

Comparative Analysis of Clinical and Functional Outcomes: Intramedullary Kirschner-wire Versus Elastic Stable Intramedullary Nailing for Pediatric Diaphyseal Forearm Fractures

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Article information

Abstract

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Background: Elastic Stable Intramedullary Nailing (ESIN) using Nancy nails is the preferred treatment for pediatric diaphyseal forearm fractures failing conservative management. However, specialized implants can be costly and unavailable in resource-limited settings, prompting surgeons to use Kirschner-wires (K-wires) as an alternative.

Materials and Methods: A randomized trial was conducted over a one-year period at Misurata Central Hospital and Aljazeera Hospital, involving 32 pediatric patients (aged 5–12 years) with unstable diaphyseal both-bone forearm fractures. Patients were allocated to receive either intramedullary K-wire fixation (\$n=17\$) or elastic Nancy nail fixation (\$n=15\$). Functional and clinical outcomes were evaluated at six months postoperatively using the Price et al. criteria.

Results: Bony union was achieved in 100% of patients in both groups within 12 to 14 weeks. According to the Price et al. criteria, an 'Excellent' or 'Good' functional outcome was achieved by all patients, with 88.2% in the K-wire group and 86.7% in the Nancy nail group scoring 'Excellent'. Surgical duration, immobilization period, and time to implant removal were comparable. Complications were limited to minor, transient superficial skin irritation (11.8% for K-wires vs. 6.7% for Nancy nails) which resolved with conservative care. No deep infections or implant failures occurred.

Conclusion: Intramedullary K-wire fixation yields clinical and functional outcomes fully comparable to specialized elastic Nancy nails. Given their widespread availability and cost-effectiveness, carefully pre-bent K-wires serve as a highly reliable primary surgical treatment option, especially in resource-constrained healthcare settings

I) INTRODUCTION:

Forearm fractures represent a significant portion of pediatric trauma, accounting for approximately 45% of all childhood fractures [1, 2]. The incidence is notably higher in males and peaks between the ages of 6 and 16 years [2, 3]. While most of these fractures can be managed conservatively with closed reduction and immobilization, approximately 5–7% of cases experience loss of reduction or unacceptable malalignment, necessitating surgical intervention [15, 16].

The primary goal of surgical management is to maintain alignment and restore the rotational function of the forearm. Historically, open reduction and internal fixation (ORIF) with plates and screws provided stable anatomical reduction but were associated with larger scars, increased infection risk,

and the need for extensive secondary surgery for implant removal [14]. The introduction of Elastic Stable Intramedullary Nailing (ESIN), specifically the Nancy nail, in the 1980s revolutionized treatment by providing a minimally invasive approach that respects the biology of the growing bone while allowing early mobilization [7]. ESIN has since become the preferred surgical technique for unstable diaphyseal forearm fractures in children due to its biomechanical advantages, minimal soft tissue disruption, and excellent cosmetic results.

However, the widespread adoption of ESIN is often hampered by logistical and economic factors, particularly in developing countries or smaller trauma centers where the consistent supply of specialized elastic nails is not guaranteed. In such circumstances, surgeons frequently resort to using Kirschner-wires (K-wires) as an alternative intramedullary device. K-wires are readily available, inexpensive, and versatile, making them an attractive option. Despite their common use, robust comparative data on the efficacy and safety of K-wires versus ESIN for pediatric diaphyseal forearm fractures remain limited in the literature. This study aims to address this gap by comparing the clinical and functional outcomes of intramedullary K-wire fixation against elastic Nancy nail fixation in pediatric patients with diaphyseal both-bone forearm fractures, thereby evaluating whether K-wire fixation can serve as a reliable and equally effective alternative without compromising patient outcomes.

II) Materials and Methods

Study Design and Patient Population: This retrospective randomized trial was conducted at two major medical institutions, Misurata Central Hospital and Aljazeera Hospital, spanning a one-year period from December 2016 to December 2017. The study cohort comprised 32 pediatric patients who presented with diaphyseal both-bone forearm fractures. Inclusion criteria mandated patients aged between 5 and 12 years, presenting with either closed fractures or Gustilo-Anderson Type 1 or 2 open fractures. Crucially, all included patients had initially failed conservative management, defined as inability to achieve or maintain acceptable reduction with closed methods and casting [6]. Exclusion criteria included Gustilo-Anderson Type 3 open fractures, pathological fractures, and any history of previous fracture in the ipsilateral forearm. Informed consent was meticulously obtained from the parents or legal guardians of all participating children prior to their enrollment in the study.

Surgical Technique: All surgical interventions were performed under general anesthesia by a consistent team of orthopedic surgeons, adhering to a standardized surgical protocol. Patients were positioned supine, and intraoperative fluoroscopic guidance (C-arm) was utilized to ensure precise reduction and implant placement. A pneumatic tourniquet was applied to the affected limb to minimize intraoperative blood loss. Following successful closed manipulation to restore anatomical length, rotation, and angulation, the intramedullary devices were introduced. The standard distal approach to the radius and proximal approach to the ulna, as originally described by Lascombes et al. [7], were strictly followed. For radial fixation, a retrograde nailing technique was employed through the anterolateral aspect of the distal radius, proximal to the radial physis, with meticulous care taken to protect the superficial radial nerve. Ulnar fixation was achieved via an antegrade nailing technique through the lateral surface of the olecranon, approximately 1.5 to 2 cm distal to the physis. Both K-wires and elastic Nancy nails were pre-bent slightly to achieve a stable three-point fixation within the medullary canal. In the K-wire group, the tips of the wires were blunted using a specialized cutter and bent by the surgeon at an angle of 30 degrees to facilitate smooth intramedullary passage and prevent cortical impingement. Open reduction was selectively performed only in cases where closed reduction proved unsuccessful due to irreducible fracture fragments or soft tissue interposition. After implant insertion, the ends of the wires were bent and cut to bone level, ensuring sufficient length for subsequent removal, and were buried subcutaneously. Skin closure was performed, followed by appropriate sterile dressing and the application of an above-elbow back slab.

Post-operative Care and Outcome Assessment: Postoperatively, all patients across both treatment groups underwent stitch removal at two weeks. The above-elbow back slab was maintained for a period of 4 to 6 weeks, after which it was removed, and a structured regimen of mobility exercises for both the wrist and elbow

was initiated. Regular follow-up assessments were scheduled at 2, 4, 12, and 24 weeks post-surgery to monitor fracture healing and functional recovery. All patients subsequently underwent a second surgical procedure for implant removal. Functional outcomes were comprehensively evaluated at six months postoperatively using the well-established criteria developed by Price et al. [6]. This assessment included objective measurements of pronation and supination ranges of motion of the fractured forearm using a conventional goniometer [8], alongside subjective evaluation of pain and functional limitations. The detailed Price et al. criteria are presented in Table 1.

Outcome	Symptoms	Loss of Forearm Rotation (degrees)
Excellent	No complaint with strenuous activity	< 15
Good	Mild complaint with strenuous activity	15 – 30
Fair	Mild complaint with daily activity	31 – 90
Poor	All other results	> 90

Table 1: Price et al. Criteria for Functional Outcome Assessment

III) Results

The study cohort comprised 32 pediatric patients, with a mean age of 8.5 years (range: 5–12 years). The gender distribution revealed 21 males and 11 females, resulting in a male-to-female ratio of 1.9:1. Analysis of fracture laterality indicated that the right forearm was involved in 20 cases (62%), while the left forearm accounted for 12 cases (38%). The anatomical distribution of fracture sites showed that the middle third of the forearm was the most affected region (50%), followed by the distal third (31%) and the proximal third (19%). All patients included in the study had initially failed conservative treatment and were subsequently randomized into two distinct treatment groups: 17 patients received intramedullary K-wire fixation, and 15 patients were treated with elastic Nancy nails.

Clinical Outcomes: Union was achieved in all patients across both treatment groups within a consistent timeframe of 12 to 14 weeks post-surgery, with no instances of non-union or malunion observed. Functional outcomes, assessed using the Price et al. criteria, demonstrated highly favorable results in both groups. In the K-wire group, 15 patients (88.2%) achieved an ‘Excellent’ outcome, and 2 patients (11.8%) achieved a ‘Good’ outcome. Similarly, in the elastic Nancy nail group, 13 patients (86.7%) achieved an ‘Excellent’ outcome, and 2 patients (13.3%) achieved a ‘Good’ outcome. No ‘Fair’ or ‘Poor’ outcomes were recorded in either treatment arm, indicating a high rate of successful functional recovery. Furthermore, most patients in both groups achieved full extension and flexion. Specifically, 15 patients in the K-wire group and 14 patients in the elastic Nancy nail group achieved full extension. Only 2 patients in the K-wire group and 1 patient in the elastic Nancy nail group experienced a loss of less than 10 degrees of extension. All patients in both groups achieved full flexion.

Complications: The incidence of postoperative complications was low and comparable between the two groups. Superficial skin irritation at the implant entry site was observed in 2 cases (11.8%) in the K-wire group and 1 case (6.7%) in the elastic Nancy nail group. All these minor irritations resolved successfully with conservative management, primarily oral antibiotics. Open reduction was required in 3 cases (17.6%) in the K-wire group and 1 case (6.7%) in the elastic Nancy nail group, primarily due to irreducible fracture fragments. Mild limitations in forearm rotation (supination and pronation), specifically a loss of less than 15 degrees, were noted in 2 patients (11.8%) in the K-wire group and 2 patients (13.3%) in the elastic Nancy nail group. No instances of deep infection, neurovascular injury, or implant failure were reported in either group. The average duration of surgery, time of back

slab application, and time to implant removal were also comparable between the two groups, as detailed in Table 2.

Parameter	Elastic Nancy Nail (n=15)	K-wire (n=17)
Average time of surgery (min)	38.53 ($\pm$ 9.0)	44.00 ($\pm$ 9.0)
Average time of back slab (weeks)	4.73 ($\pm$ 0.8)	4.58 ($\pm$ 0.8)
Average time of implant removal (weeks)	16.66 ($\pm$ 0.7)	16.88 ($\pm$ 0.9)

Table 2: Comparative Perioperative Data

IV) Discussion

The management of pediatric diaphyseal both-bone forearm fractures presents a unique challenge, balancing the need for stable fixation with the preservation of growth plate integrity and future functional outcomes. Our study provides compelling evidence that intramedullary K-wire fixation offers clinical and functional outcomes that are comparable to those achieved with elastic stable intramedullary nailing (ESIN) using Nancy nails. This finding is particularly significant for healthcare systems in resource-limited settings where the availability of specialized ESIN implants may be inconsistent.

Outcome Parameter	K-wire Fixation	Elastic Nancy Nail Fixation
Price et al. criteria: Excellent	15	13
Price et al. criteria: Good	2	2
Extension: Full extension	15	14
Extension: Lost <10 degrees	2	1
Flexion: Full flexion	17	15
Union: Achieved	17	15
Complications: Superficial irritation	2	1

Table 3: Clinical and Functional Outcomes

Our results, demonstrating high rates of excellent and good functional outcomes (based on Price et al. criteria) and consistent union times (12–14 weeks) across both K-wire and ESIN groups, are consistent with existing literature [9, 11]. Several studies have highlighted the effectiveness of intramedullary fixation techniques in pediatric forearm fractures, emphasizing their advantages over traditional plate fixation, such as minimal soft tissue dissection, reduced risk of refracture, and improved cosmetic results [14]. The low complication rates observed in our cohort further corroborate the safety profile of both intramedullary methods, aligning with previous reports [12, 13, 14].

The biomechanical principles underlying the success of intramedullary fixation, whether with ESIN or K-wires, involve achieving a three-point fixation within the medullary canal, which provides axial and rotational stability while allowing for controlled micromotion conducive to bone healing. While ESIN nails are specifically designed with a pre-contoured shape and specific elasticity to optimize this three-point fixation, our study suggests that careful surgical technique, including appropriate pre-bending and blunting of K-wires, can effectively replicate these biomechanical advantages. This adaptability of K-wires makes them a valuable tool, especially when ESIN is not available.

One of the most critical implications of our findings pertains to the cost-effectiveness and accessibility of treatment. K-wires are significantly less expensive and more widely available than specialized ESIN implants. In regions facing economic constraints or supply chain challenges, the ability to achieve equivalent outcomes with K-wires means that timely and effective surgical care for pediatric forearm fractures can be provided without compromising quality. This can prevent delays in treatment, reduce the need for patient transfers to higher-level facilities, and ultimately improve public health outcomes for pediatric orthopedic patients.

Limitations of this study include its retrospective design and relatively small sample size. While randomization was performed, the inherent biases of retrospective studies cannot be eliminated. Future prospective, multi-center studies with larger cohorts would further strengthen these findings and provide more definitive evidence regarding the long-term outcomes and potential subtle differences between these two fixation methods. Nevertheless, our study provides valuable insights into the utility of K-wires as a viable alternative in the surgical management of pediatric diaphyseal both-bone forearm fractures.

V) Conclusions:

Intramedullary fixation is a highly effective and safe surgical strategy for the treatment of diaphyseal both-bone forearm fractures in children. This comparative study unequivocally demonstrates that intramedullary K-wire fixation yields clinical and functional outcomes that are comparable to those achieved with elastic Nancy nails. Both methods exhibit similar rates of complications, achieve robust union within a consistent timeframe, and restore excellent ranges of elbow and wrist movement, including supination and pronation. Given the widespread availability and lower cost of K-wires, we advocate for their use as a reliable and primary treatment option, particularly in healthcare settings where specialized elastic nails may not be consistently accessible. This approach ensures that pediatric patients receive timely and high-quality surgical intervention, preventing unnecessary delays and optimizing their recovery.

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