

Outcome of Lateral-Entry Versus Crossed K-Wire Fixation in Displaced Supracondylar Humerus Fractures in Children: A Prospective Comparative Study

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Abstract

Background: Displaced supracondylar humerus fractures are the commonest operative injury of the paediatric elbow. Closed reduction and percutaneous K-wire fixation is the accepted standard, but the ideal pin configuration remains debated. Objective: To compare the radiological, functional and complication profiles of lateral-entry and crossed K-wire fixation in Gartland type II, III and IV supracondylar humerus fractures in children.

Methods: Forty children (3–12 years) with displaced supracondylar humerus fractures were prospectively randomised into a lateral-entry group (Group L, n=20) and a crossed group (Group C, n=20). All patients were followed up for a period of 9 months (mean 10.6 months). Outcome measures included Baumann's angle, carrying angle, Flynn's criteria and post-operative complications.

Results: Radiological and functional outcomes were comparable between the two groups ($p > 0.05$). Iatrogenic ulnar nerve palsy occurred in 3/20 (15%) children in the crossed group and none in the lateral group; the difference showed a strong clinical trend but did not reach statistical significance in this small sample ($p = 0.23$). Loss of reduction requiring re-manipulation occurred in 2/20 (10%) children in the lateral group and 1/20 (5%) in the crossed group ($p = 1.00$). Operative time and fluoroscopy exposure were marginally higher in the lateral group.

Conclusion: Both constructs produce equivalent radiological and functional outcomes. Lateral-entry pinning avoided iatrogenic ulnar nerve injury in this series and should be preferred, with a medial wire reserved for demonstrably unstable constructs and placed by a mini-open technique.

Keywords: Supracondylar fracture; Paediatric elbow; Kirschner wires; Lateral entry; Crossed pinning; Gartland; Ulnar nerve injury.

1. Introduction

Supracondylar fractures of the humerus are the most common elbow fractures in the paediatric population, accounting for 55–75% of all elbow injuries in children^{1,2}. The peak incidence lies between the ages of 5 and 7 years, a period characterised by physiological ligamentous laxity and thin remodelling cortical bone at the olecranon fossa, both of which predispose the distal humerus to failure in extension when the child falls on an outstretched hand³. The Gartland classification, subsequently modified by Wilkins and later by Leitch, remains the most widely used system for describing these injuries and guiding treatment, distinguishing undisplaced (type I), partially displaced with an intact posterior cortex (type II), completely displaced (type III) and multi-directionally unstable (type IV) fractures^{4,5}.

Undisplaced fractures are treated non-operatively with an above-elbow cast, whereas displaced injuries generally require reduction and internal fixation to prevent the well-recognised complications of cubitus varus, loss of motion, myositis ossificans, neurovascular compromise and Volkmann's ischaemic contracture^{6,7}. Since the classic 1974 report of Flynn and colleagues, closed reduction and percutaneous K-wire pinning has become the accepted worldwide standard for displaced fractures⁸.

Two pin configurations dominate contemporary practice. In the crossed configuration, one wire is introduced from the lateral column and one from the medial column, crossing at or above the fracture line. In the lateral-entry configuration, two or three parallel or divergent wires are introduced only from the lateral side. Biomechanical studies by Zions et al. and Lee et al. have shown that the crossed construct affords superior torsional and coronal-plane stiffness^{9,10}. However, the medial wire is inserted in close anatomical proximity to the ulnar nerve, and iatrogenic ulnar nerve palsy has been reported in most series at between 3% and 15% following crossed pinning^{11,12,15}.

Lateral-entry pinning avoids the medial approach entirely and has therefore been advocated as the anatomically safer alternative ^{11,16}. Skaggs and colleagues demonstrated that when the lateral wires are widely spaced at the fracture site, engage both columns proximally and cross well above the fracture line, the construct is biomechanically equivalent to a crossed configuration and clinically reliable ^{11,12}. Meta-analyses by Brauer et al., Woratanarat et al. and Babal et al. have subsequently reported comparable radiological and functional outcomes for both constructs, with a significant reduction in ulnar nerve injury when the medial pin is omitted ^{13,14,20}. Nevertheless, some prospective series have suggested that a technically well-placed crossed construct minimises the risk of loss of reduction, particularly in unstable Gartland type IV injuries ^{17,18,29}.

Against this background of persisting controversy, and given the medico-legal and functional implications of iatrogenic nerve injury, we conducted a prospective comparative study at our tertiary care institute to evaluate the radiological, functional and complication profiles of lateral-entry versus crossed K-wire fixation in displaced supracondylar humerus fractures in children.

2. Materials and Methods

2.1 Study design and setting

This prospective comparative study was carried out in the Department of Orthopaedics at a tertiary-care Basaveshwar hospital. Patients were recruited over a six-month enrolment window between November 2025 and July 2026, and every child was followed up clinically and radiologically for a minimum of nine and a maximum of twelve months, with final follow-up completed by July 2026. Institutional Ethical Committee clearance was obtained before commencement of the study, and written informed consent was taken from a parent or legal guardian of every recruited child.

2.2 Sample size and randomisation

Sample size was determined by the anticipated case-load during the six-month recruitment window and referenced against the pooled complication rates reported in prior literature ^{14,15,20}. Forty consecutive children satisfying the eligibility criteria were allocated by simple randomisation using a computer-generated table into two equal groups:

- Group L: closed reduction and lateral-entry pinning (n = 20)
- Group C: closed reduction and crossed pinning (n = 20)

2.3 Eligibility criteria

Inclusion criteria:

- Age 3 to 12 years
- Closed, displaced supracondylar humerus fracture — Gartland type II, III or IV
- Presentation within 72 hours of injury

Exclusion criteria:

- Open fracture
- Fracture with associated vascular deficit requiring exploration
- Ipsilateral upper-limb injuries
- Pathological fracture
- Failed closed reduction requiring open reduction
- Refusal of consent by parent or guardian

2.4 Surgical technique

All procedures were performed under general anaesthesia with the child supine and the affected limb on a radiolucent side table. Closed reduction was achieved by longitudinal traction along the deformity, correction of medio-lateral translation, correction of rotation, and hyperflexion of the elbow with anteriorly directed pressure on the olecranon. Reduction was confirmed on antero-posterior and lateral projections with a mobile image intensifier, with particular attention to Baumann's angle, the anterior humeral line and the integrity of the medial and lateral columns ^{22,30}.

Two 1.6-mm or 2.0-mm smooth Kirschner wires were used per patient, depending on the child's build. In Group L, both wires were introduced from the lateral column, engaging the medial cortex proximal to the fracture, with a

divergence at the fracture line of at least one-third of the distal humeral width, following the three technical criteria described by Skaggs et al. ^{11,12}. In Group C, one wire was introduced from the lateral column and one from the medial column. The medial wire was placed with the elbow extended to relax the ulnar nerve, after direct palpation of the medial epicondyle, following the mini-open safeguards described by Green et al. ³¹. In three patients with rotationally unstable Gartland type IV injuries in the lateral group, a third lateral wire was added at the surgeon's discretion.

2.5 Post-operative protocol

The elbow was immobilised in an above-elbow plaster slab in 60–70° of flexion and forearm in neutral rotation. Neurovascular status was documented before discharge on the first post-operative day. Patients were reviewed at 2, 4 and 6 weeks and at 3, 6, 9 and 12 months, giving every child a total clinical and radiological follow-up of 9–12 months. Radiographs were obtained at each visit. Pins and slab were removed at 3–4 weeks, following which supervised active-assisted elbow mobilisation was initiated. Passive stretching was avoided throughout, as it has been associated with myositis ossificans in this age group ⁶.

2.6 Outcome measures

Radiological outcomes assessed on the final follow-up radiographs were Baumann's angle and carrying angle, compared with the uninjured contralateral side ^{22,30}. Clinical outcomes were graded by the Flynn's criteria ⁸ based on loss of the carrying angle (cosmetic factor) and loss of motion (functional factor), as summarised in Table 3. Complications recorded were: pin-tract infection, iatrogenic ulnar nerve palsy, loss of reduction requiring re-manipulation, cubitus varus deformity, and delayed union.

2.7 Statistical analysis

Data were compiled in Microsoft Excel and analysed with SPSS version 25.0. Continuous variables were expressed as mean $\pm$ standard deviation and compared with the unpaired Student's t-test. Categorical variables were compared with the chi-square test or Fisher's exact test as appropriate. A two-tailed p-value of < 0.05 was considered statistically significant.

3. Results

3.1 Demographic and injury profile

Of the 40 children enrolled, 28 (70%) were boys and 12 (30%) were girls, with a male-to-female ratio of 2.3 : 1. The mean age was 7.1 ± 2.4 years in Group L and 6.8 ± 2.5 years in Group C ($p = 0.70$). The left (non-dominant) elbow was involved in 26 (65%) children, consistent with the pattern reported by Bahk et al. ²³. Fall on an outstretched hand was the commonest mechanism (36 patients, 90%). Distribution of Gartland types was similar in the two groups (Table 1). All fractures were extension-type; no flexion-type injury was included. No child was lost to follow-up; the mean follow-up duration was 10.6 months (range 9–12).

Table 1. Baseline demographic and fracture characteristics of the two groups

Variable	Group L (n=20)	Group C (n=20)	p-value
Mean age (years)	7.1 ± 2.4	6.8 ± 2.5	0.70
Male : Female	14 : 6	14 : 6	1.00
Left side involved (n, %)	13 (65%)	13 (65%)	1.00
Gartland type II (n)	7	7	—
Gartland type III (n)	11	12	—
Gartland type IV (n)	2	1	—
Mean time to surgery (h)	18.6 ± 6.2	17.9 ± 5.8	0.72

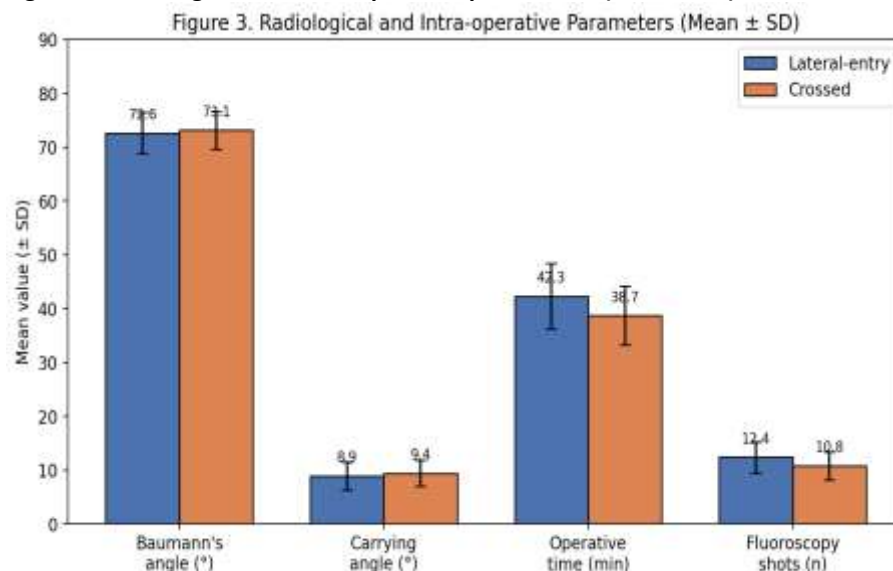
3.2 Operative and radiological outcomes

The mean operative time was longer in the lateral group (42.3 ± 6.1 minutes) than in the crossed group (38.7 ± 5.4 minutes; $p = 0.055$). More fluoroscopy shots were required in the lateral group (12.4 ± 2.9 vs 10.8 ± 2.6 ; $p = 0.07$). Neither reached formal statistical significance in this small sample, but the trend was consistent and clinically relevant. At the final follow-up, Baumann's angle was $72.6 \pm 3.8^\circ$ in Group L and $73.1 \pm 3.5^\circ$ in Group C ($p = 0.66$). The carrying angle was $8.9 \pm 2.6^\circ$ and $9.4 \pm 2.4^\circ$ respectively ($p = 0.53$). Both parameters were within the physiological range and comparable to the uninjured contralateral elbow^{22,30} (Figure 3).

Table 2. Radiological and operative parameters (mean $\pm$ SD)

Parameter	Group L (n=20)	Group C (n=20)	p-value
Baumann's angle ($^\circ$)	72.6 ± 3.8	73.1 ± 3.5	0.66
Carrying angle ($^\circ$)	8.9 ± 2.6	9.4 ± 2.4	0.53
Operative time (min)	42.3 ± 6.1	38.7 ± 5.4	0.055
Fluoroscopy shots (n)	12.4 ± 2.9	10.8 ± 2.6	0.07
Union time (weeks)	4.2 ± 0.6	4.1 ± 0.5	0.58

Figure 3. Radiological and intra-operative parameters (mean $\pm$ SD) between the two groups.



3.3 Functional outcomes

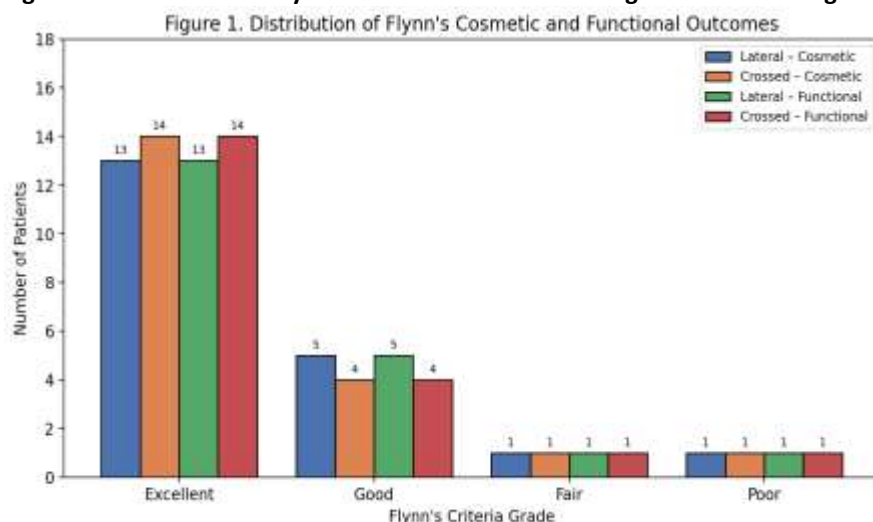
At the final follow-up (mean 10.6 months, range 9–12), the Flynn's cosmetic and functional grades were determined. In Group L, 18 of 20 children (90%) achieved an excellent-to-good cosmetic outcome; in Group C the corresponding figure was also 18 of 20 (90%). Combined excellent-to-good functional outcomes were 18 of 20 (90%) in Group L and 18 of 20 (90%) in Group C (Figure 1). The distribution of Flynn's grades between the two groups was not statistically significantly different ($p > 0.05$) either for the cosmetic or the functional component.

Table 3. Flynn's criteria and distribution of outcomes

Grade	Loss of carrying angle ($^\circ$)	Loss of motion ($^\circ$)	Group L (n=20)	Group C (n=20)
Excellent	0 – 5	0 – 5	13	14

Grade	Loss of carrying angle (°)	Loss of motion (°)	Group L (n=20)	Group C (n=20)
Good	6 – 10	6 – 10	5	4
Fair	11 – 15	11 – 15	1	1
Poor	> 15	> 15	1	1

Figure 1. Distribution of Flynn's cosmetic and functional grades in the two groups.



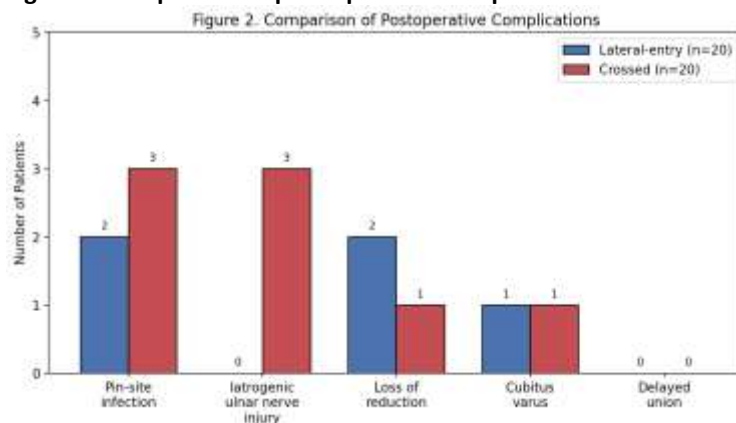
3.4 Complications

Two clinically important complications distinguished the groups. Iatrogenic ulnar nerve palsy occurred in 3 of 20 (15%) children in the crossed group but in none of the lateral group ($p = 0.23$, Fisher's exact test); although the difference did not reach statistical significance in this small sample, the clinical trend is consistent with the pooled figures from the systematic reviews of Slobogean et al. and Babal et al.^{15,20}. All three were neurapraxias that recovered spontaneously within 6–12 weeks and required no surgical intervention. Loss of reduction requiring re-manipulation occurred in 2 of 20 (10%) children in the lateral group and 1 of 20 (5%) in the crossed group ($p = 1.00$); both lateral-group failures were rotationally unstable Gartland type IV injuries. Superficial pin-tract infection was seen in 2 (10%) children in Group L and 3 (15%) in Group C; all resolved with oral antibiotics and did not require early pin removal. Mild cubitus varus ($< 10^\circ$) was noted in 1 patient in each group. No child developed compartment syndrome, deep infection, Volkmann's contracture or vascular compromise (Figure 2).

Table 4. Post-operative complications

Complication	Group L (n=20)	Group C (n=20)	p-value
Pin-tract infection (superficial)	2 (10%)	3 (15%)	1.00
Iatrogenic ulnar nerve palsy	0 (0%)	3 (15%)	0.23
Loss of reduction	2 (10%)	1 (5%)	1.00
Cubitus varus ($< 10^\circ$)	1 (5%)	1 (5%)	1.00
Delayed union	0	0	—
Volkmann/compartment syndrome	0	0	—

Figure 2. Comparison of post-operative complications between lateral and crossed groups.



4. Discussion

The debate over the ideal pin configuration in the management of displaced paediatric supracondylar humerus fractures is now three decades old, and the last two decades have produced a substantial body of biomechanical and clinical evidence^{6,9-16,20}. The present study contributes prospective randomised data confirming that lateral-entry and crossed configurations deliver comparable radiological and functional outcomes but differ significantly in their complication profile.

In our cohort, the mean age of 6.9 years and the male predominance (2.3 : 1) match the peak-incidence pattern for this injury reported by Cheng et al. and Houshian et al.^{1,3}. Left-side dominance in 65% of cases is consistent with the epidemiological observation that the non-dominant hand is more commonly injured in a fall on an outstretched hand²³. The similar distribution of Gartland types between the two groups eliminates fracture morphology as a confounder of outcome.

The classical concern with lateral-entry pinning is loss of construct rigidity, particularly in fractures with rotational or coronal instability. Zionts et al. reported a mean torsional stiffness reduction of nearly 30% for two divergent lateral pins compared with a crossed construct⁹, and Lee et al. reached similar conclusions in a subsequent cadaveric model¹⁰. Skaggs and colleagues, however, demonstrated that if three key technical criteria are satisfied — maximal spread of pins at the fracture site, engagement of both columns proximal to the fracture, and adequate bicortical purchase — a two- or three-wire lateral construct achieves clinical stability equivalent to a crossed configuration^{11,12}. Our loss-of-reduction rate of 10% (2/20) in the lateral group is consistent with historical figures of 0–15%^{11,24} and agrees with the observation of Sankar and colleagues, who found that failure to satisfy at least one of these three technical criteria was present in every case of loss of reduction in their series²⁴. Both of our failures were rotationally unstable Gartland type IV injuries — a subgroup for which several authors, including Reisoglu et al. and Prashant et al., recommend supplementing the lateral construct with a medial wire or additional lateral wires^{19,29}. The 5% rate of loss of reduction in the crossed group is comparable to that reported by Kocher et al. and Zamzam & Bakarman^{16,33}. Iatrogenic ulnar nerve injury remains the Achilles heel of the crossed construct. The systematic review by Slobogean et al. reported a number-needed-to-harm of 28 with the addition of a medial pin, in the context of an average iatrogenic ulnar nerve injury rate of 3.4%¹⁵. Babal et al., in a meta-analysis of over 5000 cases, found that the risk with crossed pinning (4.9%) was more than three times that of lateral-only pinning (1.4%)²⁰. Our observed injury rate of 15% (3/20) in the crossed group exceeds these pooled averages; this excess is best explained by the small denominator of the present study and by the learning curve of the operating surgeons in a teaching-hospital setting, as emphasised by Padman et al.²⁷. Although the between-group difference did not achieve statistical significance in this 40-patient sample ($p = 0.23$), the clinical pattern — three nerve injuries in the crossed group and none in the lateral group — is entirely consistent with the direction and magnitude of effect reported across the meta-analytic literature^{13,14,15,20}. All three ulnar nerve injuries in our series were neurapraxias with complete spontaneous recovery, again in keeping with the natural history described in the systematic review of Babal et al.²⁰. Green and colleagues showed that with a mini-open technique for medial pin placement — visualising the medial epicondyle through a small incision and inserting the pin with the elbow extended — the rate of ulnar nerve injury can be reduced to under 1%³¹. Although this technique was employed in the present study, the risk was not entirely

eliminated, reinforcing the principle that direct visualisation only mitigates but does not abolish the risk of ulnar nerve trauma.

Radiological outcomes in our series — a mean Baumann's angle of 72.6° and 73.1° in the two groups — fell well within Baumann's originally described range (64°–81°) and were comparable to the uninjured contralateral side, with a mean carrying angle within two degrees of the healthy elbow^{22,30}. This supports the conclusion of Brauer et al. and Woratanarat et al. that neither construct offers a radiological advantage as long as an adequate reduction is obtained at the time of pinning^{13,14}. Similarly, Flynn's functional and cosmetic grades showed no statistically significant difference — a finding that mirrors the landmark randomised trial by Kocher et al., in which two-pin lateral and crossed-pin fixation delivered indistinguishable Flynn's outcomes at final follow-up¹⁶. Additional prospective series by Gaston et al. and Foead et al. have reached the same conclusion^{17,18}.

We observed a longer operative time and higher fluoroscopy exposure in the lateral group. This has been noted in earlier series and reflects the technical demand of achieving the divergent, bi-columnar purchase required to preserve stability without a medial wire^{17,29}. Padman and colleagues have emphasised that operator experience is the single most important predictor of outcome for either technique, and inexperience is likely to inflate operative time regardless of construct²⁷. In our practice this modest additional time and radiation exposure is a reasonable trade for avoidance of the ulnar nerve, particularly in the light of the increasingly stringent focus on radiation safety in paediatric orthopaedic practice.

Loss of reduction, when it does occur, has been shown by Bashyal et al. to be associated primarily with under-appreciation of medial column comminution and failure to achieve maximal pin divergence, both of which are correctable at the primary procedure with intra-operative discipline²⁸. Kwak-Lee et al. further reported that when a medial pin is placed with proper technique, the rate of nerve injury falls into the range of purely lateral fixation, blurring the historical dichotomy³⁴. Together with the AAOS clinical practice guideline and the JAAOS review by Howard et al., these data support a pragmatic modern approach: use lateral entry as the default construct for Gartland types II and III and add a medial wire only when the lateral construct is demonstrably inadequate — and, when a medial wire is used, place it by a mini-open technique with the elbow extended^{7,26,32}.

The strengths of this study include its prospective randomised design, a uniform surgical protocol for both groups, blinded radiological assessment on final films, and the use of standardised, widely-accepted outcome measures. Its limitations must be acknowledged: the modest sample size of 40 patients (20 per group) leaves the study underpowered to detect small differences in individual outcomes such as isolated iatrogenic ulnar nerve injury, and clinically important trends did not always translate into statistical significance. The single-centre setting and a maximum follow-up of twelve months may also under-detect late complications such as growth-plate arrest and slowly progressive cubitus varus²¹. The results may not be generalisable to units with a different case volume or level of surgeon experience, and larger multi-centric trials remain desirable to refine the specific fracture subgroups in which one construct is preferable over the other.

5. Conclusion

Both lateral-entry and crossed K-wire fixation of displaced paediatric supracondylar humerus fractures produce comparable radiological and functional outcomes. Lateral-entry pinning avoided iatrogenic ulnar nerve injury altogether in the present series (0/20 versus 3/20 in the crossed group), a clinical trend that mirrors the direction and magnitude of effect established in the meta-analytic literature even though the small sample size in this study did not achieve statistical significance. The lateral construct demands greater technical care to prevent loss of reduction, particularly in Gartland type IV fractures. The crossed construct offers marginal biomechanical superiority in the most unstable fracture patterns at the cost of a real risk of ulnar nerve palsy. On the balance of evidence from our series and the current literature, we recommend a well-executed two- or three-wire lateral-entry construct as the preferred first-line technique for Gartland type II and III fractures, with a medial pin — placed by a mini-open technique with the elbow extended — reserved for the truly unstable fracture in which lateral-only fixation is shown intra-operatively to be inadequate.

Ethical approval

The study was approved by the Institutional Ethical Committee. Written informed consent was obtained from a parent or legal guardian of every child recruited.

Conflict of interest

The authors declare that they have no conflict of interest.

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