LATERAL PERCUTANEOUS PINNING FIXATION USING TWO DIVERGENT PINS FOR COMPLETELY DISPLACED SUPRACONDYLAR HUMERAL FRACTURES IN CHILDREN.

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ABSTRACT:

Background: Supracondylar humeral fractures are the most common elbow injury in children. The purpose of this study was to evaluate the efficacy of percutaneous two lateral divergent wire technique for the treatment of completely displaced extension type supracondylar fractures of the humerus in children.

Methods: Twenty eight children with a displaced supracondylar humeral fracture were treated between March 2008 and November 2010, with closed reduction and percutaneous two lateral divergent K. wires inserted under the fluoroscopic guidance. Primary study end points were range of movement and carrying angle relative to the contralateral uninjured elbow using Flynn's grading system and presence of iatrogenic nerve or vessel injury.

Results: Final radiographs showed no loss of reduction of any fracture. Twenty four (86%) patients had excellent results, and 2 patients (7%) had good results. One patient (3.5%) had loss of carrying angle from 14 to 0 degrees, and the appearance of the elbow was not cosmetically noticed; he had a fair result, and another patient (3.5%); had normal range of elbow motion, but had a 20-degree loss of carrying angle (from 10 to -10 degrees) and accordingly he had an objectionable (poor) result. The loss of carrying angle was due to technical errors. Two patients had a pin-track infection.

Conclusion: The use of two divergent lateral-entry pins is a safe and effective method with good functional outcome for the most unstable pediatric supracondylar humeral fractures. There were no iatrogenic ulnar nerve injuries, and no reduction was lost. The two lateral pins should engage both the medial and lateral columns to provide adequate stability.

KEY WORDS:
Lateral pinning Supracondylar fractures Children

INTRODUCTION:

Supracondylar fractures of the humerus, the most common elbow injury in children, are noted for complications, including Volkmann's ischaemic contracture, myositis ossifycans and permanent nerve lesions[1]. Supracondylar fracture of the humerus is a fracture of the immature skeleton, so it is age related and primarily occurs in the first decade of life with peak at 6 years of age [2]. Typically the fracture occurs due to a fall on an outstretched hand with hyperextension of the elbow joint. The distal fragment displaces posteriorly in more than 95% of fractures[3,4]. In most cases these fractures are displaced, with no cortical contact, often associated with neurological or vascular injury. Supracondylar fractures are commonly classified according to Gartland[5]. It is based primarily on the degree of displacement.

These fractures are considered to have poorer results than any other type of extremity fracture[6]. The commonest and most neglected complication is an alteration in the carrying angle of the arm with resultant cubitus varus. Cubitus varus or valgus are due to malreduction of the fracture, this is in contrary to the old belief which thought to occur because of growth arrest of the distal humeral physis. Therefore, anatomical reduction is the standard technique of treatment of such fractures[7]. Because early management concentrates on avoiding the more serious complications, control of the carrying angle may receive a low priority; this is reflected in a reported change of carrying angle of up to 57% and averaging 30%[8]. Minor increases in the carrying angle, that is, increased valgus, may be acceptable but, if the normal valgus angle is reversed, the ugly deformity of cubitus varus results. This may be a serious cosmetic problem requiring operative correction by supracondylar osteotomy[9].

Percutaneous pinning is the gold standard treatment for displaced supracondylar humeral fractures [10,11], but the optimal pin configuration remains controversial[6,12]. Crossed wiring is believed to provide greater torsional stability of the fracture fixation thus decreasing the potential for loss of reduction. This is at the possible increased risk of iatrogenic ulnar nerve injury. Advocates of the lateral wiring technique will cite the avoidance of iatrogenic ulnar nerve injury at the expense of a less biomechanically stable construct [13,14]. The purpose of this study is to evaluate the efficacy of percutaneous two lateral divergent pins for the treatment of completely displaced extension type supracondylar fractures of the humerus in children.

PATIENTS AND METHODS:

A total of 28 children who had extension-type Gartland type-III displaced supracondylar humeral fractures were treated surgically by closed reduction and lateral percutaneous pinning procedure. There were 17 boys (60.7%) and 11 (39.3%) girls. The left elbow was involved in 19 fractures and the right in 9 fractures. The mean age of the children at the time of the operation was six years (range, three to ten years). The children were treated consecutively between March 2008 and November 2010. Patient demographics are summarized in (Table 1).

Patients were included if they had extension-type closed Gartland type III supracondylar humeral fracture, those presented within 4 days after injury, age between three to ten years. Patients were excluded from the study if they had type I or type II extension fractures, fractures with vascular compromise and/or nerve injury, children with associated ipsilateral forearm fractures as well as children with open fractures.

The clinical examination included evaluation of neurovascular integrity and the status of the soft tissues about the elbow. All patients were examined radiologically by anteroposterior and lateral radiographs of the elbow. The information recorded for all patients included details of operative care, preoperative, post-operative antibiotic administration, and intraoperative complications. Post-operative care, including the duration of immobilization and how long the pins were left in place, were also recorded. Finally, late complications, including evidence of infection or pin site problems were also recorded.

Surgical Technique :

General anesthesia was used in all cases. Intravenous antibiotic was given on induction. We followed the pinning technique which was described by Skaggs et al.,[15]. The limb was prepared from axilla to finger tips and draped. The child was placed in the supine position, as far laterally toward the side of the table as possible, so that the affected upper extremity can be laid easily on the surface of the receiver of the image intensifier. The fracture was first reduced prior to the insertion of the Kirschner wires. Reduction involved manual traction for 30 seconds with the elbow flexed at 20 degrees, controlling rotation of the fracture by the medial and lateral humeral epicondyles (Fig.1). The forearm was then pronated, as this controls the medial rotation, and with flexion to lock the fracture in place[3]. While maintaining the arm in a flexed position, the reduction can be confirmed in both the coronal and sagittal planes by rotating the arm at the shoulder (Fig.2 A and B). Oblique views were also helpful to visualize any rotational deformity and to observe the medial and lateral columns. This technique was adequate for reduction in all the patients of the study. Once a reduction was maintained in a flexed position and confirmed with fluoroscopy, two Kirschner wires (1.6 mm) were then inserted from the lateral side and then directed upward and medially (Fig.2 C and D). The divergent pins allow for better distance between the pins as they cross the fracture. If the medially directed pin goes through the olecranon fossa, it captures two cortices in the bone near the fracture. This stiffens the construct and potentially prevents the pin from moving in the soft cancellous bone. The imperative part of the fixation is in the medial proximal portion. Missing this cortex makes loss of rotational reduction probable. The second wire was divergent and was inserted through the lateral condyle to capture the lateral column and proximally engage the medial column of cortical shaft of the humerus with maximal pin separation as was possible at the fracture site. Fracture stability was assessed by screening the fracture under varus/valgus, flexion/extension and rotational stresses. The wires were then bent and cut outside the skin, and the limb was immobilized in an above-elbow splint with the elbow flexed from 60 to 90 degrees.

All of the patients were closely followed for 24 hours postoperatively in terms of compartment syndrome before discharge and all were discharged within 72 hours of surgery. Patients were followed up postoperatively at one week, three weeks (with removal of Kirschner wires and above elbow splint under office conditions), at this point, patients were allowed full range of motion. However, they are restricted from return to full activity until 2 months after the fixation. The patients were followed up monthly until they regained full range of movement or until the clinical situation was stable. This ranged from three months to one year. Physiotherapy was rarely indicated.

Check X-rays were taken to assess maintenance of fracture reduction in the sagittal plane which was confirmed when the anterior humeral line intersected the ossified part of the capitellum; an absence of this relationship indicated loss of reduction (Fig.3). Elbow X-rays were also used to detect fracture union, and no contralateral elbow X-rays were taken for comparison. Baumann's angle measurement was not included due to its poor reliability, and accordingly the primary outcomes measured were purely clinical as documented by Flynn et al.,[16]. The Flynn's grading system, was used, namely, the difference in carrying angle (cosmetic factor) and the range of movement (functional factor), compared to the uninjured elbow. The criteria for grading results are presented in (Table 2). The overall grading was based on the worst functional or cosmetic factor.

RESULTS:

The mean age of the twenty eight children at the time of the operation was six years (range, three to ten years). All fractures were treated within twenty-four hours after injury. Closed reduction and percutaneous pinning was performed in all patients. The pin configuration used was 2 lateral divergent pins in all fractures. No wires became loose. The wires were removed after consolidation of the fracture. No patients were lost to follow-up before pin removal. The follow up ranged from three months to one year.

All children were assessed according to Flynn's grading system[16] for cosmetic and functional outcomes. This system graded the cosmetic and functional factors separately, because a patient may have deformity with good function or no deformity with poor function, it also classifies results into four categories according to loss of motion and the loss of carrying angle. The carrying angle was measured with a goniometer and compared with that of the normal opposite extremity. Any patient with reversal of the clinical carrying angle was considered to have a poor result. According to the criteria of Flynn et al.,[16] functional outcome in terms of range of movement was excellent in 24 (86%) patients (Fig. 4), good in two patients (7%); one of them had 8 degree-loss of carrying angle, and in the other patient the elbow lacked 7 degrees of the normal flexion range of motion. The fair result was in one patient (3.5%); he had loss of carrying angle from 14 to 0 degrees, but the range of motion of the elbow was normal and the appearance of the elbow was not cosmetically noticed, and poor in one patient (3.5%); he had normal range of elbow motion, but had a 20-degree loss of carrying angle (from 10 to -10 degrees) and accordingly he had an objectionable (poor) result (Fig. 5). The results are tabulated in (Table 3 and 4). Recovery of range of flexion and extension of the elbow in all patients was usually complete by one year.

Pin track infections were noted in two patients (7.14%) and were successfully treated with oral antibiotics. There were no iatrogenic ulnar nerve injuries, and no re-operation was needed for any patient.

Table (1): Patient demographics

Variable	Number
Number of patients	28
Age (mean)	6 years
Gender	
Male	17
Female	11
Side	
Left	19
Right	9

Table (2): Flynn's[16] Criteria For Grading

Result	Rating	Cosmetic Factor: Carrying-Angle Loss *(Degrees)*	Functional Factor: Motion Loss *(Degrees)*
Satisfactory	Excellent	0-5	0-5
	Good	5-10	5-10
	Fair	10-15	10-15
Unsatisfactory	Poor	Over 15	Over 15

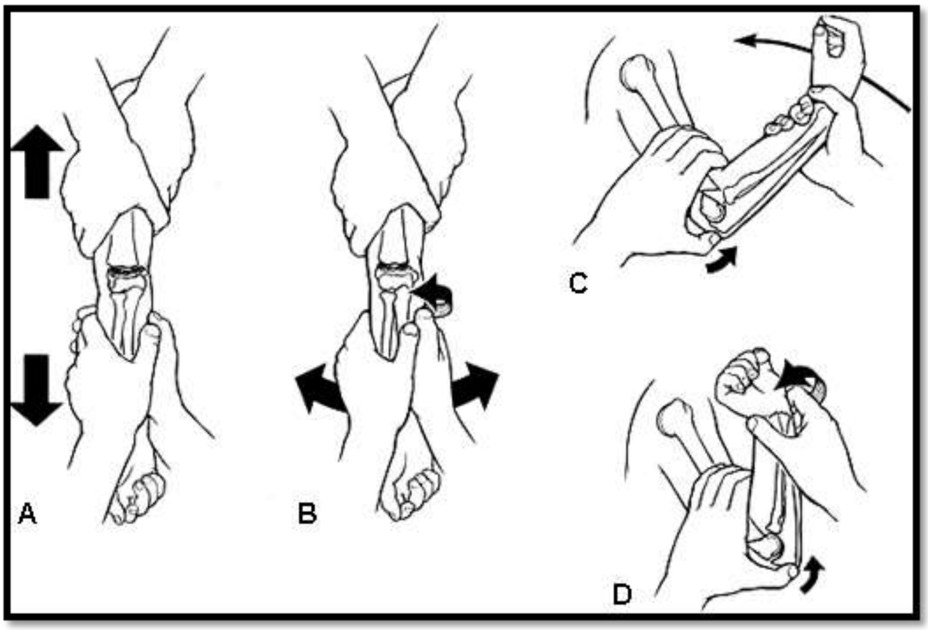
Table (3): Results In Twenty-Eight Patients

No. of Patients	Excellent	Good	Fair	Poor
28	24	2	1	1

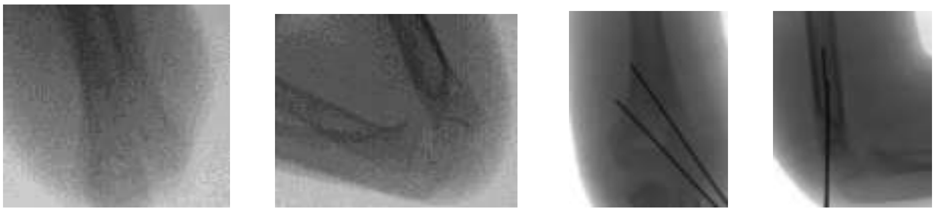
Table (4): Results of the study

Case No.	Age (Year)	Sex	Side	Carrying angle (degree)		Range of motion (degree)		Complications	Results
				N	P.U	Lack of Flexion	Lack of Extension		
1	3	M	L	13	10	0	0	---	E
2	4	M	L	11	8	5	0	Stiff elbow	E
3	9	M	R	10	10	0	0	---	E
4	7	F	L	4	4	0	0	PTI	E
5	6	M	L	15	7	0	0	Decreased C.A	G
6	5	F	L	7	4	4	0	Stiff elbow	E
7	8	F	R	16	16	0	0	---	E
8	6	F	L	14	14	0	0	---	E
9	6	M	L	12	10	0	0	---	E
10	6	M	L	14	14	7	0	Stiff elbow	G
11	6	M	R	10	8	0	0	---	E
12	4	M	L	5	5	0	0	---	E
13	8	F	L	14	0	0	0	Loss of C.A.	F
14	9	M	L	9	9	0	0	---	E
15	5	M	L	11	8	0	0	PTI	E
16	7	F	L	14	12	0	4	Stiff elbow	E
17	6	M	L	7	7	0	0	---	E
18	4	M	R	8	8	0	0	---	E
19	4	M	L	16	12	0	0	---	E
20	6	F	L	12	12	4	0	Stiff elbow	E
21	8	M	R	7	7	0	0	---	E
22	9	F	R	9	9	0	0	---	E
23	7	F	L	13	11	0	0	---	E
24	6	F	L	13	11	4	0	Stiff elbow	E
25	5	M	R	12	10	0	0	---	E
26	5	M	L	10	-10	0	0	Cubitus varus	P
27	5	F	R	4	4	0	0	---	E
28	4	M	R	11	11	0	0	---	E

CA: Carrying angle, PU: Post union, PTI: Pin track infection, N: Normal, E: Excellent, G: Good, F: Fair, P: Poor



(Fig. 1) : Showing the steps of closed reduction of extension type supracondylar fracture[3].

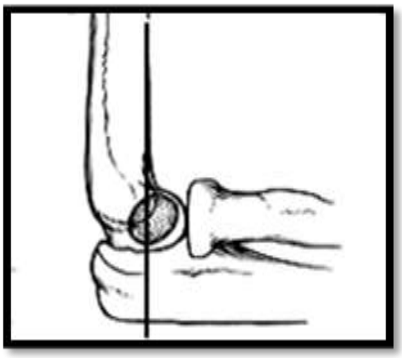


(A) **(B)** (**C)** **(D)**

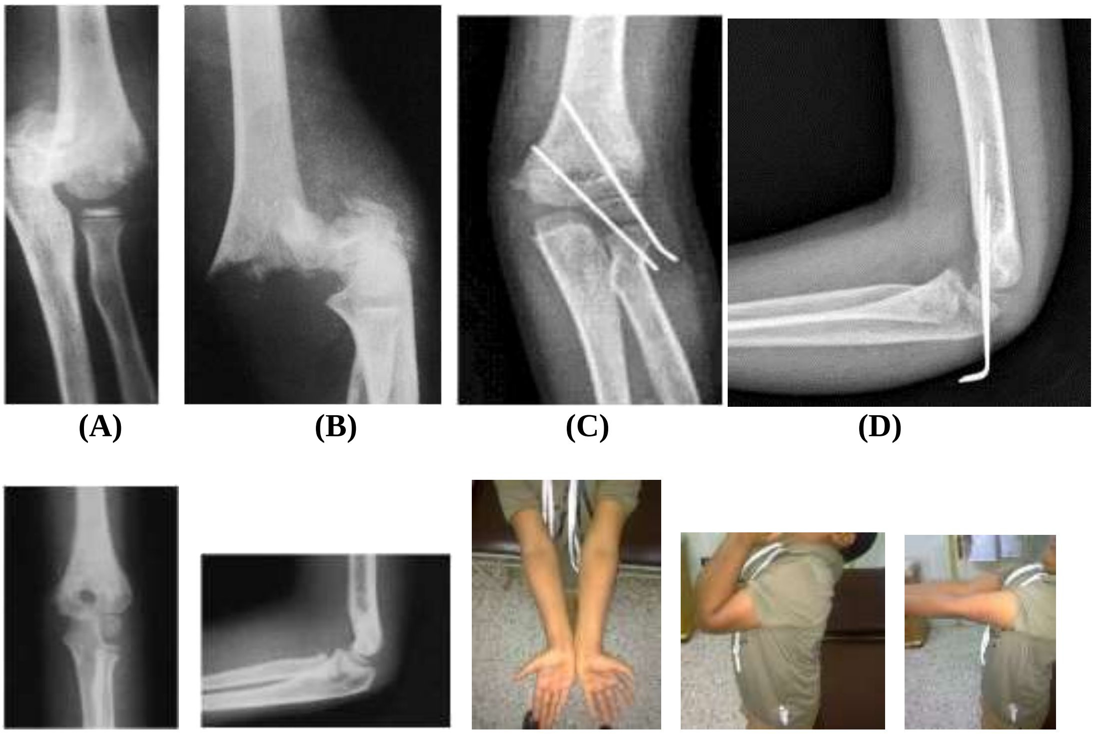
(Fig. 2) AP **(A)** and lateral **(B)** Anatomic reduction was achieved and stability was checked on the AP views and confirmed under C-arm. Two lateral pins were used for fixation.

(C) The divergence in the coronal plane and the fixation to all three columns of the distal humerus.

(D) K. wires are centered in the lateral view, which ensures the proximal fixation is in bone.



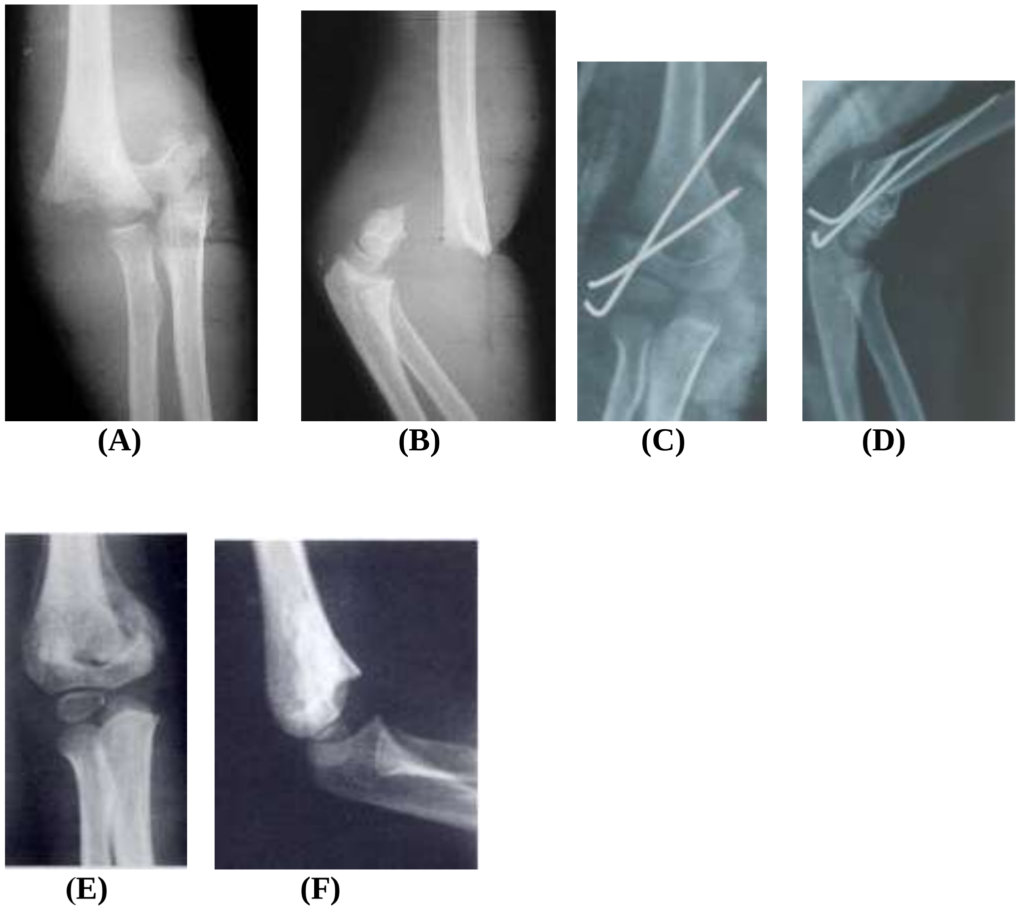
(Fig. 3): Anterior humeral line intersected the ossified part of the capitellum[3].



(A) (B) (C) (D)

(E) (F) (G) (H) (I)

(Fig. 4) (A and B) Preoperative X-rays show extensive displacement of the fracture.
(C and D) Post-operative X-ray picture of two divergent pinning and the more medial K. wire is directed toward the olecranon fossa (central column).
(E and F) AP and Lateral radiographs of the patient 17 months postoperatively show complete fracture healing.
(G, H, and I) Excellent clinical, functional and cosmetic result**.**



(Fig. 5) (A and B) Preoperative X-rays showing displacement of the fracture.
(C and D) The supracondylar fracture was reduced and pinned with the distal fragment in varus position, was rated as a poor result later because of permanent cubitus varus.
(E and F) Eight weeks after reduction. The medial tilt persists, but varus is masked by periosteal new bone remodeling.

DISCUSSION:

Supracondylar humeral fractures are common. The incidence reaches a peak about the age of 8 years[3,7]. The type-III supracondylar humeral fracture is challenging, as reflected in the literature, and there is still some controversy with regard to the ideal treatment method[12,15,17]. Fracture reduction and percutaneous fixation is the most commonly accepted treatment of displaced supracondylar fractures of the humerus in children[11,18]; however, the optimal pin configuration continues to controversial[12,19]. The ultimate goal of K-wire percutaneous fixation is to apply a stable construct. Poor pin placement is associated with loss of reduction. One study of cadaver elbows suggested that the torsional strength of crossed pins is greater than that of two lateral pins but similar to that of three lateral pins[13]. The reported prevalence of ulnar nerve injury with the use of crossed pins has ranged from 0% (of 105) to 6% (nineteen of 331)[20,21,22].

A review of two clinical studies involving a total of ninety-three patients showed that lateral pins alone were clinically as effective as crossed pins and also that the ulnar nerve was protected from injury[23,24]. Reports have shown that the incidence of iatrogenic ulnar nerve injury increases when a medial wire is used. Boyd and Aronson [25] reported ulnar nerve injury in two of seventy-one patients treated with crossed pins. Aronson and Prager[26] reported injury to the ulnar nerve in the first patient in whom they used crossed pins. Subsequently they used only lateral pins in the remaining nineteen patients in their study. There is also concern about delayed iatrogenic nerve injury using medial wires[27].

However, the lateral wiring technique is not without problems. Iatrogenic anterior interosseous branch of radial nerve injury was also reported by Shannon et al., [28] and Foead et al.,[29] during insertion of lateral pinning. Furthermore, Kallio et al.,[30] reported loss of fixation in eleven (14%) of eighty patients in whom only two lateral pins had been used. The loss of fixation was attributed to technical errors, such as failure to engage the proximal and distal cortices and crossing of the pins at the fracture site. The authors concluded that, although the use of two lateral pins eliminates the risk of injury to the ulnar nerve, it is technically very demanding. However, the technical errors that they described are not specific to the placement of lateral pins in the distal part of the humerus but they are thought to be due to poor technique in reduction and fixation[15].

Fowles and Kassab[31] reviewed the results of treatment of 110 children and recommended the use of two lateral pins. Arino et al.,[32] also used two lateral pins, in 189 patients. Royce et al.,[33] recommended the use of two lateral pins when the reduction was stable and the use of crossed pins when the reduction was unstable. Lyons et al.,[27] suggested that lateral pins are sufficient in most patients but crossed pins may be required in younger children in whom the distal part of the humerus has a small cross-sectional area, especially when there is commi-nution of the medial humeral cortex.

Lee et al.,[14] documented that the risk of displacement after lateral entry pin fixation can be reduced by proper pin placement with divergent pins that are located in both the lateral and the central column to provide torsional rigidity that is similar to that achieved with the combination of a medial and a lateral pin. They also reported that in lateral wire fixation, divergent wires have been shown to be more stable in extension and varus loading than crossed wires but not in valgus. This was found to be true in the current study, as no reduction was lost or re-displaced after fixation by two lateral divergent wiring. Skaggs et al.,[15] documented that the important technical points for fixation with lateral-entry pins are (1) maximize separation of the pins at the fracture site, (2) engage the medial and lateral columns proximal to the fracture, (3) engage sufficient bone in both the proximal segment and the distal fragment, and (4) maintain a low threshold for use of a third lateral entry pin if there is concern about fracture stability or the location of the first two pins. This was also found true in the current study, as the divergence of the wires to engage medial and lateral columns added more to the stability of the fixation and accordingly no reduction was lost.

The changes in carrying angle encountered in the current study probably are the result of medial tilt of the distal fragment during reduction. Fortunately, most of the changes in carrying angle were not objectionable.

The average loss of carrying angle was 5 degrees, with a range from 2 to 20 degrees. Fourteen patients had no change in carrying angle, eleven patients had minor loss of carrying angle from 2 to 4 degrees, and three of the fractures had major changes in the carrying angle; but one of them (3.5%) had cubitus varus; he was graded poor as he had 20° loss of carrying angle (from 10° to -10°) and accordingly he had unsatisfactory results according to Flynn's[16] criteria due to poor reduction and the pinning of the distal fragment in varus position, as remodeling of the fracture will correct some displacement, but remodeling does not correct valgus or varus angulation of the distal fragment. The loss was only esthetic, with an adequate mobility range, explaining why he did not require further treatment. Steenbrugge and Macnicol[34] believe that cubitus varus does not result in functional deficiency and that the loss is only esthetic. Since the deformity is only obvious in complete extension, this implies that the patient has recovered complete mobility.

In the current study, the range of motion at nine weeks of follow- up was comparable with others[34]. There were no iatrogenic nerve injuries. Only two patients (7.14%) presented with a pin-tract infection seven days after surgery. The children were treated with antibiotics while the pins were in situ. The pins were removed three weeks following surgery, and the infection resolved and cast immobilization was continued for one additional week for both of them.

The strengths of this study are based on its original prospective, randomized design. In addition, stringent patient inclusion criteria were used. All patients were standardized in terms of pin size, and pin location, as the K. wires were placed consistently in same position. Furthermore, full clinical and radiographic evaluation was performed at standardized intervals.

Weaknesses of the current study are due to the lack of a comparative group of another pinning technique like the cross pinning technique to get a significant difference between the two techniques in terms of loss of reduction, iatrogenic ulnar nerve injury, changes in the carrying angle, or elbow motion. The disadvantages of that technique are that the surgeon will have to reposition the pins, perhaps more than once, to obtain good fixation. Some technical difficulty can be encountered in placement of divergent pins in younger children in whom the distal part of the humerus has a small cross-sectional area. Persistent instability occurring after the placement of two lateral entry pins was not addressed in the current study, as instability after placement of pins was not encountered.

Unstable supracondylar Gartland type III can be treated successfully with a technique of closed reduction and lateral percutaneous pinning, thus avoiding open reduction. It is an effective and reliable closed method for the treatment of unstable supracondylar humeral fractures as it seems to offer stable fixation of the fracture, short immobilization, few operative complications and good end results. However, because of the small number of patients in the current study, the true need for open reduction of these fractures cannot be predicted.

CONCLUSION:

The use of lateral pins alone provides adequate fixation for even the most unstable supracondylar humeral fractures. There were no iatrogenic ulnar nerve injuries, and no reduction was lost. The important technical points for fixation with lateral-entry pins are:

1- Special attention should be directed toward anatomical reduction.

2- Pinning stability is maximized with a large pin spread at the fracture site.

3- The wires should engage the cortices of the medial and lateral columns to get bicortical fixation.

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