the first stage, closed reduction was performed under fluoroscopic guidance. In cases where the closed reduction was unsuccessful, a stab incision was made dorsal to the fracture line, and anatomical reduction was obtained with the help of curved Kelly forceps. After anatomical reduction, the entry point was determined under fluoroscopy guidance. Dorso-radial (through the Lister’s tubercle) and radial (slightly radial to Lister's tubercle) entry points were used as entry points. The entry point is created around Lister's tubercle, 0.5-1 cm proximal to the physis line. A 1.5 cm incision was made over the determined point. After subcutaneous soft tissue dissection, the curved Kelly hemostat forceps tip was opened, and the soft tissues were protected before applying the awl. The awl was placed at the determined point, and the location of the drill was confirmed by fluoroscopy. After creating the entry point, ESIN was applied in the intramedullary area with an oscillation maneuver. In case of loss of reduction due to ESIN application in fluoroscopic controls, the ESIN has withdrawn again with an oscillating maneuver. At the fracture level in the DRDMJ region, deformity with the apex on the radial side and radial translation of the distal fragment is observed due to ESIN application (Fig. 2). Retraction of the curved tip of the ESIN with oscillation creates the intramedullary area where the nail will settle within the fragment while reducing the fractured fragments while applying the nail after the poller k wire.

Before re-applicating ESIN, the poller K-wire was applied to the distal fragment on the concave side of the displacement, where we wanted the fractured fragments to move under fluoroscopic control. A 0.5 cm skin incision was made for the poller K-wire application. During the application of poller K-wire, tendon and soft tissue structures were protected by using a sleeve. 1.6 mm K-wires were preferred for the poller K-wire. After applying the poller K-wire to the ulnar part of the distal fragment, the reduction of the broken

fragments was confirmed as the ESIN passed through the radial side of the poller K-wire in the intramedullary area under fluoroscopic guidance (Fig. 3). When the reduction was insufficient, a poller k wire was applied to the proximal and distal fragments. Poller K-wire in the proximal fragment was applied to the ulnar part, which is the concave side of the angulation in the fracture. ESIN was reapplied with a poller K-wire to the volar aspect of the distal fragment for the angulation in the dorsal apex that occurred in the sagittal plane due to the ESIN application (Fig. 4). After the application, reduction, and stability were checked with fluoroscopy. After the radius fixation, the distal ulna fracture reduction was checked under C-arm fluoroscopy. If needed, antegrade ESIN was applied for ulna fracture. The tail of ESIN was then cut off and located under the subcutaneous tissue.

2.7 Postoperative Care

All patients were immobilized in a short-arm cast for four to six postoperative weeks to prevent poller K-wire migration. If sufficient union was observed, the Poller K-wire was removed at four weeks, and the short-arm cast treatment was terminated at 4–6 weeks. The free and full-arm motion was allowed after that.

2.8 Ethics

The approval of the Ethics Committee has been obtained from the institution to which the researchers are affiliated. Participation in the study has been voluntary and conducted following the principles of voluntarism. Informed consent has been obtained from the participants.

2.9 Primer & Seconder Outcomes

Coronal and Sagittal plane translation

Coronal and Sagittal plane angulation

Coronal and sagittal plane angulation change at the 6-week follow-up.

Coronal and sagittal plane translation change at the 6-week follow-up.

Forearm and wrist range of motion

Forearm and wrist functional scores according to Price et al. grading system

2.10 Statistical Analysis

Statistical analysis was performed using Statistical Package for Social Sciences version 24.0 software in the statistical analysis of the study for Windows (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp. USA). Descriptive statistics are expressed as numbers, percentage, mean, and standard deviation, median, minimum, and maximum values. Several observations of categorical variables were given as n. The normality of the variables was tested with Kolmogorov-Smirnov and Shapiro-Wilk tests. Wilcoxon's Signed Rank test was used to compare the range of motion of the injured side compared to the uninjured side.

3. Result

All cases who underwent ESIN with a poller K-wire due to DRDMJ fracture were included in the study. Data from seventeen male and nine female patients with an average age of 10.9 ± 1.45were analyzed (Table 1).

Table 1
Demographic and clinical features of patient’s

Patient Demographics (n = 26)	
Age (years; mean ± sd)	10.9 ± 1.45
Sex (Female/male)	9/17
Side (left/right)	6/20
Associated ulnar fracture	11
ESIN for ulna fracture	7
Duration of surgery (min; mean ± sd)	44 ± 9
Removal of the poller K-wire (week)	4
Removal of the short arm cast(week)	4.5 ± 0,9
Removal of the ESIN (month; mean,min-max)	4.2 (3–6)
Follow-up (month; mean, min-max)	13.6 (12–14)
ESIN: Elastic stable intramedullary nail, SD: Standard deviation, Min: minute, Min-max: Minimum-maximum	

Eleven of the patients had concomitant ulna fractures. ESIN was applied to seven patients when displacement or instability was detected in the ulna fracture after radius fixation in fluoroscopic controls. After radius fixation in five patients, the reduction was achieved in the ulna, and no instability was detected, so no additional fixation was applied. The mean operation time was 44 ± 9 min. The anatomical reduction was achieved in all cases accompanied by ulna fracture, and no reduction loss for ulna fracture was observed in clinical follow-ups. No problem, such as nonunion, was encountered for the ulna fracture. The mean coronal plane angulation in the radiographs taken immediately after the surgery of the patients was four degrees, and the sagittal plane angulations were three degrees. On immediate post-operative radiographs, the mean translation rates in the sagittal and coronal planes were 5% and 6%, respectively. No change was observed in the translation ratios in both planes in the radiographs obtained at the 6-week follow-up. On the 6-week follow-up radiographs, an average of one degree of change in the coronal and two degrees in the sagittal plane was observed (Table 2). Union was observed in all patients 4th and 6th-week control radiographs. One of the patients had skin irritation and superficial infection due to radius ESIN application and was followed up with dressing and antibiotic therapy. No tendon irritation, rupture, or neurovascular damage was observed in any of the patients.

Table 2
Radiographic evaluation data immediately after surgery and 6 weeks after fracture healing postoperatively

Parameters	Result (mean, range)
Immediate post-operative	
Coronal plane translation	6%(range, 0–9)
Sagittal plane translation	5% (range, 0–6)
Coronal plane angulation	4° (range, 0–5)
Sagittal plane angulation	3°(range, 0–4)
Radiological changes in the 6th week after surgery	
Coronal plane translation	0%
Sagittal plane translation	0%
Coronal plane angulation	1° (range, 0°-2°)
Sagittal plane angulation	2° (range, 0°-3°)

The forearm and wrist range of motion data obtained at the last follow-up of the patients are presented in Table 3. In terms of forearm and wrist movements, when compared to the healthy side, no significant difference was observed in terms of flexion, extension, pronation, and supination($p > 0.05$). At the last follow-up, none of the patients had a forearm rotation loss of more than 15 degrees and no limitations in their strenuous activities (Fig. 5). The patients recovered with an excellent score according to the grading system of Price et al.

Table 3
Clinical outcomes at the last follow-up

Range of motion	Injured side, degree Median (min-max)	Uninjured side, degree Median (min-max)	p*
Flexion	84.00 (82–85)	84.00 (83–85)	0.42
Extension	79.00 (78–80)	79.00 (79–80)	0.25
Supination	84.00 (82–85)	84.00 (83–85)	0.55
Pronation	84.00 (82–85)	84.00 (83–85)	0.36
* Wilcoxon's Signed Rank test			

4. Discussion

As a result of our study, 1 and 2 degrees of changes were observed in the coronal and sagittal planes, respectively, in the 6th-week follow-up of the patients due to the application of TEN with the poler K-wire. All patients healed with fracture angulation of less than 10 degrees at the 6th week follow-up. In the 6th week follow-up of the patients, no change was observed in the fracture apposition rates in both the sagittal and coronal planes. As a result of the study of Tarr et al. [18], they observed a 13% loss of forearm rotation in patients who recovered with more than 10 degrees of angulation. In their study, Satto et al. [8] considered angulation more significant than 10 degrees after surgery as a malunion that affects clinical results. In our research, angulation of more than 10 degrees was not observed in any cases in which ESIN was applied with the poler K-wire, and the forearm rotation limitation of the patients improved below 10%.

The fracture healing capacity is low in this region because the fracture location is far from the metaphyseal area with good blood supply, and the plasticity is low [19, 20, 21]. Satisfactory alignment is not achieved due to the displacing effect of the muscles and tendons passing close to the fracture side [22]. Surgical treatment is recommended for fractures in which closed reduction fails due to high complication rates due to reduction losses and malunions [23, 24, 25]. There is no consensus on the surgical treatment of pediatric irreducible DRDMJ fractures. Lieber et al. defined a fracture application that remains too distal for K-wire application and too proximal for ESIN application for fractures in the DRDJM region [9]. Reduction losses were observed in the follow-ups due to insufficient K-wire fixation of fractures due to applications with very high angles to the fracture [8]. Transepiphyseal intramedullary applications have been described previously due to the difficulty of applying ESIN and the inability to obtain proper alignment [4, 9, 26]. In trans epiphyseal applications, there is a risk of injury to the physis plate due to multiple entry attempts [27].

In our practice, ESIN is applied 1.5-2 cm proximal to the physical plate by the classical definition, and poller K-wires are applied close to the fracture line. There are publications on changing the entry point to achieve more successful results in ESIN applications [28, 29]. In our applications, even if the entry point was taken posteromedially, it was observed that sagittal plane deformity developed due to the transition region of the DRDMJ and the narrow medullary cavity. After ESIN application with poller K-wire, alignment was provided in the sagittal plane (Fig. 3). Other techniques described in DRDMJ fractures are the previously bent ESIN and short double ESIN applications [6, 7, 11]. The narrow medullary cavity is also disadvantageous in these techniques regarding iatrogenic fracture. No iatrogenic fracture was observed in the technique we described. Antegrade ESIN applications have been described in DRDMJ fractures [30, 31]. There is a risk of posterior interosseous nerve injury during the application or removal of ESIN in antegrade applications. The poller screw application is widely used to treat metaphyseal fractures during intramedullary nailing [32]. Poller screw applications both provide reduction and increase fixation strength during intramedullary nail application in metaphyseal fractures [33, 34]. After ESIN application with poller K-wire, the intraoperative reduction was improved, and sufficient fixation strength was provided in clinical follow-ups. ESIN application with a poller K-wire is a minimally invasive technique, and no delayed union or neurovascular damage was observed due to the application. OR-IF is recommended for older children because it provides more stable fixation and satisfactory reduction [12].

However, some complications could be seen, such as more extensive skin scars, slower healing, a high rate of refractures, and physical injury [35, 36]. Some publications also show that OR-IF and intramedullary fixation give similar results regarding significant complication rates [37, 38]. No delayed union or nonunion was observed in cases where ESIN was applied with the poller K-wire. None of the patients required additional surgical intervention.

The main limitation of our study is that a small population was evaluated retrospectively. The second limitation of our study is that the incidence of DRDMJ fractures was low, and the treatment modality was not standardized, so a control group could not be established. The third limitation of our study is that DRDMJ fractures accompanied by ulna fractures cannot be evaluated separately due to the low number of cases. The last limitation is the long learning curve for precise and accurate poller K-wire placement.

5. Conclusion

ESIN application with poller K-wire is an effective, safe, minimally invasive method for the surgical treatment of pediatric DRDMJ fractures. Poller K-wire application is effective both in providing reduction during surgery and increasing stability in clinical follow-ups.

Declarations

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Availability of data and materials: The data cannot be shared with the public because individual privacy may be compromised. It can be shared by the corresponding author upon request.

Declarations Ethics approval and consent to participate: The study was approved by the local ethics committee of the University of Ahi Evran University, Kirsehir, Turkey. Written informed consent was obtained from all patients. Analyzes comply with the standards of the Declaration of Helsinki, published in 1975 and revised in 2000.

Consent for publication: All subjects have been informed about the open access publication of this work. A declaration of informed consent to publication was signed by each subject.

Competing interests: None.

Conflict of Interest: None

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Figures

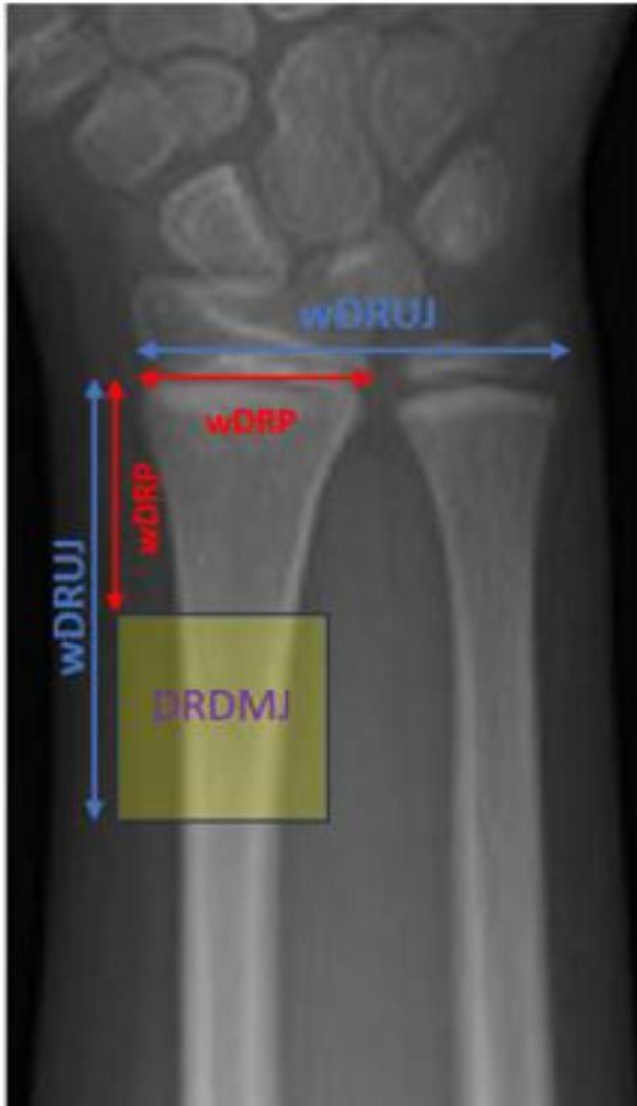

Figure 1

The distal radius diaphyseal metaphyseal junction is shown with a yellow square described by Lieber et al. (9).

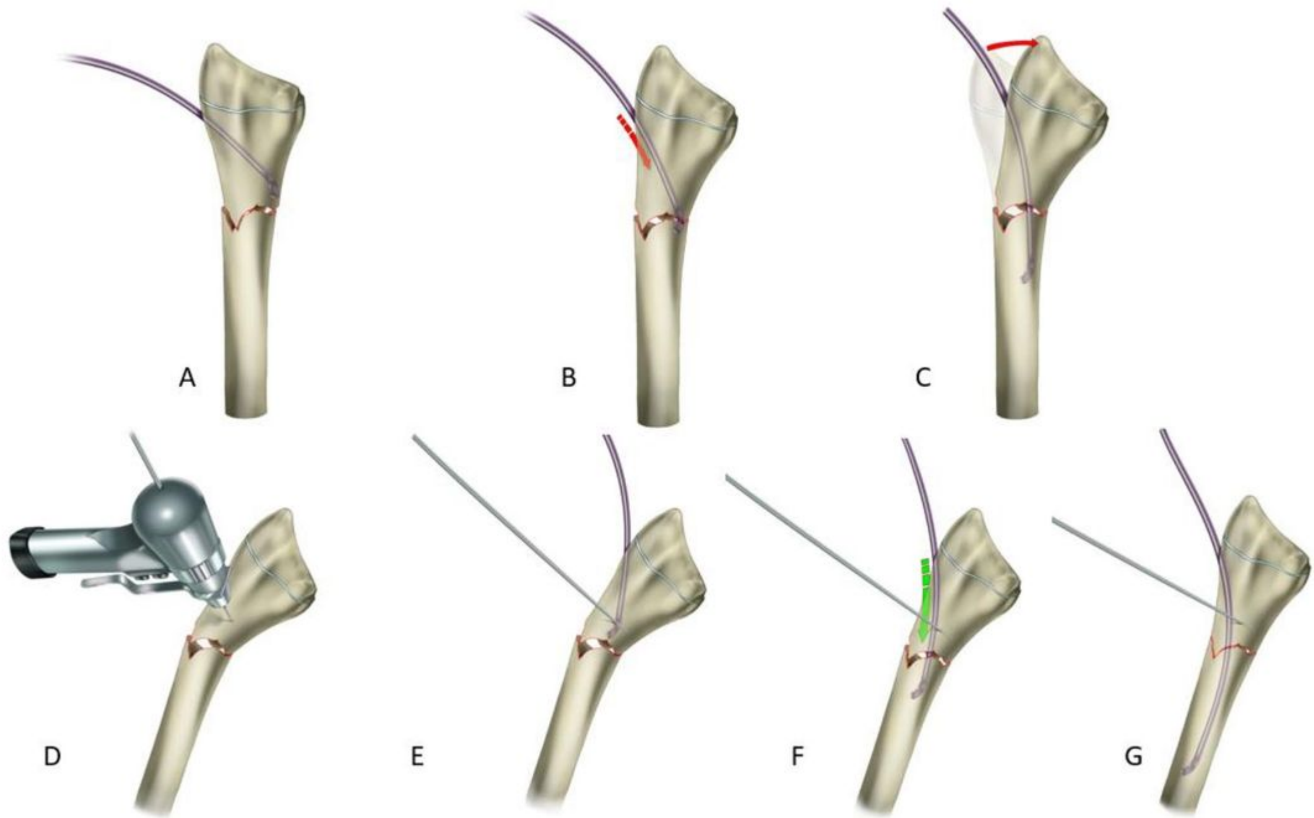

Figure 2

(A, B, C) Loss of reduction due to ESIN application with classical technique in DRDMJ fractures. D: Poller K-wire application to the ulnar side of the distal fragment. E: Application of ESIN to the intramedullary space from the radial side of the poller K-wire, F: Advancing of the ESIN in the proximal fragment in the intramedullary space. G: Obtaining reduction with ESIN applied with Poller K-wire

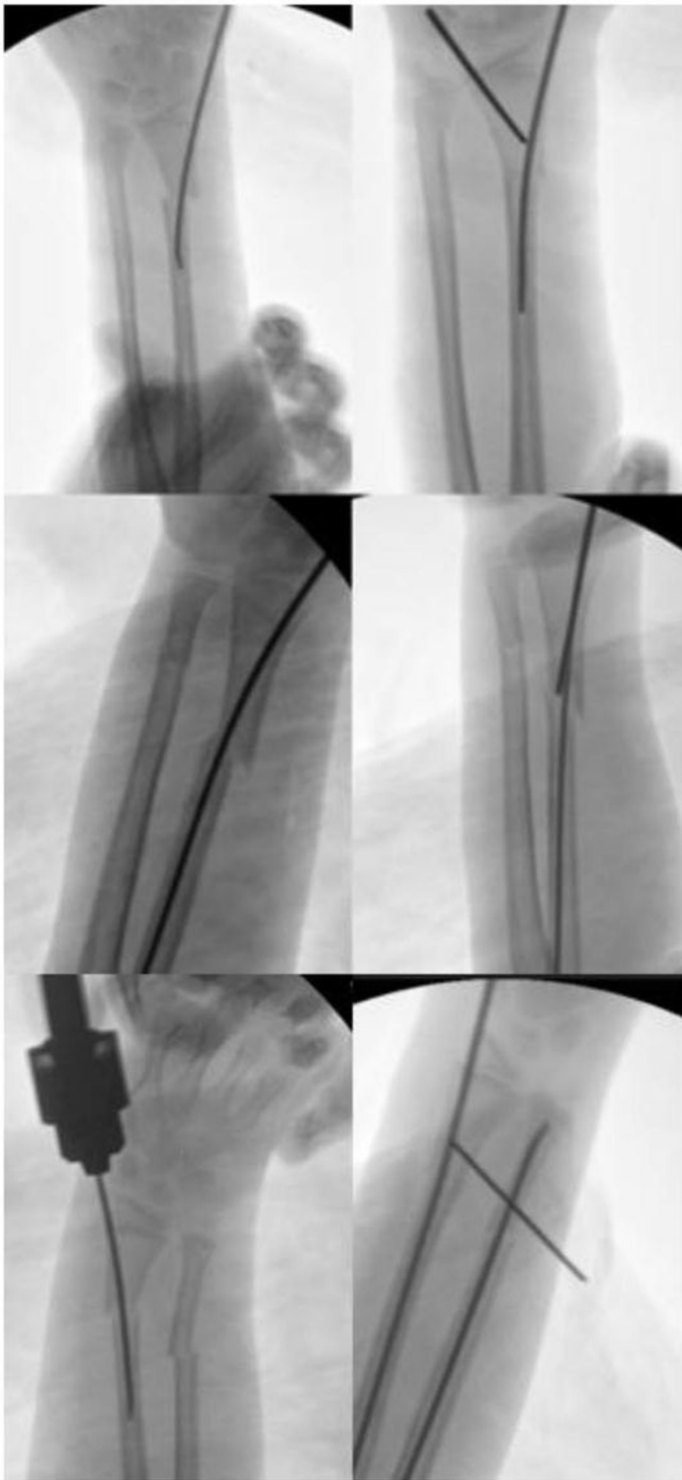

Figure 3

Correction of reduction loss due to ESIN application in the coronal plane with a poller K-wire

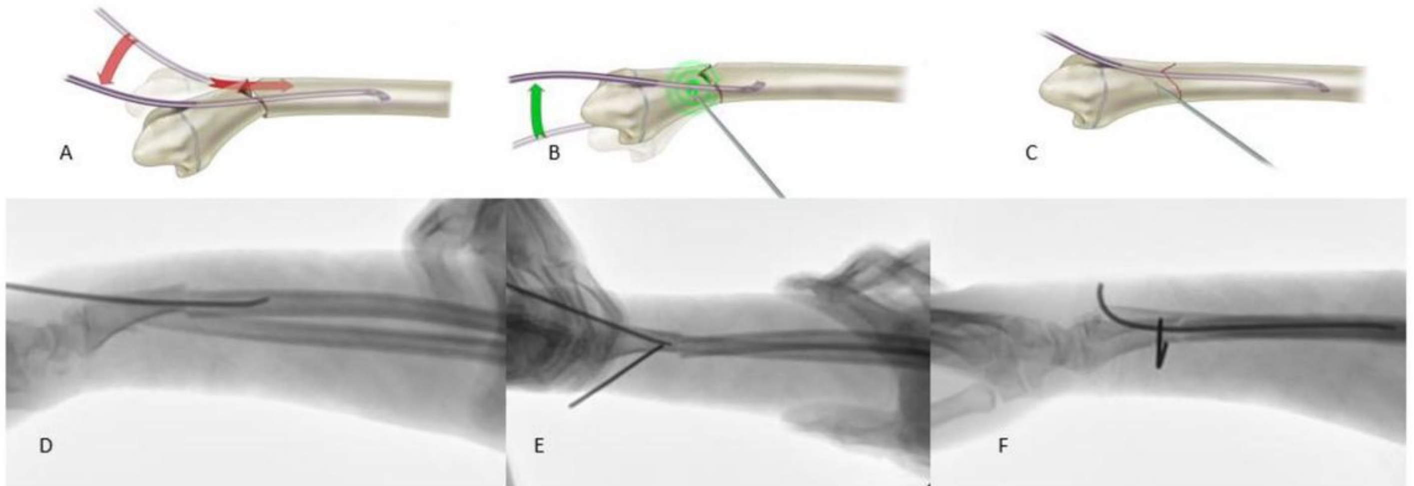

Figure 4

(A, B, C) Illustration of reduction loss due to ESIN application in sagittal plane and correction with poller K-wire. D: Sagittal deformity development due to ESIN application. E: Volar poller K-wire application with ESIN. F: Correction of loss of reduction in the sagittal plane with minimal angulation after Poller K-wire application.

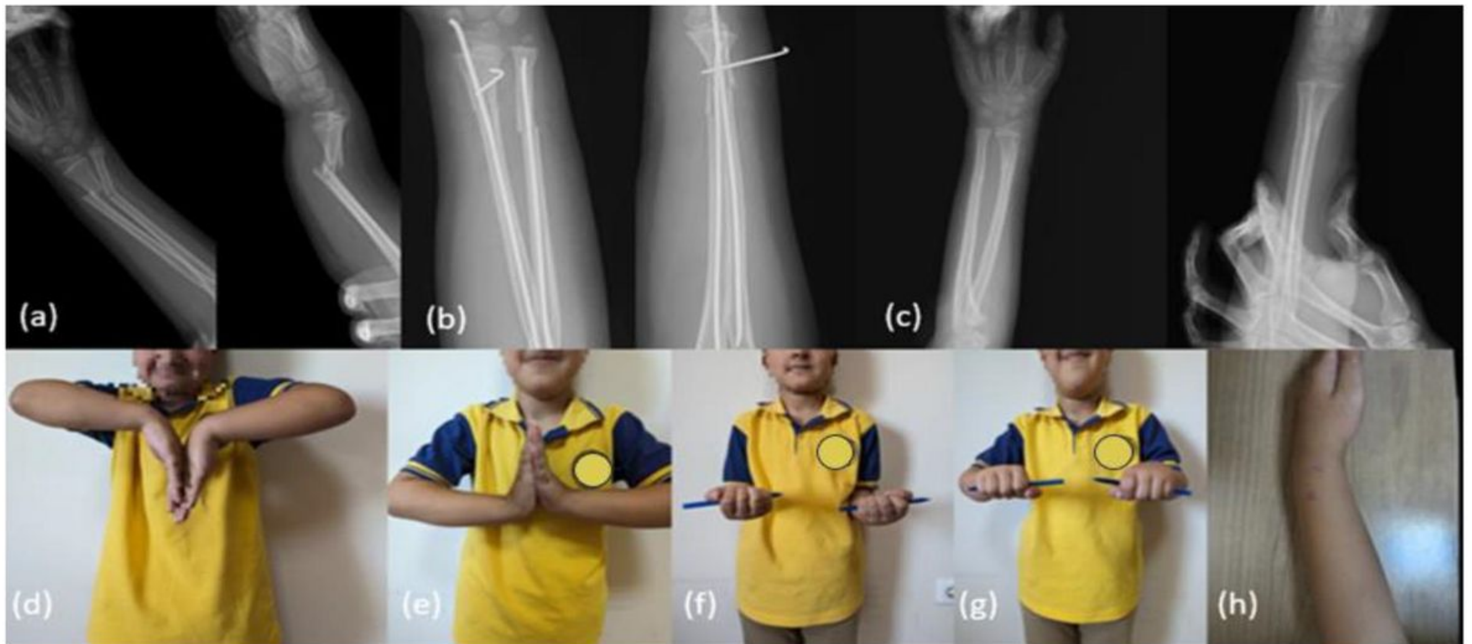

Figure 5

A male patient, 11 years old, with a left DRDMJ fracture accompanied by an ulna fracture. Anterior-posterior and lateral radiographs: (a) preoperative; (b) day one postoperative; (c) 3 months postoperative.

Wrist and forearm range of motion examination at last follow-up: (d) flexion; (e) extension; (f) supination; (g) pronation; (h) scar