

Original Article (Pre-Reviewed)

Outcomes of Closed Reduction and Percutaneous Pinning for Paediatric Epiphyseo-Metaphyseal Upper Limb Fractures: A Retrospective Cohort Study and Predictors of Failure.

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Abstract:

Objectives: Minimally invasive, closed reduction and percutaneous pinning (CRPP) is widely practiced for displaced paediatric epiphyseo-metaphyseal upper limb fractures to achieve the best outcomes, without significant complications. However, native data is meagrely available. This study reports comparative outcomes and identifies predictors for failures of closed reduction commonly observed in our native practice.

Methods: This observational study included 40 children aged 1-18 years who underwent CRPP, at Dr. Ziauddin University Hospital Clifton, Karachi managed between January 2022 and June 2025. Demographics, fracture morphology, radiological parameters, clinical outcome as per Quick DASH scores or Flynn's criteria and Paediatric quality of life (PedsQL) were assessed at a mean follow-up of 6 months (minimum 6 months).

Results: Among cohort of the 40 children, male to female ratio was 2:1. Metaphyseal fractures were encountered in 20 (50%) patients, supracondylar humerus fractures (SCHF) in 17 (42.5%) while 3 (7.5%) were epiphyseal injuries. Overall, CRPP succeeded in 33 (82.5%), while 7 (17.5%) required Open reduction (OR) including 2 (5%) with planned OR. Among 17 SCHF, mean Baumann's angle achieved is 73.8 ± 9.1 degrees, radiological parameters were also within normal limits in other epiphyseo-metaphyseal fractures. Two of SCHF (11.8%) had transient elbow stiffness. No deep-seated infections, growth arrests, or permanent neurovascular deficits occurred among both groups. Overall, Quick DASH scores was excellent in 30 (75%) including 87% of SCHF. Whereas mild-to-moderate disability was observed in 10 (25%) of overall cases. As per PedsQL 86.8 ± 6.3 patients appreciated good overall quality of life.

Conclusion: CRPP is safe and effective method to manage Paediatric epiphyseo-metaphyseal fractures reporting early within 2 weeks of injury, whereas delayed presentation leads to compromised outcome. The teenage with high BMI, single-bone fracture in forearm, comminution, gross swelling and delayed were the significant predictor for the failed closed reduction.

Keywords: Paediatric fractures; Upper Extremity; Closed Fracture Reduction; Fracture Fixation; Complications; Supracondylar Distal Humerus Fractures; Wrist Fracture; Treatment Outcome; Outcomes Assessment

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Introduction

Upper limb fractures are the most common injuries of paediatric population, the most common of them being distal forearm epiphyseo-metaphyseal 25% and 15-18% being supracondylar Humerus (SCH) fractures [1, 2, 3]. The majority of these can be managed conservatively, wherein some degree of left-over angulation is remodelled to in due course of time [4]. Whereas, grossly displaced unstable fractures like Gartland 3, 4 / AO 13-M/3.1 (III) - (IV), distal radio-ulnar overlapped and distal radius single bone displaced fractures, often require requires expertise to reduces and thereafter CRPP to achieve anatomical reduction, prevent ensuing deformities, functional disability and achieve optimum outcomes during subsequent growth [1, 5]. The MI-CRPP reduced surgery time, minimise soft tissue damage, scar as none, minimum risks of surgical site infection and almost none physeal growth disturbances at long term [6, 7]. Nevertheless, beside expertise to develop, the surgeon's patience and adherence to follow principles, minimised complications that may arise during the procedure, like tethering of neurovascular bundle, tendon injury pin track infection and failure reductions [8]. We are presenting outcome of cohort of 40 children with displaced upper limb supracondylar and epiphyseo-metaphyseal fractures managed with CRPP, including early to delayed presenting cases, findings compared to published literature and to define the predictors of failure of CRPP.

Hypothesis:

Earlier presentation, lower body mass, reduced swelling and less comminution of fractures are associated with better clinic-radiological outcomes.

Working Definitions:

Kapandji Technique A percutaneous reduction method in which a Kirschner wire is inserted into the fracture site, to leverage and lock the bone fragments into place, mostly at distal radius. [17]., **Joystick Manoeuvre** A reduction method in which a percutaneously inserted K-wire or instrument is used as a lever to manipulate and align fracture fragments under imaging guidance. [16]., **Blount's Technique** A method of closed reduction for supracondylar humerus fractures involving traction followed by elbow hyperflexion to maintain fracture alignment, often relying on an intact posterior periosteum for stability. [12]., **Mubarak and David's Technique** A PP method for SCHF in which lateral entry K-wires are inserted in a divergent configuration to stabilize both the medial and lateral columns of the distal humerus, providing adequate fixation while avoiding the risk of ulnar nerve injury associated with medial pin placement.[15]., **Radial Epiphyseal Angle** the angle between the long axis of the radial head and the line perpendicular to the physis, to assess alignment at the growth plate region, in paediatric fractures involving the physis. [26] [27]. **Metaphyseal-Diaphyseal Angle** A radiographic angle formed between the metaphysis and diaphysis of a long bone, to evaluate alignment and detect angular deformities following fracture reduction. [26]. **Baumann's Angle** A radiographic measurement on anteroposterior elbow X-rays, between the

long-axis of the humeral shaft and the physal line of the lateral condyle, to assess coronal alignment in SCHF. [26]

Methods

This observational study cohort included 40 children aged 1-18 years of either gender, who underwent CRPP and planned OR, for epiphyseo-metaphyseal upper limb fractures at Dr. Ziauddin University Hospital Clifton, Karachi from 1st January 2022 to 30th June 2025. The study followed STROBE guidelines and received institutional ethical approval (Reference: 11531125TMORT). Patient's data extracted from HIMS, using consecutive sampling technique to minimize selection bias. Inclusion criteria comprised of SCHF, metaphyseal, and epiphyseal fractures of upper limb treated CRPP, with or without conversion to open reduction. Patients presenting with open fractures, pathological fractures, metabolic bone disease, osteogenesis imperfecta or fractures older than 3 weeks were excluded. Techniques followed Arbeitsgemeinschaft für Osteosynthesefragen (AO) principles [10-11]. The follow-up protocol adopted with clinical and radiological evaluation as per fracture, at 2, 4, 12 weeks, 6 months (minimum), and 12 months. Outcomes were assessed using QuickDASH and PedsQL questionnaires. Radiological parameters included Baumann's angle (SCHF), epiphyseal angle, and metaphyseal-diaphyseal angle.

Patients were prepared with standard general anaesthesia protocol and sterile attire. Epiphyseo-metaphyseal fractures were manipulated with "Closed reduction technique" as defined in AO surgery methods [10-11]. SCHF were manipulated using Blount's technique [12]. Once stable position was achieved and confirmed under C-arm, fractures were fixed with CR-PCP pinning. SCHF were fixed with lateral-entry K-wires (typically two for

stable fractures and three or more for unstable patterns), ensuring bi-cortical fixation and adequate pin spread [13, 14]. Unstable fracture with medial comminution is were either stabilized with K-wires through medial epicondyle via a 1 cm incision with safe mobilization of ulnar nerve or by Mubarak and David's technique [15]. Other epiphyseo-metaphyseal fractures were fixed with crossed K-wires following adequate reduction under C-arm. Few cases however required joystick maneuver [16] or Kapandji technique for distal radius fractures [17]. Pins were bent, cut and left exposed under protected dressing and cast. Failed CR were managed with mini incision open reduction, along with few planned open reductions for stable reduction and fixation. Pins were mostly removed within three weeks, with dressing through window at 2 weeks, after pin removal, a skin-tight cast was applied for another 2-3 weeks as needed, with monitoring of progressive callus formation on radiographs.

The evaluation parameters included patient demographics, fracture generics, radiological parameters and complications, at average follow-up duration of 6 months. Clinically assessed with Quick DASH score and Paediatric Quality of Life Assessment. While radiologic evaluation made on individual criteria for each fracture region using epiphyseo-metaphyseal, metaphyseal-diaphyseal angles, rotational profile and Baumann's angle in SCHF.

Data Analysis:

Data were analysed using SPSS version 23, Descriptive statistics are presented as mean \pm SD for continuous variables and frequencies/percentages for categorical variables. Due to the small number of failures (n=7), formal comparative statistics for predictors were not

performed; associations are reported descriptively. $P < 0.05$ was considered significant where applicable. No adjustment for confounders was made given the descriptive design.

Results:

A total of 40 paediatric patients were included in the study. Of these 40 children

26 (65%) were male, females 14 (35%). Twenty of them were minor children (1-6 years), 16 in school age (7–12 years) while 4 children were teenage (13–18 years) were included. Similarly, male children experienced the higher number of injuries across most mechanisms, including high impact force injures in 23 male children, while 11 children were female (**Figure 1**)

Figure 1 Mechanism of Injury across age group and genders

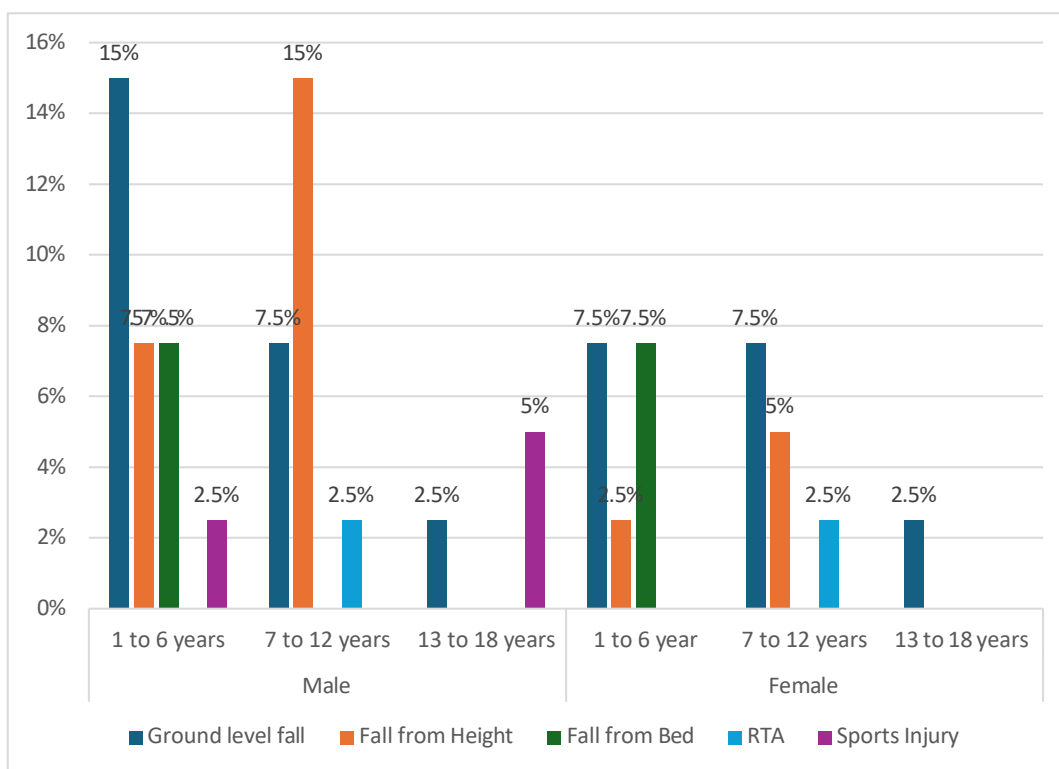


Table 1, revealed; the most common fracture (50%) were the metaphysis, followed by SCH (42.5%) and epiphyseal injuries in 3 (7.5%). The closed reduction was the most common procedure performed with total of 33 patients (82.5%) patients.

All cases were divided in 2 groups, Group 1 - 17 (42.5%) were SCH fractures and Group 2 – 23 (57.5%) were epiphyseo-metaphyseal fractures. In group 1, 3 (18%) patients with SCHF required open reduction (1 (6%) planed OR and 2 (12%)

failed CR) while 14 (82%) were successfully treated with CRPP. Among epiphyseo-metaphyseal fractures 4 (18%) required open reduction (1 (4%) planed OR and 3 (14%) failed CR) while 19 (82%) were treated with CRPP.

In total, 7 (17.5%) cases, required open reduction. Two (5%) were planned OR and 5 (12.5%) converted to OR after failed CR. However, fracture classification or injury pattern did not influence the treatment modality.

Three months post-surgery Baumann’s angle of SCH fractures treated with CR

and OR was within normal range of 73.8 ± 9.1 . -The mean metaphyseal-diaphyseal angle was within normal range, $2.8 \pm 3^\circ$ ulna, $3.5 \pm 2.5^\circ$ radius and humerus $8.3 \pm 9.4^\circ$. The mean radial epiphyseal angle was $8.75 \pm 4.7^\circ$ for 2(66%) fractures treated with CR, however 1 (33%) required OR intra-operatively.

Functional outcomes in patients with supracondylar fracture were assessed using Flynn's criteria. All patients achieved satisfactory results, with most classified as excellent (70%) or good (17%) outcomes. A smaller proportion of patients fell into the fair category, accounting for 2 (13%) of cases, while no patients had poor outcomes.

Quick DASH score, evaluated in other epiphyseal-metaphyseal fractures, showed that majority of the patients 30 (75%) had a score between 0-25, depicting excellent recovery and very low disability. Ten patients (25%) had an average score between 25-50 showing mild to moderate disability, and no patient suffered from severe or extremely severe disability.

PedsQL assessment demonstrated favourable outcomes across all domains. The highest mean score was observed in physical functioning (89.2 ± 6.8), indicating excellent recovery of physical activity. Social functioning (87.6 ± 6.2) and emotional functioning (84.5 ± 7.4) were also high, reflecting good psychosocial well-being. School functioning showed comparatively lower but still satisfactory scores (81.3 ± 8.1). The PedsQL score was 86.8 ± 6.3 , indicating good overall quality of life in the study population following treatment.

Table 1 Fracture with AO Classification [18] and the mode of treatment used

Site of fracture	Bone Involved	AO Classification		Treatment method			Radiological Evaluation		
Site & Frequency	Site & Frequency	Frequency		CR N-33	Planned OR N-2	Failed CR-OR N- 5	Mode of Evaluation	Mean Angle	P-Value
Supracondylar 17 (42.5%)	Distal Humerus SCHF only 17 (100%)	13-M/3.1 (III)	12 (70%)	9	1	1	Baumann's angle	73.8 ± 9.1	< 0.05
		13-M/3.1 (IV)	5 (30%)	4	0	1			
Epiphysis 3 (7.5%)	Proximal Radius 3 (100%)	21r-E/1.1 (II)	3 (100%)	2	0	1	Radial Epiphyseal angle	8.75 ± 4.7	0.034
Metaphysis 20 (50%)	Proximal Humerus 3 (15%)	11-M/3.1	3 (100%)	3	0	0	Metaphyseal-diaphyseal angle	8.3 ± 9.4	0.026
	Proximal Ulna 1 (5%)	21u-M/3.1	1 (50%)	1	0	0		2.8 ± 3	0.073
	Distal Ulna 1 (5%)	23u-M/3.1	1 (50%)	1	0	0			
	Distal Radius & Ulna 6 (30%)	23-M/3.1	6 (100%)	5	1	1			
	Proximal Radius 1 (5%)	21r-M/3.1 (II)	1 (11.1%)	1	0	0		3.5 ± 2.5	< 0.05
	Distal Radius 8 (40%)	23r-M/3.1	8 (88.9%)	7	0	1			
N=40				33 (82.5%)	2 (5%)	5 (12.5%)			

Abbreviations: CR – closed reduction, OR – open reduction; P values have been compared to normative values (one-sample t-test)

Table 2 Flynn's criteria for supracondylar humerus fractures

Result	Rating	Cosmetic factor: Carrying angle	Functional factor: Motion Loss	Our Outcome
Satisfactory	Excellent	0-5	0-5	12 (70%)
	Good	>5-10	>5-10	3 (17%)
	Fair	>10-15	>10-15	2 (13%)
Unsatisfactory	Poor	>15	>15	0

Table 3 Functional Outcome Evaluation with Quick Dash Score

Score	Interpretation	Outcome
0-25	Excellent recovery, low disability	30 (75%)
25-50	Mild to moderate disability	10 (25%)
50-75	Severe disability	0
75-100	Extremely severe disability	0

Table 4 Paediatric quality of life outcome at 6 months follow-up

Domain	Mean ± SD	p-value
Physical Functioning	89.2 ± 6.8	<0.001
Emotional Functioning	84.5 ± 7.4	<0.001
Social Functioning	87.6 ± 6.2	<0.001
School Functioning	81.3 ± 8.1	0.003
Total Score	86.8 ± 6.3	<0.001

p-value derived using one-sample t-test comparing observed means to normative population value (mean=80)

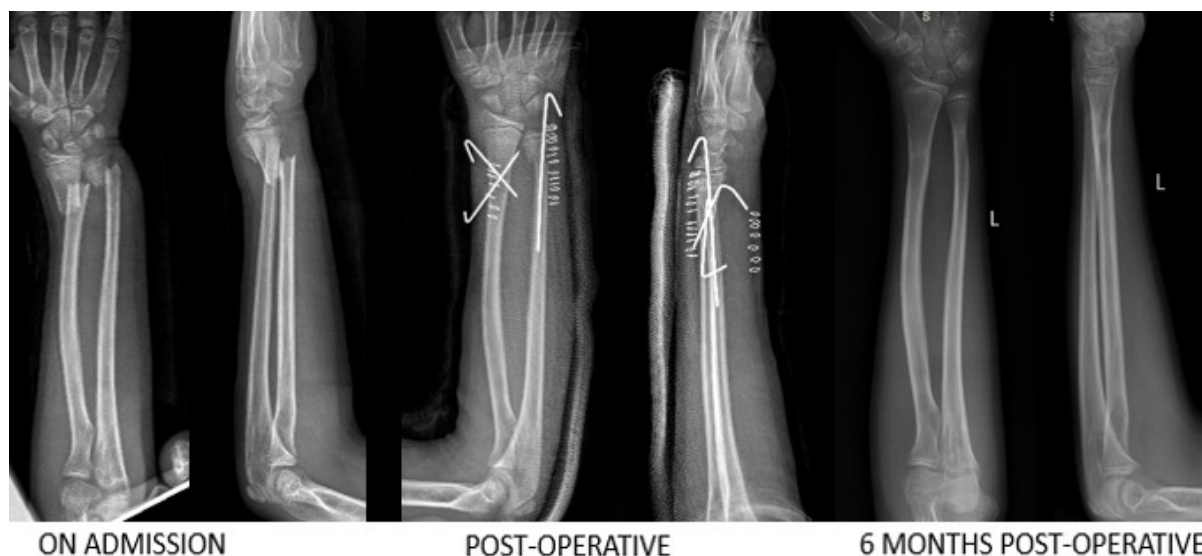
Figure 2 shows Supracondylar humerus fracture (AO 13-M/3.1, Gartland III) in a 10-year-old male. Failed initial CR, subsequently treated with CRPP under GA using the Mubarak maneuver and three lateral-entry K-wires. At 6 months: full ROM (range of motion) and normal Baumann's angle.



Figure 2 Proximal radial epiphyseal fracture (AO 21r-E/1.1, Judet II) in a 7-year-old female. Managed with CRPP using joystick technique and two K-wires. At 6 months: full elbow ROM and normal radial epiphyseal angle



Figure 3 Distal radius and ulna metaphyseal fracture (AO 23-M/3.1) in an 8-year-old female presenting after 1 week. CR unsuccessful; treated with OR and K-wire fixation (radius $\times 2$, ulna $\times 1$). At 6 months: full ROM at wrist and elbow with normal metaphyseal-diaphyseal angle.



Ten patients (25%) who underwent percutaneous pinning for SCHF or epiphyseo-metaphyseal fractures reported mild to moderate disability with decreased range of motion of the operated limb and pain at surgical site after removing cast at 4 weeks. Two-patients (13%) who underwent percutaneous pinning for supracondylar humerus fractures reported decreased range of motion at the elbow. Regular physiotherapy was required to improve mobility and improving results were seen at follow-up. Apart from this, no cases of deep infection, growth arrest, or permanent neurovascular deficit were noted in our study. No growth disturbance observed at 6 months.

Discussion:

The majority of the population studied was male, with male to female ratio 2:1 which is in line with the existing literature showing higher incidence of fractures among males due to increased outdoors activities [1]. No patients were excluded

after enrolment and no missing data were observed for primary outcomes, and all completed the required follow-up.

Closed reduction was successful with normal radiological parameters, good functional outcome and no major complications in the majority of cases (n=33, 82.5%). This proves the success of this minimally invasive technique, given proper expertise. Failed closed reductions, necessitating an open reduction were uncommon (n=7, 17.5%).

The 7 cases requiring open reduction, helped understanding factors contributing to closed reduction failure. In our study open reduction was required, particularly among supracondylar fractures, where 3 patients (7.5%) could not be managed with closed techniques. Of these, two had comminuted fracture patterns, while one had marked soft tissue swelling that made intraoperative manipulation difficult. Delayed presentation was another important factor. One patient with a distal

radius–ulna fracture presented after one week, and another with a radial neck fracture presented after two weeks; in both cases, early callus formation made closed reduction unsuccessful. In one distal radius–ulna fracture, a higher BMI of 23 (at risk of over-weight), made closed reduction technically challenging. Average BMI in our population was 19 (healthy). Additionally, a distal radius fracture with an intact ulna could not be adequately reduced due to bony overlap and mechanical restriction.

Taken together, these cases suggest that delayed presentation, fracture complexity, and soft tissue factors play a key role in the failure of closed reduction. Patients presenting more than 48 hours after injury often had increased swelling and bruising, which further complicated manipulation. Similarly, gross displacement, comminution, and complex fracture patterns were important predictors for the need for open reduction. These findings highlight the importance of early intervention and careful selection of cases for minimally invasive management as illustrated by Ulus et al. [19].

The mean Baumann's angle for supracondylar fractures was within normal limits, thus showing that proper coronal alignment has been achieved [20, 21], similar to the results reported by Hasan et al [13]., who emphasized that maintaining Baumann's angle is critical in preventing cubitus varus deformity. Clinically the patients were assessed via Flynn's criteria [21] and we achieved satisfactory results, with the majority classified as excellent or good. A smaller proportion, 2 (13%), demonstrated mild to moderate residual limitation in range of motion at the elbow

with loss of $>10-15^\circ$ while no patients had worse outcomes. These patients subsequently underwent structured physiotherapy, which led to significant improvement in elbow mobility and overall function during follow-up. No additional interventions were required.

Patients with epiphyseo-metaphyseal fractures were assessed with Epiphyseo-metaphyseal and Metaphyseal-diaphyseal angles. All radiological parameters were within normal range. Quick DASH scoring was done to evaluate functional outcome of all cases involved [22]. It showed a promising outcome with majority of the patient having excellent functional recovery with a few patients suffering from mild to moderate disability. Overall, the findings indicate favourable functional recovery in most patients, minimal residual deformity, and good restoration of limb function following treatment, supporting the effectiveness of closed reduction percutaneous pinning over other treatment modalities for epiphyseo-metaphyseal fractures [21].

The high PedsQL scores observed in this study indicate favourable physical and psychosocial recovery, supporting the effectiveness of minimally invasive surgical management in improving overall quality of life in paediatric patients [23]. These findings correlate with the excellent and good functional outcomes assessed by Flynn's criteria, as well as with mild to moderate disability observed with quick DASH score thus suggesting that restoration of anatomical alignment and function translates into improved patient-reported outcomes.

A smaller proportion, 10 (25%), demonstrated mild to moderate residual

limitation restricted range of motion of the arm and pain at surgical site after removal of cast at 4 weeks. These patients subsequently underwent structured physiotherapy, which led to significant decreased pain and improvement in mobility, and overall function during follow-up. No additional interventions were required.

The results highlight that these treatment modalities not only have comparable post-operative radiological parameters but also have better patient satisfaction with the least complications, reduced blood loss, exposure, infection rate and heterotopic calcification in open surgeries. It gives valuable insight into the current practices and outcomes, thereby emphasizing the importance of minimally invasive fixation as the treatment of choice for paediatric upper limb fractures as demonstrated by recent meta-analysis, that closed reduction and percutaneous pinning provides outcomes comparable to open reduction for paediatric supracondylar fractures, with lower soft-tissue complications and improved cosmetic results [24].

The present study did not perform a direct comparison between closed and open reduction techniques because the choice of fixation method was primarily determined by fracture pattern, anatomical location, skin condition and stability, rather than surgeon preference. Similar methodological approaches have been reported in previous paediatric fracture studies, where outcomes of minimally invasive fixation techniques were evaluated descriptively without direct comparison due to heterogeneity of fracture types and treatment indications. Several retrospective series evaluating

CRPP for supracondylar fractures have reported outcomes independently rather than comparatively, emphasizing safety, union rates, and complication profiles within each modality [25]. Furthermore, retrospective observational studies with limited sample sizes are often not powered for subgroup comparison, and performing statistical comparisons may introduce bias. The aim of the present study was therefore to evaluate overall clinical and radiological outcomes of minimally invasive fixation strategies in paediatric upper limb fractures rather than establish superiority of one technique over another. Future prospective comparative studies with homogeneous fracture patterns are required to allow meaningful comparison between treatment modalities.

Limitations: Retrospective design. with a potential selection and information bias, short minimum 6 month follow up, precludes assessment of late growth disturbances or remodelling; single-centre study with modest sample size.

Recommendation: CRPP should remain the first-line treatment modality in patients with epiphyseo-metaphyseal fractures of upper limb in paediatric age. Prospective studies with longer follow-up are needed to confirm long-term outcomes.

Conclusion

Closed reduction and percutaneous fixation in paediatric epiphyseo-metaphyseal fractures of upper limb showed satisfactory outcomes, both clinically and radiologically, with minor complications and highlighting the factors that lead to failure of closed reduction. The findings also demonstrated favourable paediatric quality of life outcomes, with

high PedsQL scores indicating good physical and psychosocial recovery following treatment.

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Conflict of Interest

None Declared

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