Open Versus Percutaneous Cross K-Wires Fixation for Displaced Supracondylar Fractures of the Humerus in Children

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ABSTRACT

Background: Supracondylar fractures of the humerus are common injuries in children. It represents 17% of all childhood fractures. The peak age of fracture is 5 to 7 years. The vast majority of supracondylar fractures of the humerus are of extension type (97%). Flexion-type injuries also occur but it is rare (3%).

Objective: To compare the outcome results of surgical closed reduction to open reduction with cross-pinning fixation in Gartland type II and III extensions type supracondylar humeral fracture in children.

Methods: During the period between February 2014 and March 2016, we made a case-series study of (20) patients collected from the emergency unit of Al-Kindy Teaching Hospital, suffered from Gartland type II and III supracondylar humeral fracture extension type. They were managed surgically with either closed reduction (10 children) or open reduction (10 children), both with cross pinning fixation. The study includes (13) boys and (7) girls with a mean age of (6) years. We chose two surgical means of fixation; open and percutaneous randomly and we tried to compare between the two.

Results: All the (20) patients were followed-up, clinically and radiographically evaluated pre-surgery, post-surgery and finally (6) months after surgery. Radiologically, after surgery in both groups anterior humeral lines cross the capitellum in all patients. At the same time all Baumann's angles were in the normal range, and in comparison with contralateral side all differences less than 5º except one case treated by percutaneous method it was about 6º difference. At the last follow-up (after 6 months), patients were assessed functionally according to Flynn's criteria. Range of motion in flexion, extension of the elbow was the functional parameter in our study in addition to carrying angle as graded by the Flynn's grading system. In open surgery group**:** we obtained an outcome of excellent results in (8) patients (80%), good results in (1) patient (10%) and fair in (1) patient (10%). In percutaneous surgery group: we obtained an outcome of excellent results in (8) patients (80%), good results in (2) patients (20%). The results in both groups were satisfactory and we have no poor results in both.

Conclusions: In spite of approximated results, a long list of advantages make percutaneous method as an effective modality of surgical treatment in comparison with open method. Closed reduction with percutaneous pinning is believed to represent a reliable method of managing displaced supracondylar fractures in children, reduces hospitalizations, physical therapy, with less complications and faster return to daily activities of children. Giving good and excellent results.

Keywords: Supracondylar fractures, Pediatric humerus injuries, Open reduction, Percutaneous cross pinning, Extension type, Gartland classification.

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Supracondylar fracture in children is an extra-epiphyseal fracture of the distal humerus just above the epicondyles. While relatively rare in adults, it is one of the most common fractures to occur in children.

It accounts for about 65% of upper extremity fractures in 3-10 year age group in children, generally occur as a result of a fall onto an outstretched hand with the elbow in full extension.

Types:

A- Extension type: about 97%.

B- Flexion type: about 3% [(1)].

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Classification:

Gartland's classification, 1959:
Type I: Undisplaced.
Type II: Displaced with intact posterior cortex.
Type III: Displaced, no cortical contact.
Wilkin's modification of Gartland's classification established at 1984 [2, 3].

Supracondylar fracture is a fracture near the distal end of humerus, at transformation zone, where shape changes from tubular to flat, and fracture line crosses just proximal to the articular surface. This local anatomy makes it difficult to achieve satisfactory reduction and more so to maintain it [4].

The periosteum most commonly fails anteriorly with extension type.
The direction of displacement has implications for which neurovascular structures are at risk from the penetrating injury of the proximal metaphyseal fragment.
The ulnar nerve courses through the cubital tunnel posterior to the medial epicondyle, it is at particular risk when a medial pin is placed for fracture fixation.
The majority of supracondylar fractures of the humerus (other than extension type I fractures) are unstable; therefore, stabilization in the form of operative fixation is usually necessary [5].

Several treatment modalities have been recommended previously but recently closed manipulation and percutaneous K-wire stabilization is widely used treatment now for this condition, there is no general consensus about optimal configuration of the K-wires. The two-wire cross fixation is frequently used and good results have been reported [1, 6].

The physis of the distal humerus contributes little to the overall growth of the humerus (20% of the humerus); therefore, the remodeling capacity of supracondylar fractures of the humerus is limited. Near-anatomic reduction of these fractures is important.

This indicates getting normal anatomical lines and angles to attend best anatomical union of the fracture[5]. This include:

(1) Baumann angle: also known as the (humeral-capitellar angle), this angle is formed by the humeral axis and a straight line through the epiphyseal plate of the capitulum, (Figure 1-A). It is measured on a frontal radiograph, with elbow in extension.

It is used for the evaluation of the displacement of paediatric supracondylar humeral fractures and will reliably predict final carrying angle after reduction.

A value between (64-81º) is considered normal. But due to significant variation between individuals, Baumann's angle is better evaluated by comparison to the contralateral side. A difference of more than 5° between the two sides is considered abnormal and suggests a coronal plane deformity [7].

(2) Anterior humeral line: A line drawn on a lateral view along the anterior surface of the humerus should pass through the middle third of the capitellum, (Figure 1-B).

It is commonly used to evaluate sagittal alignment after fracture reduction in children with supracondylar humeral fractures.

In cases of a supracondylar fracture the anterior humeral line usually passes through the anterior third of the capitellum or in front of the capitellum due to posterior bending of the distal humeral fragment.Children with AHL crossing the middle and posterior thirds of the capitellum appear to have slightly better early elbow flexion and total range of elbow motion[8].

Normal ranges of elbow movements are variable with different references but generally elbow extension = 0-5°, elbow flexion = 140-150° [9].

In our study we follow a standard of (0°) extension, (150°) flexion, normal carrying angle in children (5-15years) is about (5-15°): Approximately: male= 7°, female= 8°.

This degrees increase with age till reach about 15 years old [10].

At the last follow-up after (6) months patients were assessed both radiologically for union and alignment and functionally according to Flynn's criteria, (Table 1). Comparison of postoperative carrying angle and range of motion were performed using a Goniometer to record elbow flexion-extension and the carrying angles of both arms.

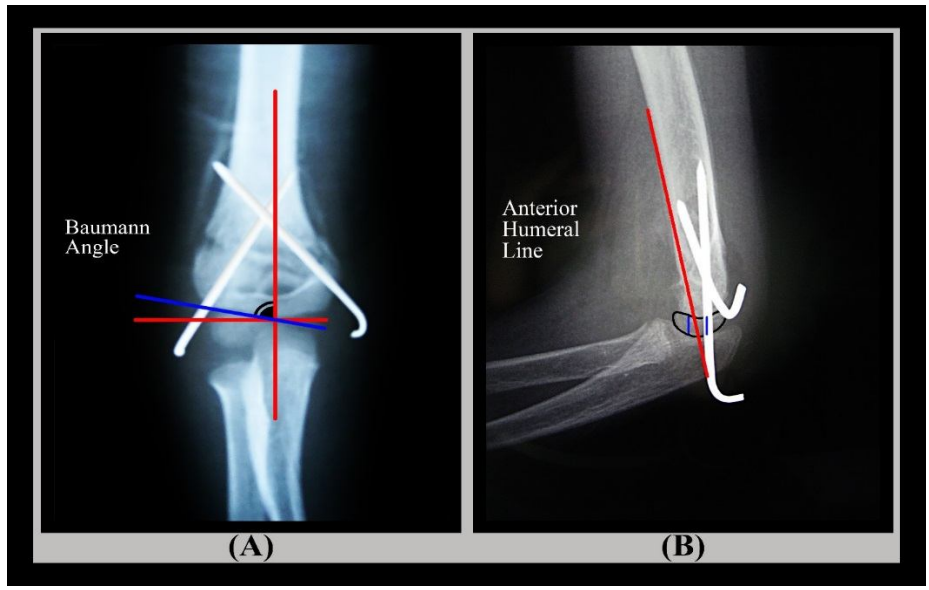

Figure 1: Anatomical angle and line measurement (A) Baumann angle. (B) Anterior humeral line.

Table 1: Flynn's criteria (functional grading system).

(Flynn's Criteria)			
Results	Rating	Loss of carrying angle (°)	Loss of elbow motions (flexion-extension) (°)
Satisfactory	Excellent	0-5	0-5
	Good	6-10	6-10
	Fair	11-15	11-15
Unsatisfactory	Poor	>15	>15

These criteria are used to compare the motion (flexion-extension arc) and carrying angle of the affected and unaffected elbows. This is the most rigorous grading method in the literatures and is recommended to facilitate comparative studies. The function is graded in 5 degree intervals of loss of the total arc of flexion and extension, and the cosmetic appearance of the elbow is graded in 5 degree intervals of change in the carrying angle. A small change in the carrying angle in such cases may lead to a varus elbow, and, by definition, a poor result[11,12].

The purpose from the study was to compare between the two methods, regarding technique of the operation, post-operative morbidity, complication rates and functional results.

Methods

Between February 2014 and March 2016, we presented a prospective study of 20 children with Gartland type II and III supracondylar humeral fractures extension in type severe that require surgery were

seen at Al-Kindy Teaching Hospital and managed with surgical closed or open reduction, both with cross pinning fixation. The study included 13 boys (65%) and 7 girls (35%) with an age range from 4 to 10 years, (mean= 6 years.).

On presentation, patients underwent thorough clinical assessment with special attention to peripheral circulation and neurological status. The selection of surgical procedure was done randomly.

Closed reductions of fractures (utilizing image intensifier) were performed in (10) patients (50%). Open reductions of fractures were performed in (10) patients (50%). All patients underwent fracture management within first (12) hours of the trauma.

All patients had isolated supracondylar fracture without associated neurovascular injury or other associated injuries. There were no known preoperative median, radial or ulnar nerve injuries in the study cohort and in all cases radial pulse were positive.

All patients had normal contralateral upper limb and this help us in comparison of x-rays and movements. Follow-up cases range from 6-8 months with mean of (7) months at the outpatient unit.

The following patients were excluded from our study:

1) Six patients lost from follow-up four percutaneous and two open. 2) Two patients end with failure of percutaneous fixation changed to open.

Mean time of surgery was about (45) minutes for open type and (17) minutes for percutaneous type. All operations were performed by the same surgeon.

Care was taken for postoperative neurological assessment of median, ulnar, and radial nerves function.

Period of hospitalization was (2) days in open surgery group and (1) day for percutaneous surgery group. All patients checked for neurologic, vascular status and soft tissue condition before discharged from hospital.

Procedures: (A) Closed reduction and percutaneous pinning of supracondylar fracture (crossed medial and lateral pins): We placed the patient supine on a fracture table, prepare and drape the elbow on the radiolucent arm board of the C-arm which is used to support the elbow.

We reduce the fracture by applying longitudinal traction with the elbow in 20º-30º of flexion to prevent tethering of the neurovascular structures over the anteriorly displaced proximal fragment; extending the fracture; and manipulating with the thumbs to correct lateral tilt, medial impaction, or posterior displacement. The elbow is gradually flexed while applying anterior pressure on the olecranon (and distal condyles of the humerus) with the thumbs. With full flexion we take a transcondylar view (Jones View). Checking later anteroposterior and lateral reduction with the aid of an image intensifier.

Under the control of image intensifier, we insert a lateral pin across the fracture site and engage the medial cortex (Figure 2 A and B). After the lateral pin insertion, extend the elbow to 45 degrees of flexion. Identify the medial epicondyle and ulnar nerve sites. Insert a medial pin through the apex of the medial epicondyle across the fracture site to engage the lateral cortex (Figure 3A). Lastly we cut off the pins outside the skin and bend the pin tips [13].

(B) Open reduction and cross pinning of supracondylar fracture by posterior approach: The standard posterior Campbell's approach was used in all patients. Ulnar nerve was identified but not isolated. Triceps muscle was vertically split to expose fractured site and clearly visualize it. Fracture was reduced manually. Once good reduction was confirmed the lateral pin was placed at the center of lateral epicondyle obliquely across fracture site to engage the opposite cortex of the proximal fragment. The medial pin placed second through the apex

of the medial epicondyle. The fractures were secured with 1.5-2.0 mm K-wires depending upon the size and age of the patient (Figure 3 B). Tourniquet released lastly [14].

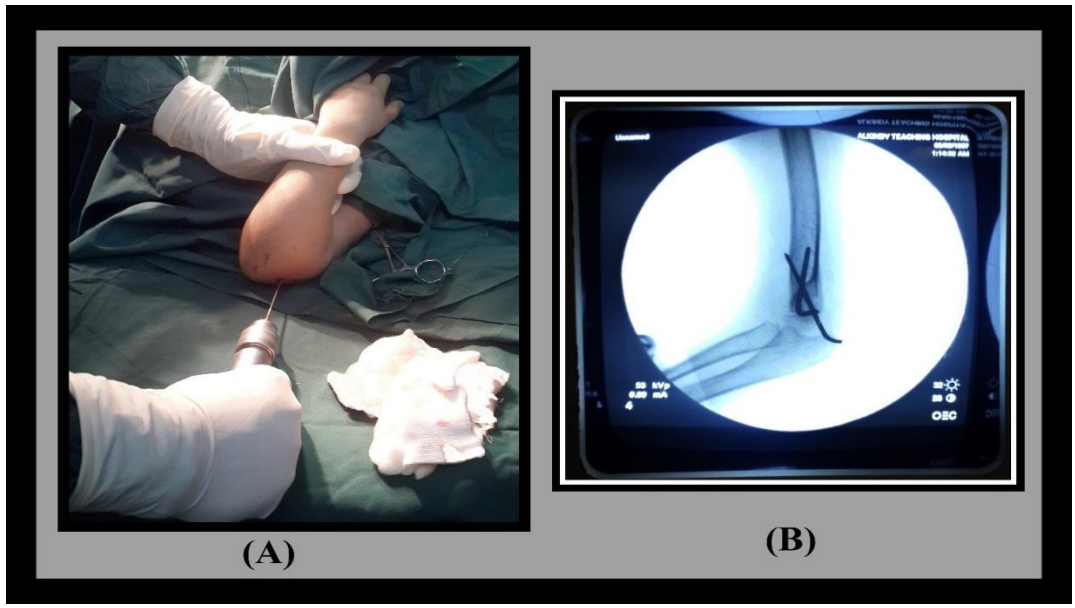

Figure 2: Percutaneous method (A) How to take Jones view and insert a lateral pin. (B) Checking fracture fixation with the aid of an image intensifier.

Figure 3: Techniques: (A) Closed percutaneous fixation. (B) Open surgery fixation.

Post-operative care: A long-arm posterior plaster splint in less than 90º of flexion is worn for 4 weeks. Ulnar, radial, and median nerve function and vascular status checked after operation.

Posterior splint and pins were removed after 4 weeks in the outpatient clinic without anesthesia. During this period weekly change dressing and checking the fracture site by X-ray done.

Intravenous antibiotics were used for 3 days postoperatively in open surgery group while simple oral antibiotics were used in percutaneous surgery group for 2 days only.

Intermittent active range-of-motion exercises are started at home; we made instruction to the child and the parent, explaining that the child is to carry out his or her own active range-of-motion program. Passive motion and forceful manipulative motion must be avoided in a child.

Results

Callus formations were seen in all patients at the (2-3) weeks post-operatively and before removing the K-wires. All patients achieved radiographic healing at a mean of (4) weeks.

There was no major postoperative complication like compartment syndrome, Volkmann ischaemic contracture, neurovascular injury, deep wound infection, secondary displacement or myositis ossificans.

All patients had positive distal radial pulse post-surgical reduction except one case with open method shows negative pulse after reduction and removal of tourniquet. The capillary filling was positive, limb was worm and pulse oximeter was reading. The radial pulse eventually reappeared after (2) weeks.

There was no incidence of severe pin tract infection in both groups. Only (2) cases of simple pin tract infection (1) in each group, resolved with oral antibiotics and after pin removal. They did not require premature pin removal.

For the cases that were treated with open reduction, there were no superficial or deep infections recorded. Patients did not complain about the scar.

No iatrogenic nerve injuries were observed during follow-up. Transient ulnar nerve palsy seen in (1) case treated by percutaneous method resolved spontaneously within 6 weeks. No patient developed tourniquet palsy postoperatively in open surgery group. Deformities like cubitus varus were not present in any patient. Clinical outcome was evaluated both radiologically and functionally.

A) Radiological:

1) Baumann's angle (in AP view): Post-operatively all angles in both groups were in normal range values and between (69º) and (81º).

In comparison with contralateral side all differences were less than (5º) except for one case treated by percutaneous method it was about (6º) difference. Fortunately this case didn't show significant difference in carrying angle in later follow-up.

2) Anterior humeral line (in lateral view): Radiologically, after surgery in both groups Anterior Humeral Lines cross the capitellum in all patients.

All lines crossed either the middle or posterior third of capitellum except (2) cases in which the line crossed the anterior third. (1) was open and (1) was percutaneous, both of them showed inability to reach full flexion of elbow till final follow-up.

B) Functional: Functional results based on Flynn's criteria:

1) Carrying angle loss: Range between (6-13º). In both groups, it was within normal range except one case with comminuted fracture treated by open method shows carrying angle of about (17º) with (11º) difference from normal side. Graded later as fair result case.

2) Loss of elbow motion (flexion and extension): ROM (range of movement) in open and percutaneous methods checked after 6 months. After closed reduction and percutaneous pinning of elbows, ROM return to normal or near normal by about 2-3 months after pinning. They show earlier return to elbow function than open type which takes more time, (3-5) months after pinning.

The rate of stiffness is much less in percutaneous type compared to the open type. All studied children had full or satisfactory range of the elbow motion (flexion and extension). No case showed poor unsatisfactory result in both groups. All children had satisfactory cosmetic and functional results, (Table 2).

In open surgery group, we obtained an outcome of excellent results in (8) patient (80%), good results in (1) patient (10%) and fair in (1) patient (10%).

In percutaneous surgery group, we obtained an outcome of excellent results in (8) patient (80%), good results in (2) patient (20%), (Figure 3).

Table 2: Results of all patients of the study regarding radiological and functional data gained (6) months after surgeries.

Pt. No.	Sex	Age (Yr.)	Type of surgery	Follow -up (m)	Post-op. Baumann angle (º)	Flexion deficit (º)	Extension deficit (º)	Increased carrying angle (º)	Clinical results
1	M	6	Percut.	7	75º	0º	0º	0º	Excellent
2	M	4	Percut.	6	70º	0º	0º	3º	Excellent
3	M	10	Percut.	6	81º	6º	8º	8º	Good
4	F	6	Percut.	8	72º	0º	3º	0º	Excellent
5	M	5	Percut.	8	72º	0º	0º	0º	Excellent
6	F	7	Percut.	7	78º	0º	0º	0º	Excellent
7	M	4	Percut.	6	69º	0º	0º	0º	Excellent
8	M	5	Percut.	7	70º	0º	3º	2º	Excellent
9	F	8	Percut.	6	73º	7º	7º	6º	Good
10	M	6	Percut.	6	78º	3º	0º	0º	Excellent
11	F	6	Open	6	69º	0º	0º	0º	Excellent
12	F	4	Open	6	80º	0º	0º	3º	Excellent
13	M	7	Open	8	76º	6º	9º	7º	Good
14	M	6	Open	6	72º	0º	5º	0º	Excellent
15	F	4	Open	7	76º	0º	0º	0º	Excellent
16	M	8	Open	8	78º	11º	13º	11º	Fair
17	M	5	Open	8	77º	0º	0º	0º	Excellent
18	M	7	Open	6	76º	0º	2º	0º	Excellent
19	F	10	Open	8	70º	2º	0º	0º	Excellent
20	M	7	Open	7	75º	0º	0º	0º	Excellent

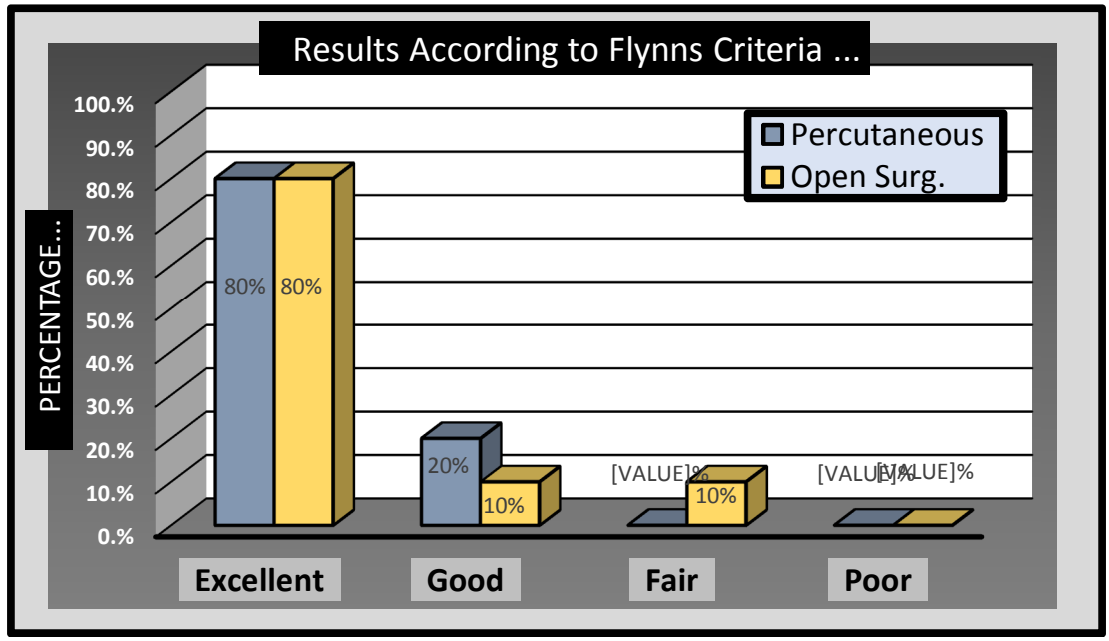

Figure 3: Results in percentage (%) according to the functional grading system of Flynn.

Discussion

Displaced supracondylar fractures of the humerus are one of the commonest childhood injuries and the main goal of the treatment is to obtain the best functional recovery results and good cosmetic and morphological outcome with the least number of complications [15].

In the present study, the ultimate aim of any treatment of displaced supracondylar fractures is the recovery of full function with no deformity or residual neurovascular deficits, this is achieved through an anatomical reduction ideally in a single intervention. Difficulty in obtaining or maintaining reduction will lead to poor late results because of stiffness of elbow or mal-union.

In a study by Prasad (series of 30 patients), he had three iatrogenic ulnar nerve palsies. Though in his study, he isolated ulnar nerve during operation, he thought it may be due to over stretching of nerve during operation especially while putting K-wires on medial side and may be also due to compression of nerve by the K-wire postoperatively, but all patients recovered in a matter of 3-6 months [14].

Wasim in his study showed that iatrogenic ulnar nerve injury is the most common complication of percutaneous pinning but usually resolves spontaneously [16].

In the present study, we don't isolate the ulnar nerve during open surgery, we only localize the nerve, so we don't have nerve injury. In percutaneous group we have only (1) case of transient ulnar nerve palsy resolve spontaneously within 6 weeks.

The main goal of surgical treatment of pediatric supracondylar humerus fracture is to safely create an adequately stable construct to prevent axial rotation and coronal or sagittal tilt to avoid post-operative deformity, which historically has been reported as high as 17%. Internal rotation of the distal fragment is the major predisposing factor to varus deformity and is necessary for coronal varus tilt to occur [4].

Mohammad in his study showed that the effect of rotation on the relationship

between the angles has not been studied in detail. Computed tomography (CT) studies have shown that ≤ 40 degrees of rotation may still be present after closed manipulation of a supracondylar fracture.

The Baumann angle was found to be an inaccurate indicator of the carrying angle when treating displaced supracondylar fractures [17].

In the present study the patient with about 6º difference in Baumann angle from normal side showed normal range of carrying angle post-operatively. We also think that the rotation is an important parameter in prognosis.

Taking this fact into consideration some authors recommended (2) lateral pins over (2) cross pins. Medial and lateral pin insertion provides better stabilization but opinion varies about stability of two lateral pins [4].

In a study by Devkota, there was no incidence of ulnar nerve injury where pinning was done from the lateral side; and he did not find any difference in bone healing and stability between lateral-pin insertion and cross-pin insertion as he followed the same treatment protocol for both the groups[18].

In biomechanical studies comparing different wire configurations used for osteosynthesis in the management of supracondylar humeral fractures, it has been found that medial and laterally inserted crossed K- wire model is the most stable configuration [19].

In the present study, we think that crossed K-wire model is a stable configuration. We don't face any case of re-displacement of fractures after surgeries.

Mazda and his group chose to bury the wires routinely, both when using the percutaneous and the open technique. This avoids pin site infection which can have serious consequences [6].

The disadvantage of burying K-wires in paediatric population is that it will need to be removed as a day case surgery under general anaesthesia with considerable financial implications. The time taken to remove each Kirschner wire is short, and the procedure is not considered to be painful [20].

In this study, the wires left outside the skin, no serious pin tract infection was faced and all wires removed in outpatient unit without anaesthesia.

The results of Haziq study showed that open reduction and internal stabilization is a better choice of treatment with good postoperative functional results, especially if fluoroscopy is not available [21].

Khurram et al treated 48 patients with closed or open reduction and crossed K-wires, 30 obtained excellent results, nine good, four fair and none had a poor result [11]. This result is approximately near to the present study results.

Closed reduction and percutaneous pinning is a sound and effective modality for the treatment of displaced supracondylar fractures. Along with the advantage of decrease duration of hospital stay, stable fixation and early mobilization, it also reduces the incidence of cubitus varus deformity if the surgical technique is followed strictly [22].

In the present study, a long list of advantages we see it when using percutaneous technique of supracondylar fracture fixation and all of these advantages are practical and superior to the open technique by our opinion. Most important advantages can be listed in the following table (Table 3) for comparison.

Table 3: Advantages of percutaneous technique of supracondylar fracture fixation over open technique

Percutaneous	Open
(1) Short time procedure (mean=17 min). Minimize the length of anesthesia time and by this decrease complication of anesthesia.	(1) Longer time procedure (mean=45 min.) with Longer anesthesia time.
(2) No tourniquet used.	(2) Tourniquet used.
(3) Less traumatic to the patient. There are no sutures and virtually no surgical wound.	(3) More traumatic to the patient (surgical wound with sutures).
(4) Less postoperative pain because the skin portal almost pin sized.	(4) Pain post operatively is usually severe and needs analgesia because there is long surgical incision.
(5) Less Hospitalization Time: (1) day.	(5) More Hospitalization Time: (2) days.
(6) More cosmetic because there is no wound, only pin hole sites.	(6) Less cosmetic because there is always healing scar.
(٧) Earlier return to elbow function (2-3) months. The rate of stiffness is much less.	(٧) More time, (3-5) months after pinning to return to elbow function.
(٨) More psychologically supportive to both child and parents.	(٨) Less psychologically supportive.

In conclusion; there was no significant difference in functional results regarding carrying angle and range of motion following treatment with percutaneous or open reduction for Gartland type II and III supracondylar humeral fractures. Closed reduction with percutaneous K-wire pinning is believed to represent a safe, reliable, cost effective, time saving and provides greater skeletal stability with efficient method of managing displaced supracondylar fractures in children, reduces hospitalizations, duration of immobilization, physical therapy, with faster return to daily activities of children and effective in obtaining good results.

We recommend using percutaneous cross K-wire pinning technique because it is a simple, easy to master and reliable method of surgical treatment which provides good functional results and has a long list of advantages in comparison with open method.

Open reduction should only be performed if closed reduction fails to achieve reduction or when no intraoperative radiographic facilities are available.

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