e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(8); 899-906

Original Research Article

Clinical, Radiographic and Functional Outcomes of Percutaneous Criss-Cross Kirschner Wire Fixation for Displaced Supracondylar Humerus Fractures in Children: A Prospective Cohort Study

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Received: 01-05-2026 / Revised: 15-06-2026 / Accepted: 21-07-2026

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Conflict of interest: Nil

Abstract

Background: Displaced supracondylar fractures of the humerus are common paediatric elbow injuries in which accurate reduction and stable fixation are essential to restore alignment and motion while limiting neurovascular and angular complications. Crossed Kirschner-wire fixation offers strong mechanical stability, although safe placement of the medial pin is important because of the proximity of the ulnar nerve.

Methods: Our study prospectively followed 20 children aged 2-12 years with closed displaced supracondylar humerus fractures treated at the orthopaedic units attached to J.J.M. Medical College, Davangere, from September 2020 to September 2022. Closed reduction was attempted when satisfactory alignment could be achieved; open reduction was used when closed reduction was inadequate or the fracture was multidirectionally unstable. All fractures were stabilized with criss-cross Kirschner wires. Clinical and radiographic follow-up was performed at 1, 3 and 6 months. Range of motion, carrying angle, change in Baumann angle and postoperative complications were analysed.

Results: The mean age was 7.4 ± 2.5 years; 85% were boys and 70% involved the left elbow. Gartland type II and III fractures each accounted for 45%, while 10% were documented as type IV. Closed reduction was achieved in 9 children (45%) and 11 (55%) required open reduction. At final assessment, 50% had an elbow arc of 0-135°, 20% reached 0-140°, 25% reached 0-125° and 5% reached 0-130°. Mean carrying angle was 10.50 ± 0.61°. A change in Baumann angle of no more than 5° was recorded in 85%. Sixteen children (80%) had no postoperative complication; pin-tract infection and pin migration each occurred in two children (10%). Final range-of-motion distribution did not differ significantly by Gartland type ($p = 0.746$) or by closed versus open reduction ($p = 0.489$).

Conclusion: Criss-cross Kirschner-wire fixation provided stable alignment and useful elbow motion in most children in our study. Early presentation favoured successful closed reduction, whereas delayed or multidirectionally unstable fractures more often required open reduction. Complications were limited to minor pin-related events in this small cohort.

Keywords: Supracondylar Humerus Fracture; Paediatric Elbow; Kirschner Wire; Crossed Pinning; Closed Reduction; Open Reduction.

DOI: 10.25258/ijcpr.18.8.138

Introduction

Supracondylar fractures are the most frequent fractures around the elbow in children and account for a substantial proportion of paediatric upper-limb injuries. They typically occur after a fall on the outstretched hand, with the peak incidence in early school-age children. Boys and the non-dominant limb are affected more often in many clinical series. [1,2,10,12] The clinical importance of these injuries extends beyond fracture union. The distal humerus has limited capacity to remodel coronal malalignment, and an inadequately reduced fracture may later present with cubitus varus or valgus. Displaced injuries can also be associated with acute nerve or vascular compromise, compartment syndrome and loss of elbow motion. The Gartland classification remains the common framework for describing extension-type fractures; multidirectional instability has subsequently been recognized as type IV. [3,9]

Closed reduction followed by percutaneous pinning is widely used for displaced fractures because it provides stability while avoiding the morbidity of a formal exposure. Open reduction is reserved for fractures in which acceptable alignment cannot be achieved or maintained by closed methods, as well as selected unstable or complicated patterns. The central technical goal is anatomical restoration of the distal humerus with fixation that is sufficiently stable to preserve the reduction until healing. [1,4,23]

The ideal pin configuration remains debated. Lateral-entry pins reduce the possibility of iatrogenic ulnar nerve injury, whereas crossed medial and lateral pins generally provide greater torsional rigidity. A mini-open medial technique, direct protection of the ulnar nerve, careful pin trajectory and bicortical purchase can reduce the neurological risk associated with a medial pin. [5,6,7,8,22,24]

Our study evaluated children with displaced supracondylar humerus fractures treated with percutaneous criss-cross Kirschner-wire fixation. The emphasis was on restoration of alignment, final elbow movement, carrying angle, radiographic maintenance of reduction and postoperative complications, with additional comparison of outcomes according to fracture type and whether reduction was achieved by a closed or open method.

Aims and Objectives: The primary aim was to assess the clinical, radiographic and functional outcome of criss-cross Kirschner-wire fixation for displaced supracondylar humerus fractures in children.

The objectives were to restore distal humeral anatomy with stable crossed-pin fixation; evaluate postoperative elbow motion, carrying angle, maintenance of radiographic alignment and complications; compare observed outcomes between fracture types and between closed and open reduction; and place the findings in the context of previously published experience.

Materials and Methods

Study Design and Setting: Our study was a prospective cohort study conducted in the Department of Orthopaedics at Bapuji Hospital and C.G. Hospital attached to J.J.M. Medical College, Davangere. Recruitment and follow-up extended from September 2020 to September 2022. Institutional ethics clearance was obtained before enrolment, and written informed consent was obtained from the parent or legal guardian before data collection and treatment.

Participants: Children aged 2-12 years with closed displaced supracondylar fractures requiring operative stabilization were considered for inclusion. The protocol identified Gartland type II and III fractures at enrolment; two fractures were subsequently documented in the clinical records as multidirectionally unstable type IV injuries. Gartland type I fractures, open fractures, children with nerve or vascular injury at presentation, and patients outside the specified paediatric age range were not included. Participants were recruited by purposive sampling until the target sample was reached.

Sample Size: The target sample was based on the expected number of eligible cases during the recruitment period and was estimated using Yamane's equation for a finite population:

$$n = N / [1 + N(e^2)]$$

Using the anticipated eligible population and a 5% margin of error produced a minimum sample close to 17 patients. The final target was increased to 20, and all 20 enrolled children were included in the analysis.

Preoperative Assessment: A structured clinical assessment recorded age, sex, side of injury, history of fall or trauma, swelling, deformity and distal neurovascular status. Standard anteroposterior and lateral elbow radiographs were used to classify the fracture and plan treatment. Particular attention was paid to distal perfusion and neurological examination before manipulation.

Closed Reduction and Criss-cross Pinning: Closed reduction was attempted under anaesthesia and fluoroscopic guidance. Longitudinal traction restored length, followed by correction of translation, coronal angulation and rotation. In extension-type fractures, the sagittal deformity was corrected by controlled elbow flexion after alignment of the distal fragment. Reduction was accepted only when satisfactory alignment was demonstrated on orthogonal fluoroscopic views.

Fixation was performed with 1.2-2.0 mm Kirschner wires. A lateral pin was inserted first and its position confirmed under the image intensifier. Before medial pin insertion, a small medial incision was made to permit safe placement and reduce the risk to the ulnar nerve. The medial and lateral pins were directed across the fracture to obtain opposite-cortex purchase and columnar spread. Stability, elbow movement and carrying angle were checked after fixation. The wires were bent and cut, and the limb was immobilized in a well-padded above-elbow posterior slab at approximately 90° of flexion.[6,8]

Open Reduction: Open reduction was used when a satisfactory anatomical reduction could not be obtained by closed manipulation or when the fracture was considered markedly unstable. A posterior Campbell approach with triceps splitting was described in the operative protocol. The ulnar nerve was identified and protected, the fracture site was exposed, interposed tissue and haematoma were cleared as required, and the medial and lateral columns were restored. Crossed Kirschner wires were then placed using the same fixation principles as for the closed technique.

Postoperative care and follow-up: Postoperative neurovascular status was reassessed after recovery from anaesthesia. Check radiographs were obtained to confirm reduction and pin position. Percutaneous pins were generally removed at approximately 3-4 weeks once early healing was adequate, after which elbow mobilization was encouraged. Scheduled clinical and radiographic assessments were performed at 1, 3 and 6 months.

Outcome Assessment: Outcomes included final elbow range of motion, carrying angle, change in Baumann angle, maintenance of alignment and postoperative complications. Complications of interest included pin-tract infection, pin migration, nerve injury and angular deformity. Range of motion and carrying angle were examined clinically, while Baumann angle and fracture alignment were assessed on follow-up radiographs.

Statistical Analysis: Data were compiled in Microsoft Excel and analysed with SPSS version 26.0. Categorical variables are presented as frequency and percentage and quantitative variables as mean ± standard deviation. The chi-square test was used for categorical comparisons were reported. A two-sided p value below 0.05 was considered statistically significant.

Results

Demographic and fracture characteristics: All 20 enrolled children completed the reported assessment. Mean age was 7.4 ± 2.5 years. Four children (20%) were aged 5 years or younger, 14 (70%) were 6-10 years old and two (10%) were 11-12 years old. Seventeen children (85%) were boys. The left elbow was involved in 14 cases (70%). Gartland type II and III fractures each accounted for nine cases, while two fractures were recorded as type IV. Closed reduction was achieved in nine children (45%); 11 (55%) underwent open reduction (Table 1).

Table 1: Demographic and fracture characteristics of the study cohort (n = 20)

Characteristic	Finding
Age group	≤5 years: 4 (20%); 6-10 years: 14 (70%); 11-12 years: 2 (10%)
Age, mean ± SD	7.4 ± 2.5 years
Sex	Male: 17 (85%); Female: 3 (15%)
Side affected	Left: 14 (70%); Right: 6 (30%)
Gartland type	Type II: 9 (45%); Type III: 9 (45%); Type IV: 2 (10%)
Reduction method	Closed: 9 (45%); Open: 11 (55%)

Clinical and radiographic outcomes: By the final follow-up, 10 children (50%) had an elbow range of 0-135°, five (25%) had 0-125°, four (20%) had 0-140° and one (5%) had 0-130°. The mean carrying angle was 10.50 ± 0.61°. Seventeen children (85%) had a change in Baumann angle of no more than 5°, while three (15%) had a change greater than 5° (Table 2). No cubitus varus deformity was reported in the available follow-up.

Table 2: Final clinical, radiographic and complication profile

Outcome	Category	n (%) / value
Final range of motion	0-125°	5 (25%)
	0-130°	1 (5%)
	0-135°	10 (50%)
	0-140°	4 (20%)
Carrying angle	Mean ± SD	10.50 ± 0.61°
Change in Baumann angle	≤5°	17 (85%)
	>5°	3 (15%)
Postoperative complications	None	16 (80%)
	Pin-tract infection	2 (10%)
	Pin migration	2 (10%)

Range of motion according to fracture type: Final elbow movement was broadly similar across fracture categories. Among type II fractures, three children each had arcs of 0-125° and 0-135°, two reached 0-140° and one reached 0-130°. Among type III fractures, five of nine reached 0-135°, while two each had 0-125° and 0-140°. Both type IV fractures reached 0-135°. The distribution was not significantly different across fracture types (p = 0.746) (Table 3).

Table 3. Final range of motion according to Gartland fracture type

Fracture type	0-125°	0-130°	0-135°	0-140°
Type II (n=9)	3 (33.3%)	1 (11.1%)	3 (33.3%)	2 (22.2%)
Type III (n=9)	2 (22.2%)	0	5 (55.6%)	2 (22.2%)
Type IV (n=2)	0	0	2 (100%)	0

Overall comparison of range-of-motion distribution: p = 0.746.

Closed Versus Open Reduction: The mean carrying angle was comparable descriptively after closed and open reduction (10.44 ± 0.73° and 10.55 ± 0.52°, respectively).

In the closed-reduction group, four of nine children reached 0-135°, whereas six of 11 in the open-reduction group reached the same arc. The distribution of final movement did not differ significantly between reduction methods (p = 0.489).

One child after closed reduction and three after open reduction developed a pin-related complication (Table 4). Because reduction method was selected according to reducibility and fracture behaviour rather than randomized allocation, these percentages should not be interpreted as a direct treatment-effect comparison.

Table 4: Outcomes according to reduction method

Outcome	Closed reduction (n=9)	Open reduction (n=11)	p value
Carrying angle, mean ± SD	10.44 ± 0.73°	10.55 ± 0.52°	—
ROM 0-125°	3 (33.3%)	2 (18.2%)	
ROM 0-130°	1 (11.1%)	0	
ROM 0-135°	4 (44.4%)	6 (54.5%)	0.489*
ROM 0-140°	1 (11.1%)	3 (27.3%)	
Any postoperative complication	1 (11.1%)	3 (27.3%)	Not reported
No postoperative complication	8 (88.9%)	8 (72.7%)	Not reported

***p value refers to the overall distribution of final range of motion between reduction groups.**

Complications

Sixteen children (80%) had an uncomplicated postoperative course.

Two pin-tract infections and two episodes of pin migration were recorded, giving an overall minor pin-related complication rate of 20%. No postoperative nerve palsy, deep infection, septic arthritis or clinically reported cubitus varus was documented in the results available for our study.

Representative Clinical and Radiological Outcomes

Figures 1 and 2 present the representative clinical and radiological findings from our study. Figure 1 shows key intraoperative clinical images of the criss-cross Kirschner-wire technique, including fluoroscopic confirmation of pin placement and the small medial incision used for safer medial pin insertion. Figure 2 shows serial radiographs from a representative six-year-old boy with a left Gartland type II supracondylar humerus fracture treated with crossed Kirschner wires.

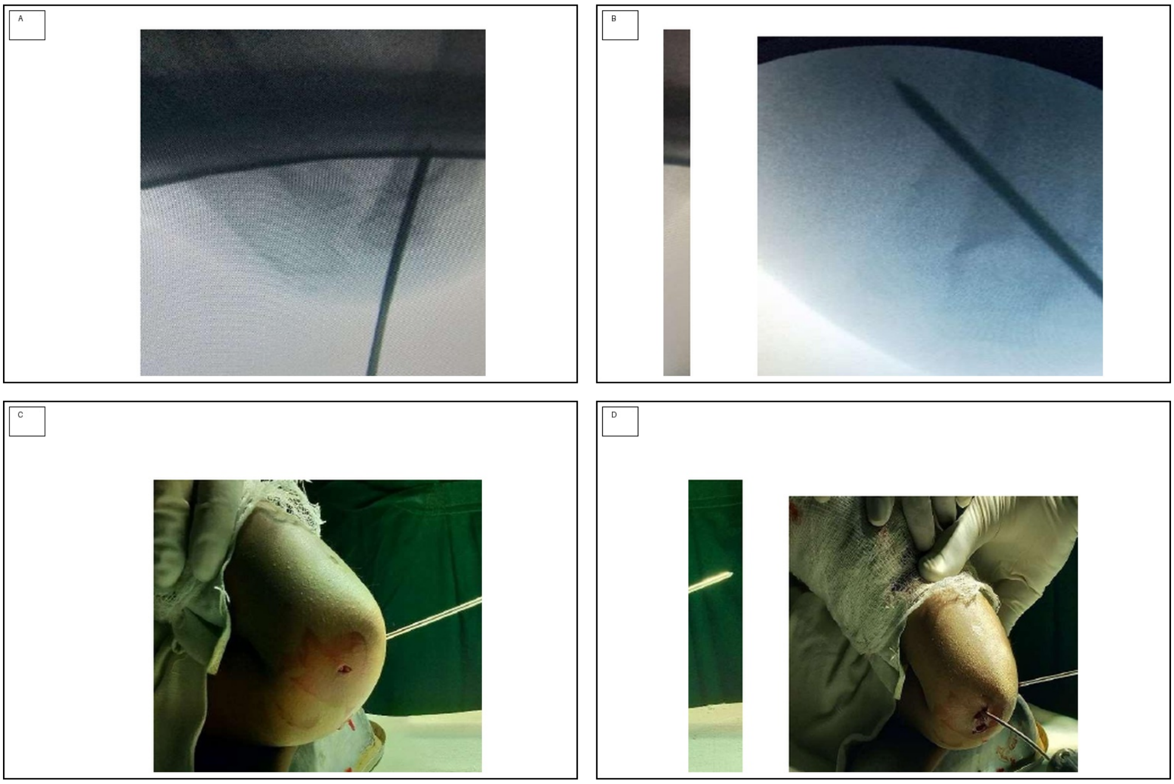

Figure 1. Criss-cross Kirschner-wire technique. (A, B) Fluoroscopic confirmation of lateral pin placement. (C, D) Small medial incision and controlled insertion of the medial pin to permit safer placement adjacent to the ulnar nerve.

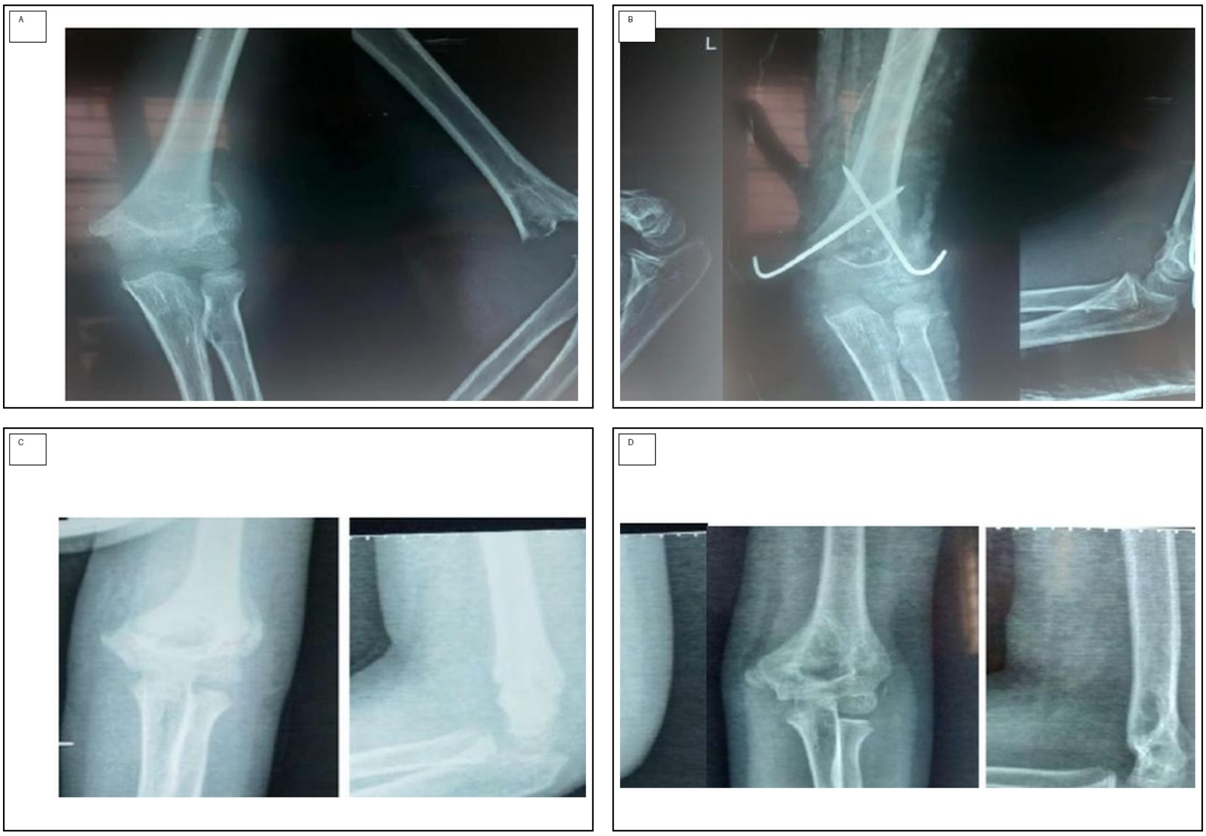

Figure 2. Representative radiographic course in a six-year-old boy with a left Gartland type II supracondylar humerus fracture. (A) Preoperative radiographs. (B) Immediate postoperative crossed-pin fixation. (C) Four-week follow-up. (D) Six-month follow-up showing maintained alignment and healing.

Discussion

Our study found that displaced supracondylar humerus fractures treated with criss-cross Kirschner wires generally maintained satisfactory alignment and recovered a useful elbow arc by six months. Four-fifths of the cohort had no postoperative complication, and the recorded adverse events were limited to pin-tract infection or pin migration. The results also suggest a practical treatment pattern: fractures presenting in a reducible position could be stabilized after closed reduction, while difficult, delayed or multidirectionally unstable injuries more often required open reduction.

The age and sex distribution was consistent with the recognized epidemiology of this injury. The mean age of 7.4 years closely resembles the 7.76-year mean reported by Sahu and the 7.9-year mean in the prospective series by Anjum and colleagues. Male predominance and more frequent involvement of the left or non-dominant extremity have also been described in paediatric series from India and other populations. [10,11,12,13]

Type II and III fractures were equally represented in our cohort, and two fractures were documented as type IV. The latter category is important because complete loss of the periosteal hinge can make the fracture unstable in both flexion and extension. Such multidirectional instability may only become obvious during reduction and explains why a fracture initially considered a conventional displaced injury can require a different operative strategy. [3,9] Crossed-pin fixation was chosen to obtain strong columnar and torsional stability. Biomechanical work has shown that a medial-lateral crossed construct can be more resistant to rotation than two lateral pins. The trade-off is the possibility of iatrogenic ulnar nerve injury from the medial wire. Our operative technique addressed this concern by making a small medial incision before medial pin insertion and by confirming pin placement under fluoroscopy. Similar mini-open strategies have been associated with a low incidence of ulnar nerve injury. [5,6,7,8]

No postoperative nerve palsy was reported in our cohort. Although the sample is too small to establish neurological safety, this observation supports meticulous protection of the medial side when crossed pins are used. Meta-analyses and comparative studies have generally found a lower ulnar nerve risk with lateral-only pinning, but crossed pins continue to be used when the surgeon judges that additional stability is required. [22,23,24] Final elbow motion was encouraging. Half of the children reached 0-135° and another 20% reached 0-140°. The distribution of motion did not differ significantly by fracture type or by reduction method. Previous series have similarly shown substantial recovery of elbow movement after stable fixation, although motion may continue to improve beyond the first few months. Mazda and colleagues, Lee and colleagues, and Shim and Lee reported high proportions of children recovering motion close to the opposite elbow after percutaneous pinning. [16,17,18,19] Maintenance of coronal alignment is particularly relevant because the distal humerus has limited capacity to remodel varus or valgus deformity. The mean carrying angle in our cohort was 10.50°, and 85% had a change in Baumann angle within 5°. No cubitus varus was reported during the available follow-up. These findings suggest that the reduction was generally maintained, although longer surveillance would be needed to determine whether subtle deformity becomes clinically apparent with growth. [1,4] The overall complication rate was 20%, consisting of two superficial pin-tract infections and two pin-migration events. Pin-related problems are familiar after percutaneous fixation. Sahu reported superficial pin-site infection in 3.5% of a larger retrospective cohort, Kumar described two superficial infections among 35 children, and Bashyal and colleagues identified pin migration and infection among the common reasons for unplanned postoperative care. Differences in pin care, follow-up duration and case mix can substantially influence reported rates. [11,13,14]

The need for open reduction in 55% of our cohort should be interpreted in the setting of presentation and reducibility. The clinical records noted that early type II or III injuries presenting within approximately 24 hours were more often amenable to closed anatomical reduction, whereas fractures presenting after 48 hours frequently could not be reduced satisfactorily by closed means. Delayed presentation is a recognized challenge, and both closed pinning and open reduction have been described depending on soft-tissue interposition, swelling, fracture stability and the ability to obtain an acceptable reduction. [20,21] Closed and open reduction were not randomized groups in our study. Open reduction was selected because the fracture was harder to reduce or was more unstable; therefore, the numerically higher complication frequency after open reduction cannot be attributed to the exposure itself. The absence of a significant difference in final range of motion is reassuring, but the cohort is far too small for equivalence or non-inferiority conclusions.

Our study has several strengths. The cohort was followed prospectively, the fixation principle was consistent, and both clinical and radiographic outcomes were recorded through six months. In addition, the operative photographs document a practical medial mini-incision during crossed pinning, which is directly relevant to ulnar nerve protection. The limitations are important. Only 20 children from a single institution were studied, sampling was non-random, and there was no lateral-pin control group. Closed and open reduction were chosen according to clinical need rather than randomized allocation, creating unavoidable selection bias. Follow-up ended at six months, so late angular change and longer-term elbow function could not be assessed.

The available dataset also did not contain a validated composite functional score or a separate quantitative pain scale, limiting the precision of functional comparison. Finally, two fractures were recorded as type IV despite the initial eligibility wording focusing on types II and III; this likely reflects instability recognized during treatment but should be standardized prospectively in future work.

Clinically, the findings support an approach in which reduction quality takes priority over preserving a closed technique at all costs. When acceptable alignment can be achieved early, closed reduction with stable crossed pins can minimize surgical exposure. When reduction is unsatisfactory or the fracture proves multidirectionally unstable, timely open reduction can restore anatomy without sacrificing useful short-term motion. In either setting, careful medial pin placement and structured follow-up remain essential.

Conclusion

In our study, criss-cross Kirschner-wire fixation provided stable radiographic alignment and useful elbow motion for most children with displaced supracondylar humerus fractures. Eighty per cent had no postoperative complication, and the recorded adverse events were minor pin-related problems. Final range of motion was similar across Gartland types and between children treated after closed or open reduction.

Early, reducible type II and III fractures were more likely to be managed successfully by closed reduction, while delayed or multidirectionally unstable injuries often required open reduction to restore anatomy.

These findings support individualized reduction based on fracture behaviour, followed by meticulous crossed-pin fixation when that construct is selected. Larger comparative studies with longer follow-up are needed to define the long-term balance between mechanical stability and pin-related neurological risk.

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