

Original Article

ULNAR SHAFT FRACTURE FIXATION BY ANTEGRADE VERSUS
RETROGRADE INTRAMEDULLARY K WIRES IN CHILDREN:
A COMPARATIVE STUDY

Yasser Othman Sorour, Mahmoud Redwan^(*), El Shazly S. Mosa, & Moustafa Elsayed

Orthopedic Surgery dept., Sohag Faculty of Medicine, Sohag, Egypt

E-mail: mahmoud_ahmed_post@med.sohag.edu.eg

Received 8/6/2025

Accepted 17/9/2025

Abstract

Background: Diaphyseal ulnar fractures in children can be managed with either antegrade or retrograde intramedullary K-wire fixation, but their relative effects on recovery, healing time, and complications are still uncertain. **Aim:** To compare functional and radiological outcomes of antegrade versus retrograde intramedullary K-wire fixation in pediatric diaphyseal ulnar fractures. **Methods:** This prospective study of 60 children with diaphyseal ulnar fractures compared antegrade (n=24) and retrograde (n=36) intramedullary K-wire fixation. Preoperative clinical and radiological evaluations were performed, and outcomes—including union time, hardware removal, joint function, pain, and complications—were assessed until fracture union. Data were analyzed using appropriate parametric and non-parametric tests, with significance set at $p < 0.05$. **Results:** Baseline demographics and fracture characteristics were comparable between groups. The antegrade group demonstrated significantly faster union (6.08 ± 1.79 vs. 7.17 ± 1.16 weeks, $p = 0.006$) and earlier hardware removal (4.83 ± 0.96 vs. 7.44 ± 1.38 weeks, $p < 0.001$). Functional outcomes favored antegrade fixation, with superior supination, pronation, wrist motion, and ulnar deviation/extension (all $p < 0.01$), and no wrist pain reported. Elbow stiffness was significantly less frequent in the antegrade group ($p < 0.001$). No cases of hardware migration, refracture, or pin tract infection occurred in either group. **Conclusion:** Antegrade intramedullary K-wire fixation offers superior functional outcomes, faster healing, earlier hardware removal, and lower pain and stiffness rates compared to retrograde fixation, without increasing complications. It is particularly recommended for mid-shaft and proximal ulnar fractures in pediatric patients.

Keywords: Pediatric ulnar fracture, Antegrade fixation, Retrograde fixation, Intramedullary K-wire, Functional outcome.

1. Introduction

Both-bone forearm Fractures are common injuries in children which account for 45% of all fractures in childhood, Approximately, 75 to 84% of forearm fractures occur in the distal one third, 15 to 18% occur in the middle one third and 1 to 7% occurs in the proximal one third of the forearm [1]. Unlike forearm bone fractures in adults, which are Generally treated by open reduction and osteosynthesis using plates and screw fixation, 90% of pediatric forearm fractures are successfully treated con-

servatively by closed reduction and casting. The remaining 10% are inadequately reduced or unstable after reduction of which treatment methods include closed manipulation and casting under general anesthesia, fixation with pins and plaster, closed or open reduction with a mini-incision and intramedullary nailing, open reduction and osteosynthesis with plate and screw fixation, and external fixators [1]. Fracture fixation with intramedullary nails has gained popularity due to several advantages

such as maintenance of reduction, minimally invasive, relatively easy application, protection of bone alignment and retention of biologic factors at the fracture site [2]. Titanium elastic nails are increasingly used for intramedullary nailing because of their elastic properties which allow for improved insertion and rotation while still providing adequate fracture stabilization [2]. However, titanium elastic nails are expensive for most of the patients of low socioeconomic status of developing countries on contrary to that stainless steel Rush pins are cheaper and easily available. In Fixation of the pediatric ulna fracture by antegrade intramedullary k wire the entry point will be from the Olecranon and make the wire progress through the medulla of the Ulna crossing the reduced fracture site to the distal end of the ulna, while in the retrograde group the entry point is from the distal ulna with the Wrist flexed, progress in the opposite direction of the anatomical position from distal to proximal across the fracture site to the proximal end of the ulna [2]. The purpose of the present study is to compare the functional and Radiological outcomes after treating ulnar shaft diaphyseal fractures in pediatric population by intramedullary antegrade versus retrograde Kirshner wires.

2. Patients and Methods

This was a prospective case series study conducted between July 2023 to July 2024 at the Department of Orthopaedics and Traumatology, Sohag University Hospital.

2.1. Sample size calculation

The sample size was calculated using a two-tailed hypothesis test to detect a clinically significant difference in functional outcomes between the antegrade and retrograde fixation groups. Assuming a power of 80% and a 95% confidence level ($\alpha = 0.05$), the minimum required sample per group was determined based on prior studies reporting differences in forearm rotational recovery of approximately 25–30% between techniques. Anticipating a possible 10% dropout rate, the target sample size was adjusted to 24 patients in the antegrade group and 36 in the retrograde group, totaling 60 participants.

2.2. Participants

2.2.1. Inclusion criteria

Pediatric patient aging from 4 to 15 years old with diaphyseal ulnar fracture either isolated or combined with radius fracture (both bone).

2.2.2. Exclusion criteria

Segmental fractures, Monteggia variants, Geliazzi fracture, fractures associated with radial head fracture, compound fractures and those with neurovascular affection are excluded in the study.

Preoperative Assessment

Patients with isolated limb trauma were clinically evaluated to exclude any neurovascular injury, followed by plain X-rays in anteroposterior and lateral views. In cases of polytrauma, a general assessment was performed using the ATLS protocol. All patients underwent routine laboratory investigations along with a surgical fitness evaluation to ensure readiness for the procedure.

2.3. Surgical technique

Under general anesthesia, patients were positioned supine on the operating table. A tourniquet was applied to the affected limb, and complete aseptic precautions were maintained throughout the preparation. In one group of patients, the antegrade ulnar wire was introduced through an apophyseal starting point located at the top of the olecranon, as illustrated in fig. (1).



Figure (1) Olecranon entry in the antegrade group.

2.4. Retrograde k wire in the ulna

The wire pin is inserted into the distal end of the ulna while the wrist is flexed, fig. (1).



Figure (2) Retrograde k wire in the ulna

In the two methods the wire goes in the medullary canal and cross the fracture site up to slightly before the other end.

2.5. Post-operative evaluation

Immediate Application of above elbow slab for 3 weeks postoperative, evaluate the patient Clinically by; pain, time of motion and forearm rotation, time of fracture union, Radiological, X-ray A/P and lateral evaluate fracture healing.

2.6. Follow-up schedule

The patients were followed to the bone union determined by the formation of callus and consolidation in radiology. The reduction quality was assessed using the final intraoperative or initial postoperative radiograph. Serial radiographs were made 2, 4, 6, and 12 weeks after surgery were evaluated, figs. (3 & 4).

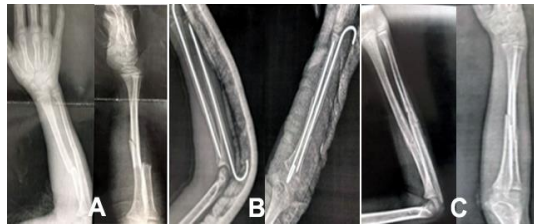


Figure (3) Xray of Rt forearm of 9 ys male patient AP and Lat. views **a.** preoperative showing fracture both bone forearm, **b.** immediate postoperative after fixation by intramedullary antegrade K-wire in Ulna, **c.** 2 months postoperative after removal of K-wires.

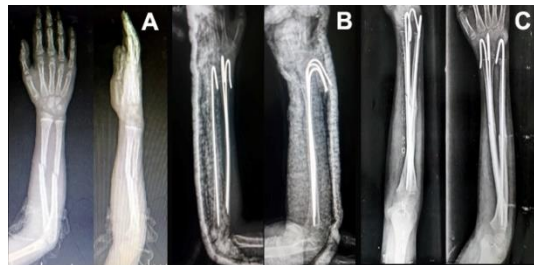


Figure (4) Xray of Rt forearm of 7 ys female patient AP and Lat. views **a.** preoperative showing fracture both bone forearm, **b.** immediate postoperative after fixation by intramedullary retrograde K-wire in ulna, **c.** 2 months postoperative showing complete union of fracture.

2.7. Statistical analysis

Statistical analysis involved assessing the normality of numerical data distribution using the Shapiro–Wilk test. Normally distributed numerical data were presented as mean $\pm$ standard deviation (SD), while categorical variables were summarized as frequencies and percentages. For analytical comparisons, the student's t-test was used to compare means between two independent groups with normally distributed variables, and the Chi-square (χ^2) test was applied to evaluate associations between cat-

egorical variables. A p-value of less than 0.05 was considered statistically significant at a 95% confidence level.

2.8. Ethical considerations

The study was submitted for approval to The Ethical Committee of Sohag faculty of medicine. An informed written consent was obtained from all participants' guardians.

3. Results

This study involved 60 pediatric patients with diaphyseal ulnar fractures, divided into two groups: 24 treated with antegrade K-wire insertion via the olecranon and 36 treated with retrograde insertion through the distal ulna, fig. (5). All patients underwent prospective clinical and radiological follow-up, with data collected on demographics, fracture details, trauma mechanism, displacement, surgery timing, postoperative complications, union time, and functional outcomes. Statistical analysis was performed to compare results between the two groups and identify significant differences.

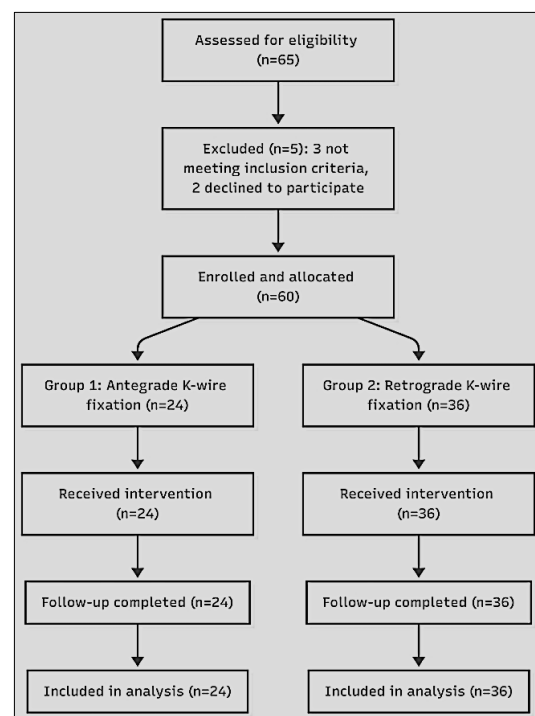


Figure (5) Consort chart of current study.

According to the demographic data, the mean age was 6.75 ± 2.17 years in the ante grade group and 6.69 ± 2.42 years in the retrograde group ($p=0.928$). The proportion of males was 83.3% in the ante grade group and 75.0% in the retrograde group, while female's comprised 16.7% and 25.0%, respectively ($p=0.654$), tab. (1). Here's a slightly condensed version that still keeps most of the numbers for context:

Fracture characteristics were largely comparable between groups, with both bone fractures in 37.5% of antegrade and 47.2% of retrograde cases, and isolated ulna fractures in 62.5% and 52.8% ($p=0.632$). Left-sided injuries were more common in the antegrade group (83.3% vs. 58.3%), while right-sided fractures were higher in the retrograde group (41.7% vs. 16.7%) ($p=0.079$). Distal shaft fractures occurred in 33.3% of antegrade and 19.4% of retrograde cases, mid-shaft fractures were equal at 41.7%, and proximal fractures were 25.0% and 38.9% ($p=0.378$). Trauma mechanisms differed significantly ($p=0.039$): motor vehicle accidents were more frequent in the antegrade group (33.3% vs. 8.3%), while direct trauma (30.6% vs. 12.5%) and falls on an outstretched hand (36.1% vs. 20.8%) were more common in the retrograde group. Skin condition differences were not significant ($p=0.103$), and no neurovascular injuries occurred in either group ($p=1.000$), tab. (2). Incomplete displacement was found in 54.2% of the antegrade group and 55.6% of the retrograde group, while complete displacement occurred in 45.8% and 44.4%, respectively, with no significant difference ($p=1.000$). The mean time to surgery was 1.12 ± 1.83 days for the antegrade group and 1.00 ± 1.17 days for the retrograde group, also showing no statistically significant difference ($p=0.747$). The antegrade group achieved fracture union significantly faster, averaging 6.08 ± 1.79 weeks, compared to 7.17 ± 1.16 weeks

in the retrograde group ($p=0.006$). Hardware removal also occurred much earlier in the antegrade group at 4.83 ± 0.96 weeks, versus 7.44 ± 1.38 weeks in the retrograde group, a highly significant difference ($p<0.001$), tab. (3). Functional results showed clear advantages for the antegrade group. Supination and pronation were significantly better, with higher rates of normal or full motion compared to the retrograde group, which had more cases of limitation ($p=0.002$ for supination, $p<0.001$ for pronation). Ulnar deviation and wrist extension were normal in all antegrade patients but in only 8.3% of retrograde cases ($p<0.001$). Wrist motion was also superior in the antegrade group, where no patient had limitation, while 91.7% of retrograde patients showed restricted movement ($p<0.001$), tab. (4). Wrist pain was significantly lower in the antegrade group, with all patient's pain-free, compared to only 8.3% in the retrograde group, where most reported ulnar deviation pain or mild pain at the ulnar styloid ($p<0.001$). Elbow pain also differed markedly ($p<0.001$), with 37.5% pain-free in the antegrade group versus 5.4% in the retrograde group. No hardware migration, refracture, or pin tract infection occurred in either group. Elbow stiffness was far less frequent in the antegrade group, where two-thirds had full movement, while the retrograde group had only 8.3% with full movement and the rest showing varying degrees of stiffness, tab. (5).

Table (1) Demographic data in studied groups.

Parameter	Category	Antegrade (n=24)	Retrograde (n=36)	p-value
Age (years)	▪ <i>Mean $\pm$ SD</i>	6.75 ± 2.17	6.69 ± 2.42	0.928
Sex	▪ <i>Female</i>	4 (16.7%)	9 (25.0%)	0.654
	▪ <i>Male</i>	20 (83.3%)	27 (75.0%)	

Table (2) Fracture Description and trauma details in studied groups.

Parameter	Category	Antegrade (n=24)	Retrograde (n=36)	p-value
Fracture Type	▪ <i>Both bone</i>	9 (37.5%)	17 (47.2%)	0.632
	▪ <i>Ulna</i>	15 (62.5%)	19 (52.8%)	
Side	▪ <i>Left</i>	20 (83.3%)	21 (58.3%)	0.079
	▪ <i>Right</i>	4 (16.7%)	15 (41.7%)	
Site	▪ <i>Distal shaft</i>	8 (33.3%)	7 (19.4%)	0.378
	▪ <i>Mid shaft</i>	10 (41.7%)	15 (41.7%)	
	▪ <i>Proximal</i>	6 (25.0%)	14 (38.9%)	
Mode of Trauma	▪ <i>Fall from height</i>	8 (33.3%)	9 (25.0%)	0.039
	▪ <i>Fall on outstretched hand</i>	5 (20.8%)	13 (36.1%)	
	▪ <i>Motor vehicle accident</i>	8 (33.3%)	3 (8.3%)	
	▪ <i>Direct trauma</i>	3 (12.5%)	11 (30.6%)	
Skin Conditions	▪ <i>Swelling, deformity</i>	4 (16.7%)	6 (16.7%)	0.103
	▪ <i>Local swelling, deformity</i>	20 (83.3%)	24 (66.7%)	
	▪ <i>Deformity, pain, swelling</i>	0 (0.0%)	6 (16.7%)	
Neurovascular Injury	▪ <i>Free</i>	24 (100.0%)	36 (100.0%)	1.000

Table (3) Operative and postoperative outcomes.

Parameter	Category	Antegrade (n=24)	Retrograde (n=36)	p-value
Displacement Status	▪ <i>Incomplete displacement</i>	13 (54.2%)	20 (55.6%)	1.000
	▪ <i>Displaced</i>	11 (45.8%)	16 (44.4%)	
Time to Surgery (days)	▪ <i>Mean ± SD</i>	1.12 ± 1.83	1.00 ± 1.17	0.747
Union Time (weeks)	▪ <i>Mean ± SD</i>	6.08 ± 1.79	7.17 ± 1.16	0.006
Hardware Removal (weeks)	▪ <i>Mean ± SD</i>	4.83 ± 0.96	7.44 ± 1.38	0.001

Table (4) Functional Outcomes in studied groups.

Parameter	Category	Antegrade (n=24)	Retrograde (n=36)	p-value
Supination	▪ <i>Normal</i>	4 (16.7%)	0 (0.0%)	0.002
	▪ <i>Full</i>	20 (83.3%)	24 (66.7%)	
	▪ <i>Mild limitation</i>	0 (0.0%)	9 (25.0%)	
	▪ <i>Supination only</i>	0 (0.0%)	3 (8.3%)	
Pronation	▪ <i>Normal</i>	12 (50.0%)	0 (0.0%)	<0.001
	▪ <i>Full</i>	12 (50.0%)	3 (8.3%)	
	▪ <i>Limited</i>	0 (0.0%)	24 (66.7%)	
	▪ <i>Incomplete</i>	0 (0.0%)	3 (8.3%)	
	▪ <i>Mild limitation</i>	0 (0.0%)	6 (16.7%)	
Ulnar Deviation/Extension	▪ <i>Normal</i>	24 (100.0%)	3 (8.3%)	<0.001
	▪ <i>Limited extension & deviation</i>	0 (0.0%)	30 (83.3%)	
	▪ <i>Limited ulnar deviation</i>	0 (0.0%)	3 (8.3%)	
Wrist Motion	▪ <i>Good</i>	14 (58.3%)	3 (8.3%)	<0.001
	▪ <i>Normal</i>	10 (41.7%)	0 (0.0%)	
	▪ <i>Limited</i>	0 (0.0%)	33 (91.7%)	

Table (5) Pain and Postoperative Complications in studied groups.

Parameter	Category	Antegrade (n=24)	Retrograde (n=36)	p-value
Wrist pain	▪ <i>No</i>	24 (100.0%)	3 (8.3%)	<0.001
	▪ <i>Pain with ulnar deviation</i>	0 (0.0%)	18 (50.0%)	
	▪ <i>Mild pain at ulnar styloid</i>	0 (0.0%)	12 (33.3%)	
	▪ <i>Pain with deviation/extension</i>	0 (0.0%)	3 (8.3%)	
Elbow pain	▪ <i>No</i>	9 (37.5.0%)	34 (94.6%)	<0.001
	▪ <i>Post operative pain with flexion and extension</i>	15 (62.5.%)	2 (5.4%)	
Hardware Migration	▪ <i>No</i>	24 (100.0%)	36 (100.0%)	1.000
Refracture	▪ <i>No</i>	24 (100.0%)	36 (100.0%)	1.000
Pin Tract Infection	▪ <i>No</i>	24 (100.0%)	36 (100.0%)	1.000
Elbow Stiffness	▪ <i>Slight extension limitation</i>	8 (33.3%)	0 (0.0%)	<0.001
	▪ <i>Full active movement</i>	16 (66.7%)	3 (8.3%)	
	▪ <i>Stiff elbow (no extension, limited flexion)</i>	0 (0.0%)	6 (16.7%)	
	▪ <i>Stiff elbow (no extension)</i>	0 (0.0%)	6 (16.7%)	
	▪ <i>Mild stiffness</i>	0 (0.0%)	3 (8.3%)	
	▪ <i>Limited extension</i>	0 (0.0%)	9 (25.0%)	
	▪ <i>Limited extension and flexion</i>	0 (0.0%)	3 (8.3%)	
	▪ <i>No stiffness</i>	0 (0.0%)	6 (16.7%)	

4. Discussion

Forearm rotation outcomes favored the antegrade group, with 16.7% achieving normal supination and 83.3% full recovery, compared to no normal cases and 66.7% full recovery

in the retrograde group. Mild or isolated supination deficits were more common in the retrograde group, and the difference was statistically significant ($p=0.002$), indicating better

preservation of supinator function with the antegrade approach. This observation is supported by Poutoglidou et al [3], and Mahecha-Toro et al. [4], who emphasized that supination can be particularly affected by distal fixation approaches if tendon or interosseous membrane irritation occurs. Pronation outcomes were markedly better in the antegrade group, with all patients achieving either normal or full motion, compared to none with normal motion and only 8.3% with full motion in the retrograde group. Most retrograde patients had varying degrees of limitation, a highly significant difference ($p<0.001$) that underscores the clinical advantage of antegrade fixation in preserving functional rotation for daily activities. Wu et al. [5] similarly demonstrated that elastic stable intramedullary nailing (ESIN), which mimics the antegrade method, resulted in better supination-pronation arcs compared to K-wire fixation across the distal radius. The consistent functional benefits of the antegrade approach, alongside faster union and earlier hardware removal, strongly support its use for mid-shaft and proximal ulnar fractures. In contrast, the retrograde method, though technically simpler for distal shaft fractures, is linked to greater stiffness and poorer rotational outcomes, aligning with previous research findings Yigit [6] and De Vitis et al. [7]. These limitations may be attributable to the approach's interference with the distal radio ulnar joint and surrounding soft tissue structures. Ulnar deviation and extension outcomes were markedly better in the antegrade group, with all patients retaining normal function, compared to only 8.3% in the retrograde group. Most retrograde cases showed combined or isolated limitations ($p<0.001$), indicating superior preservation of distal ulnar biomechanics and wrist kinematics with the antegrade approach. This result is consistent with observations from Giordano et al. [8], who utilized MRI to investigate physeal and periarticular effects of transphyseal fixation and found that fixation closer to the distal physis may compromise soft tissue and joint mobility, particularly ulnar deviation. Wrist motion was markedly better in the antegrade group, where all patients had either good or normal range with no limitations, compared to the retrograde group, in which 91.7% experienced restricted motion and none achieved normal range ($p<0.001$). These results closely reflect prior data from Wu et al. [5], who found that intramedullary fixation strategies that disrupt the distal radioulnar region may

impede wrist recovery, particularly pronation-supination arcs and deviation mechanics. Wrist pain outcomes strongly favored the antegrade group, with all patient's pain-free, compared to only 8.3% in the retrograde group. Most retrograde patients reported pain, commonly with ulnar deviation or at the ulnar styloid ($p<0.001$), suggesting greater distal ulnar irritation from retrograde pin insertion. This finding corroborates the observations by Baydar et al. [9], who noted that hardware proximity to joint surfaces often causes irritation or pain postoperatively, especially when intramedullary pins traverse near articular zones. The complete absence of wrist pain and motion restriction in the antegrade group strongly suggests that entering through the olecranon provides biomechanical advantages by avoiding the wrist and distal radio ulnar joint entirely. This was also supported by Bulut et al. [10], who advocated for proximal entry sites to reduce the risk of distal joint dysfunction. Moreover, the consistent reports of pain and motion loss in the retrograde cohort align with cautionary insights from R  ther et al. [11], who emphasized careful entry point selection in pediatric forearm fracture fixation to minimize functional complications. Trauma patterns differed significantly between groups ($p=0.039$). Antegrade cases were most often caused by falls from height or motor vehicle accidents (33.3% each), whereas retrograde cases were more frequently linked to falls on an outstretched hand (36.1%) and direct trauma (30.6%), with MVAs being rare (8.3%). These findings align with reports by Varga [12], who identified falls from a height and high-energy mechanisms like MVAs as predominant causes of pediatric upper limb fractures, particularly in mid- to proximal shaft injuries often managed with antegrade fixation. Meanwhile, Dietzel et al. [13] reported a higher proportion of distal forearm injuries resulting from low-energy trauma, such as falls on an outstretched hand, correlating with the retrograde group's injury pattern. Union was significantly faster in the antegrade group, averaging 6.08 weeks compared to 7.17 weeks in the retrograde group ($p=0.006$), indicating about a one-week healing advantage likely related to improved stability and alignment from the olecranon entry point. These findings align with studies such as Dong et al. [14], who demonstrated faster healing and recovery times in antegrade fixation approaches for pediatric forearm fractures. Similarly, Tawfiq et al. [15] and R  ther et al. [11] reported mean union times

between 6 and 8 weeks depending on fixation technique and fracture location, placing the current results well within expected clinical ranges. Hardware removal occurred significantly earlier in the antegrade group, averaging 4.83 weeks versus 7.44 weeks in the retrograde group ($p < 0.001$), a 2.6-week advantage that reflects faster healing, fewer hardware-related issues, and quicker return to normal activities. These findings are in concordance with Giordano et al. [8], who noted that earlier implant removal in well-aligned fractures improves patient comfort and reduces infection risk. Early removal is particularly beneficial in pediatric patients due to rapid healing and the need to minimize foreign body retention near growth plates. Elbow stiffness was significantly less common in the antegrade group, where two-thirds achieved full motion and the remainder had only slight extension limitation. In contrast, most retrograde patients experienced varying degrees of stiffness, with very few regaining unrestricted movements ($p < 0.001$). This stark contrast indicates a clear functional advantage for the antegrade technique regarding postoperative elbow mobility. Similar trends were reported by Yigit [6] and Bulut et al. [10], where antegrade fixation was associated with better functional outcomes and reduced joint stiffness, especially when early rehabilitation protocols were employed. The absence of major complications such as hardware migration or refracture in both groups also mirrors findings by Baydar et al. [9] and Abdulsamad et al. [16], who found that secure intramedullary fixation in pediatric patients results in high union rates and very low hardware-related complications. Moreover, the complete absence of pin tract infections in both groups (0/60 patients) is noteworthy, given that Cureus-based reviews such as Patel et al. [17] have reported pin site infections ranging from 2 – 10% in pediatric series using percutaneous K-wires, suggesting excellent procedural hygiene and follow-up protocols in the present study.

5. Conclusion

This prospective comparison of antegrade and retrograde K-wire fixation in pediatric diaphyseal ulnar fractures found the antegrade approach to deliver superior outcomes. Although baseline characteristics were similar, antegrade fixation resulted in faster union, earlier hardware removal, markedly better wrist motion and ulnar deviation, less elbow stiffness, and no wrist pain, without increasing complications or procedural complexity. These results support its use for enhanced functional recovery in this population.

References

- [1] Ameen, A., Abdulrahman, K., Megahed, R., et al. (2019). Percutaneous fixation of fractures of forearm bones in children. *Zagazig Univ. Medical J*; 25 (6): 919-927.
- [2] Kang, N., Tan, W., Phua, Y., et al. (2021). Intramedullary nail: the past, present and the future—a review exploring where the future may lead us. *Orthopedic Reviews*; 13: 25546.
- [3] Cruz, A., Kleiner, J., DeFroda, S., et al. (2017). Increasing rates of surgical treatment for paediatric diaphyseal forearm fractures: A National Database Study from 2000 to 2012. *J Child Orthop*; 11: 201-209.
- [4] Mahecha-Toro, M., Vergara-Amador, E. & Ramírez, M. (2018). Forearm diaphyseal fractures in children: Intramedullary Kirschner's wire fixation treatment. *Revista Española de Cirugía Ortopédica y Traumatología (English Ed.)*; 62 (1): 71-79.
- [5] Wu, R., Wen, Y., Wang, C., et al. (2023). Elastic stable intramedullary nailing versus Kirschner wire in the treatment of pediatric metaphyseal–diaphyseal junction fractures of the distal radius: A case-control study. *BMC Musculoskeletal Disorders*; 24 (1), doi: 10.1186/s12891-023-07055-9.
- [6] Yigit, S. (2020). Fixation of forearm fractures with intramedullary k-wire or elastic nail by fluoroscopy in children and radiation exposure. *Ann Med Res*; 27 (9): 2330-2334.
- [7] De Vitis, R., D'Orio, M., Passiatore, M., et al. (2022). Elastic stable intramedullary fixation using epibloc versus crossed Kirschner wires fixation for distal forearm fractures in children: A retrospective analysis. *African J. of Paediatric Surgery*; 19 (3): 153-159.
- [8] Giordano, M., Florio, M., Careri, S., (2025). Is transphyseal intramedullary fixation of the distal radius in pediatric fractures a safe procedure? An MRI study. *Frontiers in Surgery*; 12: 1520712.
- [9] Baydar, M., Aydın, A., Şencan, A., et al. (2021). Comparison of clinical and radiological results of fixation methods with retrograde intramedullary Kirschner wire and plate-screw in extra-articular metacarpal fractures. *Joint Diseases & Related Surgery*; 32 (2): 397-405.
- [10] Bulut, T., Eroglu, O., Husemoglu, B., (2024). Comparison of antegrade and retrograde cross pin fixation in the surgical

- treatment of pediatric supracondylar femur fractures: A biomechanical Study. *Injury*; 55 (2): 111284.
- [11] R  ther, H., Spering, C., Fortini, L., et al. (2025). Treatment of diametaphyseal forearm fractures in children and adolescents: Antegrade intramedullary nail osteosynthesis and its alternatives. *Oper Orthop Traumatol*; 37 (2):159-170.
- [12] Varga, M. (2019). New diagnostic and therapeutic possibilities in the treatment of elbow and distal forearm fractures in childhood, PhD., University of Szegedi Tudom  nyegyetem (Hungary).
- [13] Dietzel, M., Scherer, S., Spogis, J., et al. (2024). Treatment of unstable forearm fractures at the metaphyseal-diaphyseal junction in children: Antegrade ESIN vs. transepiphyseal intramedullary K-wire fixation. *Euro. J. of Trauma & Emergency Surgery*; 50 (6):2681-2687.
- [14] Dong, Z., Guo, W., Kong, Z., et al. (2025). Antegrade ESIN technique via the Kocher interval reduces radiation exposure and accelerates recovery in pediatric DRDMJ fractures: A comparative study with cadaveric validation. *Injury*; 56(6), doi: 10.1016/j.injury.2025.112348.
- [15] Tawfiq, F., Al Mutairi, K., & Al Ageely, A. (2022). A comparison study between plate fixation versus intramedullary nailing in treatment of unstable diaphyseal fractures of both bones of the forearm in children. *JMSP*; 8 (4): 120-128
- [16] Abdulsamad, A., Al Mugren, T., Alzahrani, M., et al. (2023). Outcomes of the treatment of humeral shaft fractures by closed reduction and internal fixation with multiple intramedullary Kirschner wires (K-wires). *Cureus*; 15 (12), doi: 10.7759/cureus.51009.
- [17] Patel, V., Deshpande, S., Goel, S., et al. (2024). Intramedullary Kirschner wire fixation for metatarsal fractures: A comprehensive review of treatment outcomes. *Cureus*; 16 (4), doi: 10.7759/cureus.59368.