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Minimally invasive intramedullary K-wire fixation for Gartland Type III supracondylar fractures: A safer approach with less radiation exposure

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Abstract
Background: Supracondylar humeral fractures are the most common pediatric elbow injuries, with Gartland Type III fractures being the most severe and often requiring surgical fixation. While crossed pinning offers superior stability, it carries a risk of ulnar nerve injury, prompting increased use of lateral-entry techniques. Recently, minimally invasive intramedullary K-wire fixation has emerged as a promising method that ensures stable fixation with reduced soft tissue trauma and radiation exposure.
Aim of the study: This study evaluates the functional outcomes, complication rates, and radiation exposure associated with minimally invasive intramedullary K-wire fixation in pediatric patients with Gartland Type III supracondylar fractures.
Methods: This retrospective observational study was conducted at the Department of Orthopaedic Surgery (Hand and Microsurgery), National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh and included 60 children (ages 4-12) with Gartland Type III supracondylar humerus fractures. The study duration was 12 months from January to December 2021. Patients underwent minimally invasive percutaneous intramedullary K-wire fixation under general anesthesia. Radiation exposure, operative time, and intraoperative fluoroscopy details were recorded. Postoperative care included splinting, early mobilization, and follow-up at 2, 6, and 12 weeks. Clinical outcomes were assessed using VAS, elbow ROM, Flynn's criteria, and radiographs. Data were analyzed using SPSS v26.0. Primary outcomes included radiation exposure and functional results; secondary outcomes included pain, union time, complications, and hospital stay.
Results: Out of 60 children with Gartland Type III supracondylar humeral fractures, the mean age was 7.1 years, with 73.3% males and 63.3% left-sided injuries. Falls were the predominant cause (88.3%). The average operative time was 45.2 minutes, with a low mean fluoroscopy time of 13.9 seconds. No intraoperative complications occurred. Radiographic union was achieved in 5.1 weeks, with only 3.3% developing superficial infections. At 6 weeks, 93.3% showed excellent to good outcomes according to Flynn's criteria, and all patients regained full range of motion within 3 months. Functional recovery and complication rates were highly favorable.
Conclusion: Minimally invasive intramedullary K-wire fixation is a safe, effective, and low-radiation technique for treating Gartland Type III supracondylar fractures in children. It ensures stable fixation, minimal complications, and rapid recovery, making it ideal for resource-limited settings like Bangladesh.

Keywords: Supracondylar humeral fracture, Gartland Type III, pediatric elbow fracture, minimally invasive surgery, Intramedullary K-wire fixation

Introduction
Supracondylar fractures of the humerus are the most common type of elbow fractures in children, accounting for nearly 60% of all elbow injuries in the pediatric population [1]. Among these, the extension-type Gartland Type III fractures characterized by complete displacement and loss of cortical contact are the most severe and require urgent surgical management due to the risk of neurovascular compromise and long-term functional impairment [2, 3]. The traditional gold standard for managing displaced Type III supracondylar fractures is closed reduction followed by percutaneous K-wire fixation [4]. The two commonly used techniques for fixation include crossed medial-lateral pinning and lateral-entry pinning.

While crossed pinning offers superior biomechanical stability, it poses a risk to the ulnar nerve, particularly during medial wire insertion [5]. To mitigate this, lateral-entry-only techniques have gained popularity due to their lower risk of iatrogenic nerve injury, although concerns remain regarding their comparative mechanical strength [6]. In recent years, minimally invasive approaches to fracture fixation have been explored to minimize soft tissue disruption further, reduce infection risk, and enhance recovery outcomes [7]. Among these, intramedullary fixation using percutaneous K-wires inserted through a lateral or dual-entry approach without extensive dissection has shown promise. This technique provides stable internal fixation while preserving the periosteal blood supply and minimizing scar formation [8]. Another important concern in the pediatric orthopedic setting is radiation exposure. The frequent use of fluoroscopy during fracture reduction and pin placement contributes significantly to intraoperative radiation, which may pose potential risks to patients and surgical staff [9]. Studies have emphasized reducing fluoroscopy time through better surgical planning, improved techniques, and intraoperative navigation aids [10]. In this context, the minimally invasive intramedullary K-wire approach offers a less traumatic fixation option and may reduce fluoroscopic dependence through simplified wire trajectory and shorter operative duration [11]. Although several studies have evaluated the safety and efficacy of different fixation methods, limited data exist on the outcomes of minimally invasive intramedullary K-wire fixation specifically in South Asian or Bangladeshi populations. Factors such as delayed hospital presentation, limited access to operative facilities, and lack of pediatric-specific implants may influence outcomes in this setting [12]. Therefore, there is a need to explore locally adaptable, safe, and efficient techniques for managing Gartland Type III supracondylar fractures. This study evaluates the functional outcomes, complication rates, and radiation exposure associated with minimally invasive intramedullary K-wire fixation in pediatric patients with Gartland Type III supracondylar fractures.

Fig 1: 3 month follow up at elbow flexion (frontal view)

Fig 2: 3 month follow up at elbow flexion (alt view)

Fig 3: 3-month post op follow up elbow extension

Fig 4: Intramedullary k wire in supracondylar fracture let view

Fig 5: Intramedullary k wire in supracondylar fracture A/P view

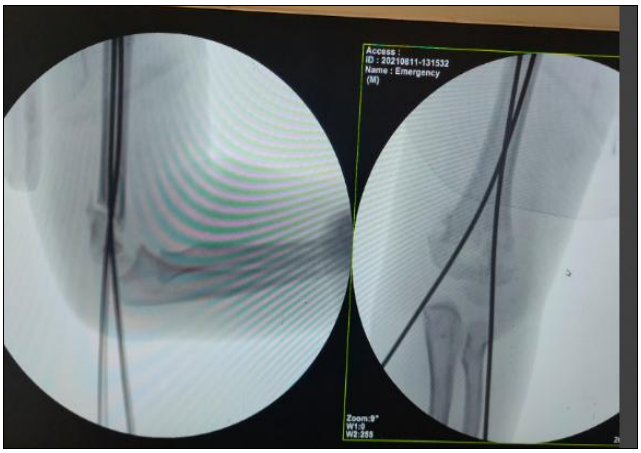

Fig 6: Intramedullary k wire in supracondylar fracture let view

Methodology and Materials

This retrospective observational study was conducted at the Department of Orthopaedic Surgery (Hand and Microsurgery), National Institute of Traumatology & Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh from January to December 2021. The study included 60 pediatric patients diagnosed with Gartland Type III supracondylar humerus fractures. Patients were selected consecutively based on eligibility criteria from those attending the emergency or outpatient departments.

Inclusion Criteria

- Patients aged between 4 and 12 years.
- Radiologically confirmed extension-type Gartland Type III supracondylar humerus fracture.
- Presented within 24 hours of injury.
- No prior surgical treatment for the current fracture.
- Written informed consent was obtained from parents or guardians.

Exclusion Criteria

- Open fractures or associated neurovascular injuries requiring vascular repair.
- Pathological fractures or polytrauma.
- Previous fractures or deformities in the same limb.
- Patients lost to follow-up before the 6-week evaluation.

Surgical Technique

All surgeries were performed under general anesthesia using a minimally invasive percutaneous intramedullary K-wire fixation technique. After closed reduction under fluoroscopic guidance, 1.6-2.0 mm K-wires were introduced through a lateral or combined lateral-medial entry point without making a large incision. Fluoroscopy was used to confirm alignment, wire placement, and stability. Reduction quality, wire position, and stability were evaluated intraoperatively. The number of fluoroscopy shots and total fluoroscopy time (in seconds) were recorded to assess radiation exposure. Sterile dressing was applied, and an above-elbow posterior splint was used postoperatively for 2-3 weeks.

Postoperative care and follow-up

Patients were monitored for immediate postoperative complications and discharged within 2-3 days. Follow-up evaluations were conducted at 2 weeks, 6 weeks, and 3 months. Clinical outcomes were assessed using:

- Visual Analog Scale (VAS) for pain
- Range of Motion (ROM) of the elbow joint
- Flynn's Criteria for functional assessment
- Presence of any complications such as infection, re-displacement, or pin-tract issues.
- Radiographs were obtained at each follow-up to monitor fracture healing and alignment.

Outcome Measures

- **Primary Outcomes:** Radiation exposure (fluoroscopy time, number of shots), time to union, and Flynn's functional grading at 6 weeks.
- **Secondary Outcomes:** Operative time, hospital stay, complication rate, and postoperative pain score.

Data Collection and Analysis

All data were recorded using a structured data collection sheet. Descriptive statistics were used to summarise patient demographics and clinical variables. Quantitative variables were presented as mean±standard deviation, while categorical data were expressed as frequency and percentage. Data analysis was performed using SPSS version 26.0.

Results

In this study involving 60 pediatric patients with Gartland Type III supracondylar humeral fractures, the mean age was 7.1±2.4 years, with a male predominance (73.3%) and a higher incidence of left-sided fractures (63.3%), which aligns with the typical demographic and fracture distribution in the pediatric population of Bangladesh (Table 1). Most injuries occurred from falls (88.3%), and all patients were right-hand dominant. Preoperative neurovascular deficit was noted in 3 cases (5%), all of which improved postoperatively. The mean operative time was 45.2±9.6 minutes, lateral wire entry was used in 63.3% of cases, while lateral and medial entries were used in 36.7% (Table 2). The average number of K-wires used was 2, and 1.6-2.0 mm wires were selected based on bone size. Fluoroscopy time averaged 13.9±2.7 seconds with 5.6±1.4 shots per procedure, indicating low radiation exposure relative to standard techniques. Notably, there were no intraoperative complications. Postoperative outcomes were excellent, with a mean hospital stay of 2.1±0.6 days and a low mean pain score on Day 1 (VAS: 3.2±1.0). Radiographic

union was achieved at a mean of 5.1±0.9 weeks (Table 3). Only two patients (3.3%) developed superficial pin-tract infections that resolved with conservative treatment. No cases of re-displacement or malunion were observed. Functional recovery was impressive: 75% of patients had "excellent" outcomes, 18.3% had "good," and only 6.7% had "fair" outcomes, with no "poor" results based on Flynn's criteria at 6 weeks (Table 4). At the 3-month follow-up, all patients had regained full range of motion, with progressive improvements observed at each follow-up visit (36.7% at 2 weeks, 90% at 6 weeks, and 100% at 3 months), and the mean VAS score had decreased to 0 by the final evaluation.

Table 1: Demographic and clinical characteristics of patients (N=60)

Variable	Frequency (n)	Percentage (%)
	Mean ±SD	
Mean Age (years)	7.1±2.4	
Sex		
Male	44	73.33
Female	16	26.67
Affected Side		
Left	38	63.33
Right	22	36.67
Mechanism of Injury		
Fall	53	88.33
RTA	5	8.33
Others	2	3.33
Time from Injury to Surgery (hours)	18.7±5.9	
Pre-op Neurovascular Deficit	3	5.00

Table 2: Operative and Radiation Parameters

Variable	Frequency (n)	Percentage (%)
	Mean ±SD	
Mean Duration of Surgery (min)	45.2±9.6	
Number of K-wires Used		
2 in	46	76.67
3 in	14	23.33
K-wire Size		
1.6 mm	34	56.67
2.0 mm	26	43.33
Image Intensifier Use	60	100.00
Mean Fluoroscopy Time (sec)	13.9±2.7	
Fluoro Shots	5.6±1.4	
Wire Entry Approach		
Lateral	38	63.33
Both	22	36.67

Table 3: Postoperative outcomes of the study patients

Variable	Mean ±SD
Mean Hospital Stay (days)	2.1±0.6
Pain Score (VAS on Day 1)	3.2±1.0
Mean Time to Union (weeks)	5.1±0.9
Infection or Pin-tract Complications (Superficial, managed conservatively)	2(3.3%)
Re-displacement or Malunion	None

Table 4: Functional Outcome at 6 Weeks (Flynn's Criteria)

Outcome	Frequency (n)	Percentage (%)
Excellent	45	75.00
Good	11	18.33
Fair	4	6.67
Poor	0	0.00

Discussion

The findings of this study demonstrate that minimally invasive intramedullary K-wire fixation for Gartland Type III supracondylar humeral fractures in children is a safe and effective technique, offering excellent functional outcomes with minimal complications and low radiation exposure. The demographic pattern observed, predominantly male patients (73.3%) with a mean age of 7.1 years, correlates well with previous reports, identifying school-aged boys as the most affected group due to their higher activity levels and propensity for falls [1, 2]. The left arm was involved in 63.3% of cases, consistent with the understanding that children often extend their non-dominant arm to break a fall [8]. Falls from height (88.3%) were the leading cause of injury, aligning with patterns seen in similar socio-economic settings where children frequently play in unprotected environments [13]. One of the key highlights of this study was the reduced mean fluoroscopy time of 13.9±2.7 seconds and an average of 5.6 shots per procedure. This is significantly lower than conventional percutaneous pinning techniques, where reported fluoroscopy times often exceed 20-30 seconds [9]. Excessive radiation exposure in pediatric orthopedics remains a concern due to the increased radiosensitivity of growing tissues and cumulative exposure risks for surgical teams [14]. The current findings support the notion that a simplified, intramedullary approach with minimal wire manipulation reduces reliance on intraoperative imaging, thus making the procedure safer regarding radiation. The surgical technique used in this study focused on closed reduction and percutaneous insertion of 1.6-2.0 mm K-wires through a lateral or lateral-medial entry approach. In 63.3% of cases, lateral-only pinning helped avoid ulnar nerve injury, a known

complication in crossed-wire techniques [5]. None of the patients developed iatrogenic nerve injuries, and all three patients with preoperative neurovascular deficits showed full recovery, underscoring the safety and adequacy of closed reduction without extensive soft-tissue dissection. The mean operative time of 45.2 minutes and a hospital stay of just over 2 days reflect the minimally invasive nature of the procedure and its suitability for high-volume centers with limited resources. These metrics are comparable or favorable to traditional percutaneous pinning techniques, especially in resource-constrained environments like Bangladesh, where surgical backlogs and operative delays are common [15]. Only two patients (3.3%) developed superficial pin-tract infections, which were managed conservatively with local care and oral antibiotics. This is in line with previously reported infection rates for percutaneous pinning, which range between 2-6% [11]. No cases of deep infection, malunion, or hardware-related complications were encountered, supporting the technique's mechanical stability and biological safety. Flynn's criteria at 6 weeks revealed that 93.3% of patients had excellent or good outcomes, comparable to larger series evaluating traditional cross-pinning and lateral-entry pinning methods [16]. At 3 months, all patients regained full range of motion, suggesting that the intramedullary trajectory of the wires did not impede joint function or remodeling a key consideration in pediatric fracture care, where functional outcomes must be optimized without compromising growth or motion.

Limitations of the study

This study had several limitations. The study lacked a comparative control group, such as patients treated with traditional cross-pinning or lateral-entry techniques, preventing direct comparisons of outcomes. Additionally, the follow-up period was limited to three months, which was insufficient to assess long-term complications such as growth disturbances or late-onset deformities.

Conclusion and Recommendations

Minimally invasive intramedullary K-wire fixation for Gartland Type III supracondylar humeral fractures in children is a safe, effective, and resource-friendly technique. This approach significantly reduces operative time and radiation exposure while providing stable fixation, minimal complications, and excellent functional outcomes. Rapid recovery, low infection rates, and early return of elbow mobility make it particularly suitable for resource-limited settings like Bangladesh. Although long-term follow-up is warranted, this method shows great promise as a reliable alternative to traditional fixation techniques for managing complex pediatric elbow fractures in developing healthcare systems.

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Conflict of interest: None declared.

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