Percutaneous cross-pinning versus two lateral entry pinning in Gartland type III pediatric supracondylar humerus fractures

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Background

Supracondylar humerus fracture is the most common elbow fracture in children aged 5–7 years, affecting boys more than girls and the majority of fractures are of the extension type. These fractures are usually associated with a number of complications including neurovascular injuries, malunion, and elbow stiffness. Gartland type III fractures are usually treated by closed reduction and percutaneous pinning.

Patients and methods

A prospective study was carried out on children with Gartland type III extension-type supracondylar humerus fractures. The patients were randomized to undergo fixation either with crossed pinning (group A) or two lateral pinning (group B). We compared both groups with regard to their passive elbow range of motion, Flynn's criteria, Baumann's angle, change in Baumann's angle, and Skaggs method of grading of loss of reduction and complications.

Results

Group A included 33 patients with a mean age of 5.4 years and group B included 34 patients with a mean age of 4.9 years. Group B had a statistically significant shorter operative time and radiation time. At final follow-up, there were no statistically significant differences between group A and group B with respect to the average Baumann's angle, change in the Baumann angle, range of elbow motion, Flynn's grade, or Skaggs criteria. There were no cases of iatrogenic ulnar nerve injury in both groups.

Conclusion

If a standardized operative technique is followed in each method, then the result of both methods will be same in terms of safety and efficacy. Orthopedic surgeons treating unstable pediatric supracondylar humerus fractures should be familiar with both pinning techniqus.

Keywords:

crossed pinning, Gartland type III, iatrogenic ulnar nerve palsy, lateral entry pinning, percutaneous pinning, supracondylar humerus fracture

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Introduction

Pediatric supracondylar humerus fracture accounts for 55–80% of elbow fractures in children. It commonly occurs in children of 5–7 years old, boys more than girls and the majority of fractures are of the extension type (98%). Management of these fractures aims at avoiding early and late complications. In fractures associated with an absent radial pulse, emergent reduction, and fixation of the fracture should be undertaken [1–10].

A high risk of developing compartment syndromes of the forearm occurred in children who undergo vascular repair and those who sustain supracondylar fractures with diaphyseal forearm fractures [1,6,11,12].

Nerve injury commonly affects anterior interosseous nerve injury which is the most common, followed by median, radial, and ulnar nerves and usually the deficit is temporary neuropraxia that resolves within 6–12 weeks. Iatrogenic ulnar nerve injuries may follow percutaneous K-wiring. Cubitus varus is the most frequent complication of supracondylar fractures and usually result from malunion and not growth disturbance [2,6,13].

Extension-type pediatric supracondylar humerus fractures are classified according to Gartland into three types: type I, undisplaced; type II, displaced with the posterior cortex intact; this type may be subclassified into type IIA: simple posterior angulation and type IIB: angulation plus malrotation. Type III, completely displaced with no cortical contact, which may be subdivided into posteromedial IIIA or posterolateral IIIB [2,6,14,15].

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The recommended method of treatment for displaced Gartland type II and type III fractures is closed reduction and percutaneous pinning. Some authors use two lateral wires and other authors recommend two crossed wires, one through the medial condyle and one laterally. Crossed pinning provides increased biomechanical stability, but it carries the risk of iatrogenic ulnar nerve injury from the placement of the medial pin. Two 'divergent' lateral pins or three lateral pins are equivalent in terms of rotational stability to crossed pins [2,3,7,8,14,16–21].

There are certain tricks to avoid ulnar nerve injury during medial K-wire stabilization. A mini-open technique is helpful to localize the medial epicondyle. The medial wire should be inserted with the elbow in extension and intraoperative pin stimulation at 2 mA may assist in the placement of the medial pin [5,16,22–24].

Injuries treated as emergencies include open fractures, fractures with abnormal vascular status, and fractures that are at particularly high risk of compartment syndrome. Open reduction is performed if an adequate reduction cannot be obtained by closed manipulation. Open reduction leads to a longer union time, significantly reduced the range of motion (ROM) of the elbow, and poorer functional outcomes [1,6,25–29].

The aim of our study is to compare the functional and radiological results of crossed medial and lateral entry percutaneous pinning versus two lateral entry percutaneous pinning in the management of Gartland type III extension-type supracondylar fractures of the humerus in children.

Patients and methods

This study was exempt according to the Institutional Review Board (ethics committee) of our institution. Informed consent was obtained from the parents of patients that their data may be published. In the period from June 2013 to October 2015, a randomized, prospective, consecutive clinical follow-up study was carried out on patients with Gartland type III extension-type supracondylar fractures of the humerus in children.

All children with supracondylar fractures of the humerus were included in our study if they had the following inclusion criteria: (a) age between 3 and 9 years, (b) unilateral fracture, (c) Gartland type III extension type, (d) no other associated injury in the same limb, and (e) no previous fracture in the same limb. Patients were excluded if they fulfill the following exclusion criteria: (a) age less than 3 years or greater than 9 years, (b) bilateral fracture, (c) flexion type, (d) associated injury in the same limb, (e) previous fracture in the same limb, (f) open fracture, (g) fracture requiring open reduction, and (h) associated neurovascular injury requiring surgical exploration.

During the study period, 122 children were treated for Gartland type III extension supracondylar fracture of the humerus. Ninety-one patients met the inclusion criteria and were included in our study. The patients were randomized into two groups by the concealed envelope technique: 45 children in group A crossed pinning technique and 46 children in group B two lateral pinning technique. Twelve patients in each group missed the follow-up. Thus, the study population consisted of 67 patients. Group A comprised 33 children and group B comprised 34 patients.

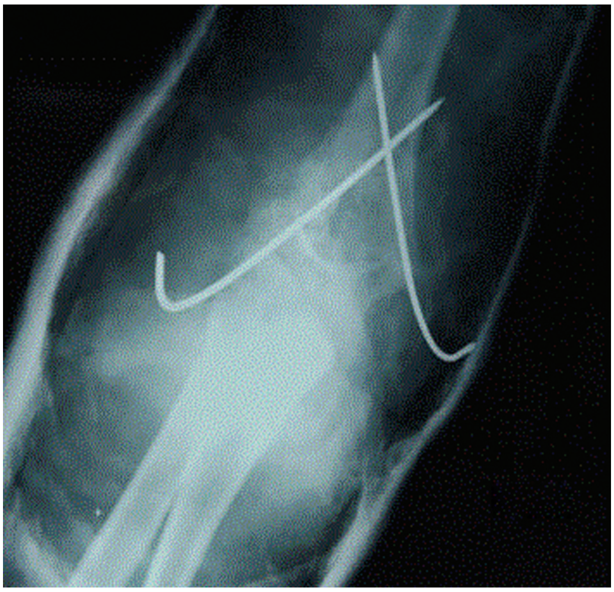
Surgical technique

All procedures were done under general anesthesia. Parenteral first-generation cephalosporins was injected on induction of anesthesia. The child was positioned supine with the fractured elbow on the image intensifier of the fluoroscopy unit as a table. Draping was done in the usual manner. Closed reduction was performed under the image guide. Following a successful reduction, the reduction was checked by image guidance. Markers of satisfactory reduction: (a) the anterior humeral line intersects the capitellum, (b) Baumann's angle is greater than 10°, (c) the medial and lateral columns are intact on oblique views. The lateral pin was always inserted first in both groups.

In the two lateral entry pin group, the two lateral wire was inserted with the elbow in hyperflexion. The wires were angulated at about 10–15° posteriorly, inserted in the lateral and central columns either in divergent or parallel manner, and engaged both lateral and medial cortices (Figs 1–6).

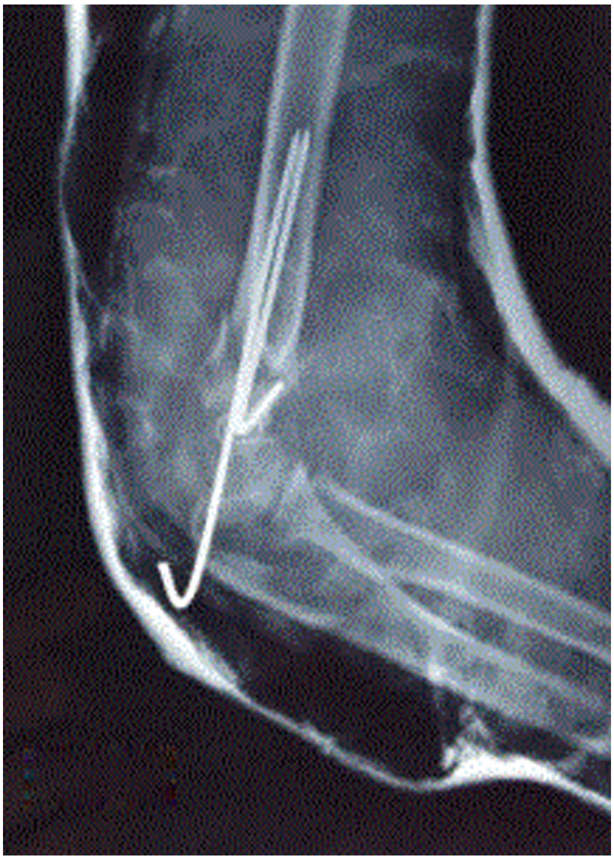
In the crossed pin group, after insertion of the lateral pin, the elbow was partially extended to less than a 90° position to avoid injury of anteriorly subluxing ulnar nerve. A small 1.5–3.0 cm incision is made over the medial epicondyle with blunt dissection to the bone and the wire was placed through the medial epicondyle, not the ulnar groove (Figs 7–11).

Figure 1



Postoperative radiograph, AP view; crossed wiring. AP, anteroposterior.

Figure 2



Postoperative radiograph, lateral view; crossed wiring.

Figure 3

Final follow-up radiograph, AP view; crossed wiring. AP, anteroposterior.

Figure 4

Final follow-up radiograph, lateral view; crossed wiring.

In both groups and after insertion of the wires, the reduction was again checked under fluoroscopy with lateral, oblique, and anteroposterior (AP) views, and stressed in varus and valgus. The wires were bent and cut 1–2 cm from the skin and above-elbow cast was applied in 45–70° elbow flexion and neutral forearm rotation.

Figure 5

Final follow-up, clinical photograph; crossed wiring: full extension.

Postoperative care

In the immediate postoperative period, the patients were evaluated clinically for the neurovascular state, and radiologically AP and lateral radiograph of the affected elbow. Regular outpatient clinic visits were at the 1st, 3rd, 6th, and 12th week postoperatively. At the 1st week AP and lateral radiographs are obtained to ensure pin fixation and fracture alignment had not changed. At the 3rd week visit, the cast and wire were removed and radiographs were obtained out of the cast. Gentle ROM exercises were started after cast removal. At the 6th week visit, the ROM were checked and advise for physiotherapy was given if there was limited ROM. At the 12th week visit, final evaluation of radiological and functional results were done.

Figure 6

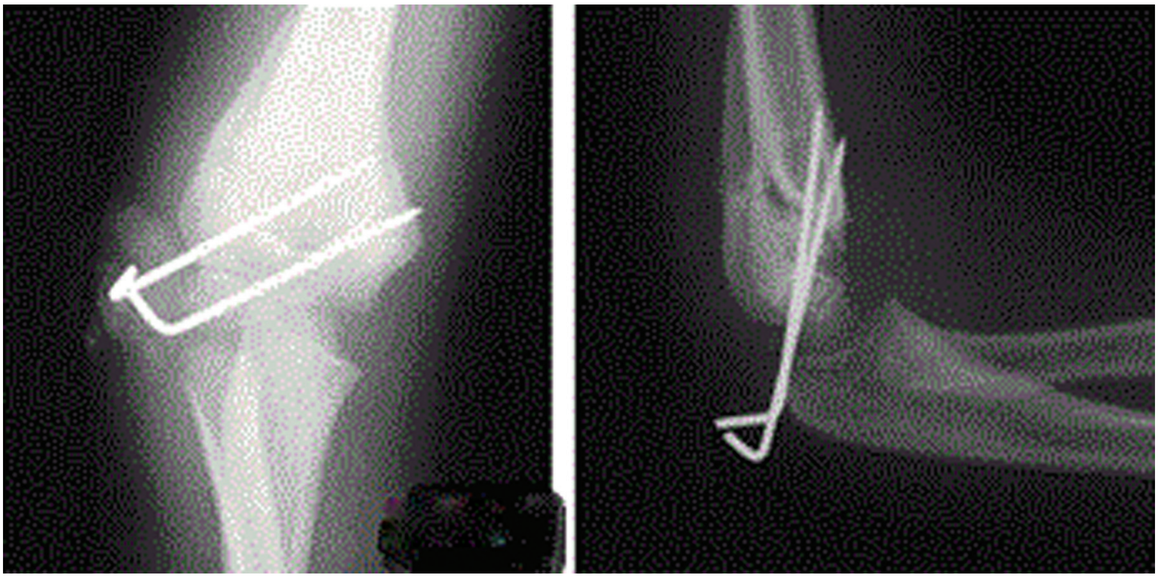
Final follow-up clinical photograph; crossed wiring: full flexion.

Methods of evaluation

Two authors examined all patients and the following information were recorded: (a) neurologic and vascular examination of the extremity, and determination of any complications, (b) carrying angle on both sides with a goniometer, (c) passive range of elbow motion for both sides with a goniometer, (d) Flynn's criteria (Table 1), which are based on the carrying angle and elbow motion, (e) Baumann's angle, (f) change in Baumann's angle between immediate postoperative radiograph and 12th week follow-up radiograph, and (g) grading of loss of reduction, based on the method described by Skaggs *et al.* [30] (Table 2) [7].

The original Baumann's angle is subtended by the longitudinal axis of the humerus and a line through the coronal axis of the capitellar epiphysis and has a mean value of 70° (range, 64–81°). The complementary angle is usually used with the normal value being 15–20. Radiological comparison with the opposite limb is recommended (Fig. 12) [31,32].

Figure 7



Postoperative radiograph, AP and lateral views; lateral wiring. AP, anteroposterior.

Statistical analysis

Statistical tests were done by using parametric and nonparametric analyses as appropriate for the data. The independent sample Student's *t* tests, χ^2 tests, Mann–Whitney *U* test were performed with use of SPSS 16.0 software (IBM SPSS, Armonk, NY, USA). A *P* value of less than 0.05 was considered to be statistically significant.

Results

The crossed entry group A and the lateral entry group B were similar in terms of mean age, sex distribution, and side of the fracture. Group A included 33 patients with an average age of 5.4±1.7 years (range, 3–9 years), 24 were men (72.7%) and the left side was fractured in 23 (69.7%) patients. Group B included 34 patients with an average age of 4.9±1.3 years (range, 3–7.5 years), 21 (61.8%) were men and the left side was fractured in 19 (55.9%) patients. There were no statistically significant differences in the average age (P=0.180), side of fracture (P=0.242), or sex (P=0.339) between our two groups.

Compared with group A, group B had a statistically significant shorter operative time and radiation time. The average operative time was 59.1±7 min in group A versus 50.6±8 min in group B (P=0.000). The average radiation time was 1.2±0.3 s in group A versus 0.8±0.1 s in group B (P=0.000).

At final follow-up, there were no statistically significant differences ($P>0.05$) between group A and group B with respect to the average Baumann's angle (P=0.081), change in the Baumann angle (P=0.121), range of elbow motion (P=0.795), Flynn's grade (P=0.541), or Skaggs criteria (P=0.548).

The final elbow ROM averaged 127.8±2.7° in group A and 127.6±2.6° in group B. In group A, one patient had lost more than 10° flexion, one patient had lost more than 15° of flexion with the average loss of ROM being 3.7±2.9° and no cubitus varus deformity. In group B, two patients had lost more than 10° flexion, with the average loss of ROM being 3.9±2.2° and one patient had cubitus varus (carrying angle, −6°). According to the Flynn criteria, group A had 27 excellent, four good, one fair, and one poor results while group B had 25 excellent, six good, two fair, and one poor results. Overall, group A had a satisfactory outcome in 32 (97%) of the 33 elbows and an unsatisfactory outcome in one (3%) elbow, while group B had a satisfactory outcome in 33 (97.1%) of the 34 elbows and an unsatisfactory outcome in one (2.9%) elbow.

Group A had final Baumann's angle averaged 16.5 ±3.8° and the average change in the Baumann angle was 2.8±1.6°, while in group B patients the average Baumann's angle was 15±3.4° and the average change in the Baumann angle was 3.6±2.4°. According to the Skaggs criteria, in group A, there were 31 (93.9%) patients with no loss of reduction, two (6.1%) patients with mild loss of reduction, and no patient had a major loss of reduction. In group B, there were 30 (88.2%) patients with no loss of reduction, three (8.8%) patients with mild loss of reduction, and one (3%) patient had a major loss of reduction.

Figure 8

Final follow-up radiograph, AP view; lateral wiring. AP, anteroposterior.

Figure 9

Final follow-up, radiograph lateral view; lateral wiring.

There were no cases of iatrogenic ulnar nerve injury in either group and no cases of superficial or deep infections.

Discussion

Supracondylar fracture of the humerus is a common childhood injury and accounts for 55–80% of all fractures around the elbow joint and mostly occurs in children around 7 years of age and usually result from a fall on an outstretched arm [33–35].

Nerve injuries have been reported in 12–20% and they mainly consist of neurapraxias. Absent radial pulse has been reported in 10–20% of children with a displaced supracondylar humerus fracture. Brachial artery lesion may be due to entrapment, division, spasm, intimal tear, or thrombus formation. Urgent brachial artery exploration is indicated in pale pulseless limb. For pink pulseless hand, some authors recommended observation claiming that the rich collateral circulation is sufficient for the viability of the arm, other authors recommended exploration of the cubital fossa only if intraoperative angiographic evaluation showed a brachial artery injury and some authors preferred surgical exploration in all cases [1,33,36–44].

According to Gartland's classification, extension pediatric supracondylar fractures of the humerus can be distinguished in three types: type I, incomplete fracture without displacement; type II, moderate displacement with intact posterior cortex; while in type III, there is no contact between the fracture ends. Closed reduction and percutaneous pinnig is the treatment of choice for Gartland type III, but controversy exists for the optimal pin configuration [7,8,22,33].

Crossed pinning had superior biomechanical stability to lateral pinning, but it carries the increased risk of iatrogenic ulnar nerve injury. On the other hand, lateral pinning has less risk of iatrogenic ulnar nerve injury, but with less biomechanical stability. Some authors claimed that three lateral entry pins or two lateral entry pins that are divergent and are located in both the lateral and the central column provide torsional rigidity similar to that achieved with the crossed pinning [16–20,45–47].

Figure 10

Final follow-up, clinical photograph; lateral wiring: full extension.

Sankar and colleagues identified important technical errors associated with loss of fracture reduction after lateral entry pin fixations. These errors include failure to engage both fragments with at least two pins, failure to achieve bicortical fixation with at least two pins, and failure to achieve more than or equal to 2 mm of pin separation at the fracture site. They advised checking the stability of fixation by stressing the fracture under fluoroscopy at the completion of the procedure and when instability found a third lateral pin or a medial pin was added [48].

In a retrospective review of 622 patients after pinning of supracondylar distal humerus fractures, Bashyal and colleagues found a total of 32 (5.1%) complications. The most common complication was pin migration (1.8%) total infection rate of 1.0%, one (0.2%) patient had a malunion, three (0.5%) patients developed compartment syndromes, and only one (0.3%) postoperative ulnar nerve injury occurred with a medial pin [49].

Cubitus varus deformity developed in 5–10% of children with supracondylar humerus fractures irrespective of the treatment. Most studies attribute the deformity as a result of malunion. However, surgical treatment has had a marked effect on decreasing the incidence of this deformity [50–52].

The incidence of iatrogenic ulnar nerve injury after medial pinning ranges from 1.4 to 15.6%. Ulnar nerve

Figure 11

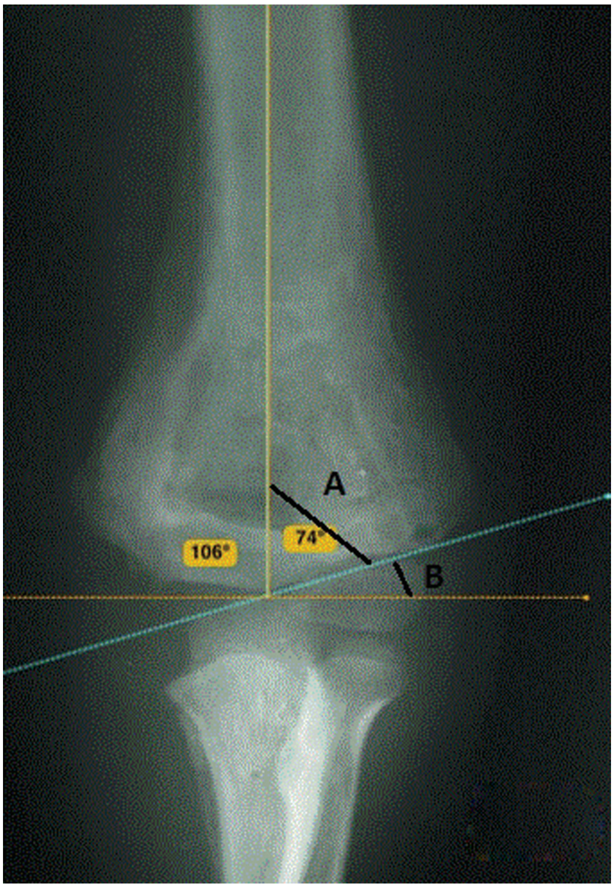
Final follow-up, clinical photograph; lateral wiring: full flexion.

is vulnerable to injury with elbow flexion because in this position it subluxes over the medial epicondyle. Several precautions are suggested to eliminate the risk of ulnar nerve palsy including fixation from the lateral side only, a small incision over the medial epicondyle for direct visualization, insertion of medial pin with elbow in

Table 1 Flynn's criteria

Results	Rating	Cosmetic loss of carrying angle (deg.)	Functional loss of motion (deg.)
Satisfactory	Excellent	0–5	0–5
	Good	5–10	5–10
	Fair	10–15	10–15
Unsatisfactory	Poor	>15	>15

Figure 12



Baumann's angle; angle A is original Baumann's angle and angle B is more commonly used currently. Normal is 15–20° and equal to the opposite side.

some extension, and attachment of the nerve stimulator to medial pin to localize the ulnar nerve [22,23,45,53–57].

Delayed pinning for up to 12 h does not result in unsatisfactory outcomes of closed, displaced suprac condylar humerus fracture (SCHF) in children who present without vascular compromise [27–29,58,59].

Crossed pin fixation has been compared with lateral entry pin fixation in numerous studies. Skaggs and colleagues reported no difference in maintenance of reduction between the two methods, but iatrogenic ulnar nerve injury was seen in 7.7% of cases treated with

Table 2 Skaggs criteria for grading loss of reduction

Loss of reduction grading	Change in the Baumann angle (deg.)
None	<6
Mild	6–12
Major	>12

a medial pin compared with no injuries in their lateral wire group. In a study of 27 patients treated with crossed pins compared with 20 patients treated with lateral pins only, Topping and colleagues found no loss of reduction in either group and one ulnar nerve injury in the group with crossed pins. Similarly, in a study of 56 fractures, Shamsuddin and colleagues found three iatrogenic ulnar nerve injuries associated with crossed pin fixation and two iatrogenic radial or anterior interosseous nerve injuries associated with lateral entry pin fixation, although there was no difference in loss of reduction. Foead and colleagues performed a randomized clinical trial in which 34 fractures were treated with medial and lateral pin fixation and 32 were treated with lateral pin fixation. There were no significant differences in terms of loss of reduction, the Baumann angle, or elbow motion between the two groups. There were five iatrogenic ulnar nerve injuries in the medial and lateral entry group, and there were two iatrogenic ulnar nerve injuries and one iatrogenic radial nerve injury in the lateral entry group [16,20,60–62].

In a systematic review of the literature, Brauer and colleagues reported five times higher risk of ulnar nerve injury, but 0.58 times lower risk of loss of reduction with crossed pinning. Kocher and colleagues compared lateral entry pins (28 patients) with medial and lateral entry pins (24 patients) and found no significant difference between these two pin-fixation techniques in terms of loss of reduction or iatrogenic ulnar nerve injury [20,63].

We carried a prospective, randomized study to compare the functional and radiological results of crossed medial–lateral K-wire fixation with two lateral entry K-wires fixation in Gartland type III extension supracondylar fractures of the humerus in children. At final follow-up, we found no statistically significant differences between both groups with respect to the average Baumann's angle, change in the Baumann angle, the range of elbow motion, Flynn's grade, and Skaggs criteria. We had no case of iatrogenic ulnar nerve injury in our series possibly because the medial pin was inserted with the elbow in some extension through a small skin incision over the medial epicondyle.

In our study, group B had a statistically significant shorter operative time and radiation time. This is quite expected since in lateral pinning both wires were inserted with the elbow in hyperflexion one after each other with no change in position of the elbow. The first wire acts as a guide to the second wire, so minimal radiation was required.

Conclusion

In conclusion, there was no significant difference in complications, the ROM, and radiographic alignment between the crossed pin group A and lateral pin group B. Ulnar nerve palpation, placing the elbow in some degree of extension during pin insertion, and mini-open technique can aid in a safer medial pin placement. If a uniform standardized operative technique is followed in each method, then the result of both the percutaneous fixation methods will be same in terms of safety and efficacy. Orthopedic surgeons treating unstable pediatric supracondylar humerus fractures should be familiar with both medial and lateral pin placement.

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Conflicts of interest

There are no conflicts of interest.

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