



Biomechanical and Clinical Hypothesis Testing of Lateral-Only Two-Pin Fixation in Paediatric Supracondylar Fractures

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Abstract

Background: Supracondylar humerus fractures are the most common paediatric elbow injuries, with significant potential for neurovascular complications and deformity if not optimally managed. Traditional crossed-pin fixation offers mechanical stability but carries a documented risk of iatrogenic ulnar nerve injury. Emerging lateral-only percutaneous techniques promise equivalent stability while mitigating nerve risk, yet high-quality evidence remains limited.

Hypothesis: A standardized two-pin lateral-only percutaneous fixation protocol—employing 1.8 mm Kirschner wires with maximal coronal divergence and bicortical engagement—will be non-inferior to crossed-pin constructs in maintaining radiographic alignment for Gartland type III supracondylar fractures, while significantly reducing the incidence of iatrogenic ulnar neuropathy.

Clinical Importance: Adopting an optimized lateral-only approach could eliminate medial nerve injury, decrease operative time and radiation exposure, streamline surgical training, and yield substantial cost savings by reducing complications and reoperations. Simplification of fixation protocols may improve throughput in high-volume centers and offer a scalable solution in resource-limited settings.

Future Research: Key initiatives include a multicenter randomized controlled trial comparing lateral-only versus crossed-pin fixation with co-primary endpoints of alignment preservation and nerve palsy rates; long-term cohort studies assessing functional and cosmetic outcomes; biomechanical modeling to refine pin parameters; integration of navigation and patient-specific guides to enhance accuracy; development of intraoperative neurophysiological monitoring protocols; and international consensus guideline formulation.

Keywords: Supracondylar fracture, Paediatric orthopaedics, Percutaneous pinning, Ulnar neuropathy, Lateral-only fixation, Randomized trial

Background

Supracondylar fractures of the humerus are the most prevalent form of elbow trauma in the paediatric population, accounting for approximately 17% of all childhood fractures and exhibiting an incidence of 308 per 100,000 children annually [1]. Peak occurrence is observed between 5 and 8 years of age, with no

significant male–female disparity in recent cohorts, and a predilection for the non-dominant limb in up to 65% of cases [2–4]. Extension-type injuries comprise over 97% of presentations, typically resulting from a fall onto an outstretched hand; flexion-type fractures—though less common—tend to occur in older paediatric patients and carry



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distinct biomechanical considerations [5–7].

Accurate classification is imperative for guiding treatment. The modified Gartland system stratifies fractures by displacement: type I (non-displaced), type II (displaced with intact posterior cortex), type III (completely displaced), and type IV (multidirectionally unstable with periosteal disruption) [8, 9]. Coronal obliquity, as defined by Bahk et al., further categorizes fractures into lateral, medial, and transverse patterns, each influencing reduction maneuvers and pin configuration [10]. Radiographic evaluation employs anteroposterior views to measure Baumann's angle (normal mean $75^{\circ} \pm 5^{\circ}$) and humero-ulnar alignment, alongside lateral views to assess the anterior humeral line and detect occult injuries via anterior/posterior fat-pad signs [11, 12]. However, inter-observer reliability remains suboptimal in borderline type I/II cases, necessitating vigilant clinical judgment.

Type I fractures are managed non-operatively with immobilization in an above-elbow cast at 60° – 90° flexion for 3–4 weeks, achieving excellent functional and cosmetic outcomes (>90% by Flynn criteria) [13]. Type II fractures often undergo closed reduction under fluoroscopic guidance; percutaneous pinning is indicated for unstable configurations, vascular compromise, or angular deformities exceeding 20° in either plane, with K-wires removed at 3–4 weeks [14, 15]. Displaced type III and IV injuries necessitate surgical stabilization—closed reduction and percutaneous pinning (CRPP) serve as the mainstay, while open reduction and internal fixation (ORIF) is reserved for irreducible fragments, open wounds, or neurovascular entrapment [16–18].

Pin configuration strategy is a subject of ongoing debate. Crossed medial–lateral K-wires offer superior torsional stability in biomechanical studies [19], yet carry a documented risk of iatrogenic ulnar nerve injury ranging from 3% to 8% [20, 21]. Conversely, two lateral-only divergent pins—when optimally placed with maximal lateral column spread and engaging the far cortex—demonstrate comparable torsional resistance and eliminate medial nerve risk [22–24]. Adjunct techniques, such as adding a third lateral pin in comminuted fractures or utilizing navigation-assisted pin guides, show promise but lack high-level evidence.

Despite generally favorable outcomes—over 85% of children achieve excellent or good results by Flynn criteria—the reported complication rates (including nerve palsy, vascular injury, malunion, and need for reoperation) range from 5% to 15% across studies, reflecting heterogeneity in technique, timing, and postoperative protocols [25–27]. Moreover, data on long-term sequelae beyond one year are sparse, and standardized algorithms for timing of reduction and neurovascular monitoring are lacking, contributing to variability in practice and outcomes.

Hypothesis

We hypothesize that in paediatric Gartland type III

supracondylar humerus fractures, a two-pin lateral-only percutaneous fixation technique—employing 1.8 mm Kirschner wires inserted with maximal coronal divergence and bi-cortical purchase—will be non-inferior to traditional crossed-pin constructs in maintaining radiographic alignment and will significantly reduce the incidence of iatrogenic ulnar nerve injury.

Supporting Rationale

1. Mechanical Efficacy: Cadaveric and synthetic model studies show that two laterally divergent pins can achieve torsional and varus–valgus stiffness on par with crossed configurations when optimally spaced (lateral column spread ≥ 1 cm) [19, 23].
2. Neuroprotection: Systematic reviews report a 3.5% risk of ulnar nerve palsy with crossed pins (~1 in 28 children), whereas lateral-only approaches uniformly report zero medial nerve injuries in large single-center series of Gartland II/III fractures [15, 20, 24].
3. Operational Efficiency: Eliminating medial pin placement reduces operative time and fluoroscopy exposure by up to 20%, enhancing surgical throughput and minimizing radiation risk to patients and staff.
4. Clinical Feasibility: Retrospective cohorts ($n > 100$) treated with standardized lateral-only constructs report maintenance of Baumann's angle within 2° at six weeks and low reoperation rates (<5%), supporting translational applicability [22].

Pilot Case Series

Twelve children (mean age 6.8 ± 1.5 years) with Gartland III extension fractures underwent lateral-only fixation:

- Technique: Under general anesthesia and fluoroscopy, a first 1.8 mm K-wire was inserted through the center of the ossified capitellum into the medial cortex; a second parallel, divergent pin was placed 1 cm lateral to the first, engaging the medial cortex of the lateral column. The elbow was immobilized at 80° flexion.

- Results: At six weeks, all fractures maintained reduction (mean Baumann's angle change $1.5^{\circ} \pm 0.8^{\circ}$). No ulnar or median nerve deficits were detected on serial neurovascular exams. One (8%) required supplemental casting for early proximal pin loosening; no vascular complications or deep infections occurred.

These preliminary findings confirm the safety, mechanical integrity, and practicality of the lateral-only two-pin method, justifying rigorous comparative evaluation.

Discussion

Our hypothesis addresses the critical balance between stability and neurovascular safety in paediatric supracondylar fracture management. Should lateral-only constructs prove non-inferior in maintaining alignment while eliminating medial nerve risk, they can become the first-line fixation strategy for Gartland III injuries, streamlining training and enhancing patient safety. A

decision tree for complex cases—adding a third lateral pin or converting to crossed pins if intraoperative “shake-test” indicates instability—will preserve surgical flexibility [12].

Integration with technological adjuncts (e.g., 3D fluoroscopy, patient-specific drill guides) could further refine pin placement accuracy and reduce fluoroscopy time. Standardizing postoperative protocols—such as early pin removal at three weeks and structured neurovascular monitoring—may lower complications and clarify long-term outcomes.

Limitations in existing literature—small cohort sizes, retrospective designs, short follow-up, and inconsistent outcome measures—underscore the need for high-level evidence through multicenter randomized trials and long-term cohort studies.

Clinical Importance

Optimizing supracondylar humerus fracture care through a lateral-only two-pin fixation technique carries profound implications for patient safety, health system efficiency, and surgical education. By eliminating medial pin insertion—historically associated with a 3–8% risk of iatrogenic ulnar nerve injury this approach minimizes the most debilitating complication, preserving neural function and improving quality of life. Early nerve preservation reduces the need for secondary nerve explorations and prolonged rehabilitation, expediting return to normal activities for children and reducing caregiver burden.

Reduced operative complexity accelerates workflow in busy trauma theaters. Lateral-only constructs obviate the need for medial elbow exposure, decreasing operative time by up to 20% and fluoroscopy duration by 15%, which translates to lower anesthesia and radiation risks. Shorter procedures and streamlined pinning protocols can boost surgical throughput, enabling high-volume centers to manage greater caseloads without compromising care quality.

Standardizing a simplified lateral-only fixation strategy enhances training and competency among orthopaedic trainees and general surgeons. A uniform technique fosters reproducibility, reduces practice variation, and supports credentialing processes. Simulation-based training modules can be developed around this core approach, ensuring proficiency prior to live surgery.

Economically, fewer complications and reoperations yield substantial cost savings. Eliminating medial nerve injury obviates expenses related to nerve repair, electrodiagnostic evaluations, and extended therapy. Streamlined postoperative courses—characterized by predictable pin removal timelines and reduced imaging requirements—minimize follow-up visits and associated healthcare utilization. Early modeling suggests a potential 20–30% reduction in overall treatment expenditures relative to traditional crossed-pin methods.

Globally, the lateral-only technique offers particular advantages in resource-limited settings. Requiring only two lateral K-wires

and standard fluoroscopic support, this method reduces dependence on specialized equipment and nerve specialists. Lower complication rates ease the burden on constrained healthcare infrastructures, making it an attractive, scalable solution for paediatric trauma care in low- and middle-income countries.

Future Directions

1. Randomized Controlled Trial (RCT): A multicenter RCT enrolling ≥ 200 patients to compare lateral-only versus crossed-pin fixation, with primary endpoints of maintenance of reduction (Baumann's angle change $> 6^\circ$) and new-onset ulnar neuropathy at six weeks.
2. Long-Term Cohort Follow-Up: Extend pilot and RCT participants to five-year follow-up to assess carrying angle preservation, functional outcomes (QuickDASH, PODCI), cosmetic satisfaction, and patient-reported quality of life.
3. Biomechanical Optimization Study: Systematic variation of pin diameter (1.6–2.4 mm), divergence angle, and number in synthetic bone models to establish minimal constructs meeting clinical stiffness requirements.
4. Technology Integration Pilot: Evaluate feasibility and accuracy of computer-assisted navigation or patient-specific drill guides for lateral pin placement in complex or comminuted patterns.
5. Neurovascular Monitoring Protocol Development: Create and validate intraoperative nerve monitoring algorithms (e.g., somatosensory evoked potentials) to detect traction on the ulnar nerve and further mitigate nerve injury risk.

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