Percutanous Crossed Pinning Versus Two Lateral Pinning for Treating Supracondylar Humeral Fracture in Children: Comparative Study

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Abstract:

Objectives: The study done to identify the advantage and disadvantage of two pinning types used for supracondylar fracture in children. The Baumann`s angle difference, ulnar nerve injury incidence and elbow flexion-extension loss.

Methods: Conducting a prospective randomized controlled study on 30 patients with extension type III supracondylar fracture from 1st January 2018 to 1st January 2019 operated by medaial-lateral pinning (n=15) or two lateral pinning (n=15).

Results: 30 patients with mean age of 6.73 years were included in the study. The mean follow-up period was 2.75 months. The Baumann`s angle mean difference between normal and injured elbow in crossed pinning and two lateral pinning was 5.46 and 4.96 and the difference was statistically not signoficant (p=0.58).The mean flexion-extension loss in crossed pinning was 8.3 and 6.25 degrees, in two lateral pinning was 11.25 and 7 degrees respectively. Mean difference of carrying angle in crossed pinning was 2.1 degrees; in two lateral pinning was 2.73 degrees. The differences between two groups were not statistically significant (p=0.65). Two iatrogenic ulnar nerve damage developed in crossed pinning while in two lateral pinning, no incidence of nerve damage seen. This difference also was not significant (p=0.14).

Conclusion: From both fixation types, we found that there isn`t statistical difference in terms of clinical outcomes.

Keywords: Supracondylar fracture, Crossed and lateral pinning, Ulnar nerve injury, Baumann`s angle, Flexion-extension loss, Trochlear osteonecrosis.

Introduction:

Supracondylar fractures of humerus are commonest elbow fractures that occur in children, they account for about (60%) of all elbow injuries in those below 10 years of age [1]. They consist of fractures above the lower humeral condyles and there are two types of these fractures which include either a hyperextension injuries that presents with posterior angulation or displacement which are the commonest (95% of all the cases) and caused by a fall on the outstretched hand, the other is flexion type that presented with anterior displacement which is rare and usually due to direct trauma to elbow for example a fall on the elbow while it's in flexion position, this is the broad classification of these injuries [2,3]. Extension type injuries are subdivided into 3 types by Gartland classification system, which includes undisplaced fractures (Type I), partially displaced fractures with intact posterior cortex (Type II) and completely displaced fractures (Type III). Considering Wilkins [4], Type III fractures can also subdivided according to sideway tilting

which are Gartland IIIA- posteromedial and IIIB – posterolateral type respectively. Clinical features of such type of injury show that patient has painful and swollen elbow, with extension type fracture, there would be a deformity like S letter shape, also irregular bony landmarks. It is important to feel the pulse and the capillary feeding, passive streching of the flexor muscles would be painless. Also nerve examinations of the wrist and the hand have to be done to exclude any associated nerve injury [2]. These injuries are diagnosed by radiograph and most clearly in the lateral view. Baumann`s angle or named as the humeral-capitellar angle, has the advantage to assess the displacement of pediatric supracondylar fractures. It is measured on antero-posterior radiograph whith elbow in extendsion position. It's produced by the long axis of the humerus and a straight line going within the epiphyseal plate of the capitulum. A number between 64 - 81º is within normal limits. because of significant difference among peoples, it`s better to be measured on both sides. And if the difference were more than 5°, it would be abnormal [5]. Treatment of these injuries may be very difficult due to the concomitant immediate and late complications that associated with such injuries as compartment syndrome, neurovascular damage, Volkmann's ischaemic contracture and malunion with deformity [6, 7, 8]. For type I, cast applications usually suffice and reassessment required after few days to rule out redisplacemen. considering type II, few of them can be treated with closed type reduction and slab placement, Dunlop traction or olecranon traction, but these conservative measures may lead to certain complications like reduction loss, compartment syndrome and malunion [9]. For type III injuries, they usually indicated for closed reduction and percutanous pinning with Kirschner wires and sometimes open reduction may be needed as well due to failure of closed reduction, open fracture, nerve or vessel entrapment or if there is associated vessel injury. Percutanous pinning and fixing the fractur segment with K-wires is now the 1st option of treatment either a cross (1 medial& 1 lateral) pins or two lateral pins. 3 lateral pins may be used if the fracture reduced is unstable or two lateral divergent pins or one medial and 2 lateral pins [10]. The commonest method of pin insertion is by a medial and a lateral pin in a cross shape or two lateral pins [6, 7]. Fixation pins has the advantage that they do not disturb physeal plate required in growth potential of the distal humeral end, providing stability, vascular safety, simplified management, reduced hospital staying, and consistently satisfactory appearance and function of the elbow [10]. Lateral pinning may be used without medial one when there is obvious oedema and marked elbow joint swelling that medial condyle would be difficult to identify and safe medial pin placement would be difficult which may lead to ulnar nerve skewing. So, there is controversy about the optimal placement of the pins. A crossed-pin placement is believed to be mechanically more stable than lateral pins only [3, 8]. Although, surgeons opinion that iatrogenic ulnar nerve damage may occur by this type of pinning by at least two to four times [11, 12]. Supracondylar area of humerus is located in distal humerus; it is weak and thin area in children, it is limited anteriorly by coronoid fossa, posteriorly

by olecranon fossa and on the sides by the supracondylar ridges and these ridges end up to epicondyles and condyles respectively. The normal trochlear tilting is about 5° valgus in males and 8° valgus in females which is called the carrying angle, also it`s rotated outward about 3-8° which leads to external arm rotation when it flexed at ninty degrees [13, 14]. Both medial and lateral supracondylar ridges, epicondyles and condyles have several muscle attachments that lead to displacement and rotation of the distal piece in relation to proximal one. Vascular structures of supracondylar area include brachial artery runs along the antero-medial portion of distal humerus above the brachialis muscle; neurological structures include median, ulnar and radial nerves that lie within supracondylar area [13]. The ossification centers of distal humerus occur at different ages. The capitellum appears at 1st year of age. The head of radius and also medial epicondyle starts to ossify at 4-5 years of age. Trochlear and olecranon epiphysis apear at 8-9 years of age. The last one is the lateral condyle that appears around 10 years old. The supracondylar area exposed to remodeling from 6 to 7 years of age, it`s mainly thinner with a fragile cortex, resulting in this area to be more prone to fracture. As elbow stressed into extension, the olecranon aids as a fulcrum and concentrating the force on the distal humerus leading to fracture [15]. A Kirschner wire (also named a K-wire) is a thin stainless steel wire or pin that utilized to fix bone pieces. They usually drilled into the bone to stabilize and hold the fragments after reduction; they either left that their tips exposed from the skin or be buried under the skin and it came in variable sizes [16].

Aim of the study:

To identify the advantage and disadvantage of each type of pinning and which one is superior regarding functional and radiological outcome to the other.

Objective of the study:

1- Measuring Baumann`s angle after each type pinning.
2- Associated nerve injury after each type pinning.
3- Flexion extension loss after each type pinning.

Patients and Methods:

A prospective study involving 30 children below age of 13 years old regardless of their gender attended West Erbil Emergency Hospital, East Erbil Emergency Hospital & Hawler Teaching Hospital suffering from extension type III supracondylar humeral fracture from 1st January 2018 to 1st January 2019. All patients suffering from flexion type injury, type I, II, compound fracture, patients previously exposed to fracure or operation around elbow and patients with congenital anomalies in elbow joint were excluded from study. All the 30 patients after failure of a trial of closed reduction inform of traction and countertraction followed by back slab application with 90º elbow flexion due to unaccepted post reduction radiographs, making these patients indicated for surgical operation.So, they were randomly divided into two groups and the randomization process was done by the odd and even number technique by which the patients with even inpatient numbers were allotted in Group A while the odd inpatient numbers were assigned in Group B. Patients in whom crossed pinning were

used, being placed in Group A (n=15), while those with lateral pinning techniques, were included in Group B (n=15).All the needed preoperative preparation was done in the form of full clinical, neurovascular status for involvement of brachial artery, anterior interosseous, radial and ulnar nerve before undergoing surgery also radiological examination (anteropsterior and lateral view of the injured elbow). A written consent was obtained from all the patients parents enrolled in the study, all 30 patients planned to undergo surgery send for investigaion of complete blood count and virology screen. Two figures below (1 A & 1 B) of an antero posterior and lateral radiographic view of elbow joint for a 10 years old child that exposed to trauma of his left elbow joint while playing and fall on the ground with an outstreched hand and extended elbow showing extended Type III supracondyar fracture.

1 A

1 B

Operative Technique:

All 30 patients were entered for operation and done by senior orthopedic and resident doctor of orthopedic surgery. Patient placed in a supine position on operating table and under general anaesthesia.The involved limb being placed out of the table for manipulation and visualizing it in C-arm of image intensifier machine and closed reduction applied inform of traction and countertraction, folowed by insertion of pins after obtaining an acceptable reduction. All the fractures were reduced and manipulated prior to operation and sterilization by traction and countertraction and the elbow

holded in hyperflexion position with pronation at the forearm. Two sterilized K-wires of either 1.5 or 2 mm diameter were used and drilled in to hold and fix the fractured segment either laterally (inserted from lateral cortex to medial one), or in cross manner (first by inserting lateral pin from lateral cortex inserted and drilled through with aiming at engaging medial cortex with elbow hyperflexed then medial pin insertion by slightly extending elbow to less than 90 degree and drilling wire in from medial cortex to lateral cortex) under C-arm guidance. After satisfactory reduction and stability of fixation were assessed intraoperatively, the wires bent and cutted, sterilization of pin entry port and dressing done, all patients were injected with a single dose of ampiclox vial (500 mg) antibiotc intraoperatively. An above elbow splint was applied from mid arm to the wrist joint with elbow at around 60º flexion and supination with long arm sling to hold the limb.4 figures below (2A&2B), (3A&3B) demonstrating antero posterior and lateral radiographic views of both cossed pinning and 2 lateral pinning types for two childs suffering from extension type III supracondylar humeral fracture.

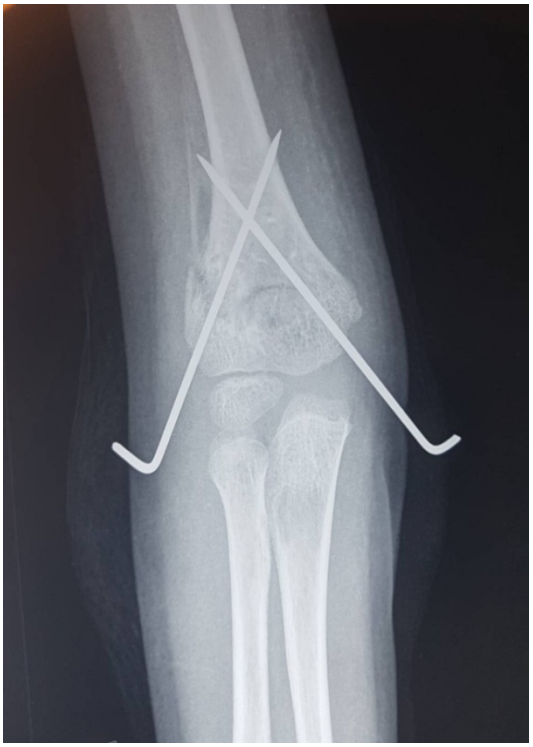

Figure (2) A: demonstrating antero posterior radiographic view of supracondylar fracture fixed with crossed pinning.

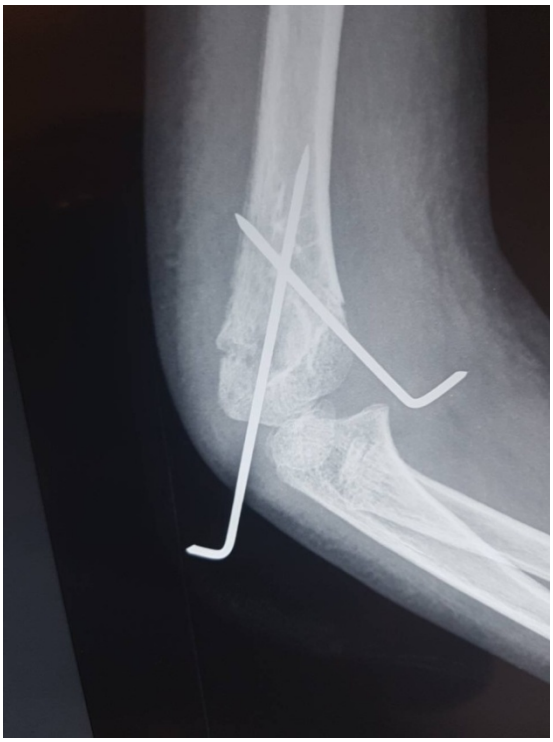

Figure (2) B: demonstrating lateral radiographic view of the suracondylar fracture fixation.

Figure (3) A: demonstrating antero posterior View of supracondylar fracture fixed with 2 lateral pinning.

Figure (3) B: demonstrating lateral radiographic view of the supracondylar fracture fixation.

Postoperative assessment of the neurovascular status was done immediately after operation and all patients send for anteroposterior and lateral radiograph, on post-operative day after surgery, all patients were discharged. Patients follow up done at interval of 3 days postoeratively, 4 weeks, 12 weeks and after 6 months both clinically and radiologically. In both groups, the k- wire and long arm slab removed after 4 weeks and active mobilization initiated with avoidance of passive movement which may predispose to stiff elbow with resultant decrease of elbow range of motion. Clinical evaluation of patients done in form of assessing neurovascular status, passive range of motion in form of flexion extension, measuring carrying angle for both affected and unaffected elbow, any associated pin tract infection and Flynn`s criteria [17] used to assess these patients clinically depending on carrying angle and range of motion, Flynn criteria has two sections, the functional and also the cosmetic sections and these sections sub-divided into excellent, good, moderate and poor with an interval of five degrees. The functional section composed of measuring the arc of motion in sagittal plane which includes flexion and extension movements, while the cosmetic section consist of measuring the carrying angle that assess the coronal movements. Greater loss of movements in both means unsatisfactory outcome as shown in figure (4) below.

Result	Rating	Carryingangle loss(º)	Flexion loss(º)	Extension loss(º)
satisfactory	excellent	0º-4.9º	0º-4.9º	0º-4.9º
	good	5º-9.9º	5º-9.9º	5º-9.9º
	fair	10º-14.9º	10º-14.9º	10º-14.9º
unsatisfactory	poor	≥15º	≥15º	≥15º

Figure (4): Showing modified Flynn's criteria with all values.

radiographic assessment done by obtaining both anteroposterior and lateral view of elbow joint to assess the fractured segment reduction and Baumann`s angle calculated for each one.

Statistical analysis:

Independent sample t-test and chi square test used to assess age of the patients, follow up duration and Baumann`s angle after each tupe of fixation. The results were expressed as mean and standard deviation and p value < 0. 05 were considered to be statistically significant. The analysis was done by using IBM SPSS Statistics 22.

Results:

The mean age of the patients for group A was 7. 02 years and for group B, it was 6. 44 years. Group A composed of 11 boys (73.3%) and 4 girls (26, 6%) and group B composed of 9 boys (60%) and 6 girls (40%). Left elbow involved in 10 cases of group A (66.7%), while right one in 5 cases (33.3%). Mechanism of injury in group A was fall on the extended elbow while running in 12 cases (80%), fall from height in one case(6.7%), road traffic accident in 2 cases (13.3%). While in group B, 13(86.7%) due to fall on ground while running and 2(13.3%) cases due to fall from height. In group B left elbow involvement was 11(73.3%), and right side was 4 cases (26.7%), posteromedial displacement was more common in both groups A and B accounting 9(60%) and 12(80%) respectively, while postero lateral displacement was less common representing 4(26.7%) in group A and 3(20%) in group B, while purely posterior was the least common 2(13.3%) in group A and 0 in group B. Mean follow-up period for group A was 2.4 months, while for group B, it was 3.1 months. And the difference between two groups was not significant (P value = 0.47). Baumann`s angle ranged from 64º to 79º with average of 74.2º on the uninjured side. The mean Baumann`s angle loss in the crosseds pinning type and the 2-lateral pinning type were 5.46º ± 1.65º and 4.96º ± 2.74º respectively. Using independent sample t test to compare loss of Baumann`s angle between two groups of fixation, no significant difference was found between two groups (p value =0.58). The carrying angle ranged from 6 to 14 º on the unaffected side and the mean was 9.5 º. In group A, carrying angle of the injured elbow ranged from 5.5 to 13 º with mean of 7.4 º, so all cases in group A had excellen outcome. For group B, it ranged from 5 to 12.5 º with mean of 6.78 º after fixation and the difference between two groups was not significant (p value = 0.65) and one female patient (6.6%) developed cubitus varus deformity in this group with more than 5 degrees loss of carrying angle and less than 10 degrees to contralateral elbow (considered as good according to Flynn`s criteria) that needed reoperation for cosmetic purposses by performing a

lateral closed wedge osteotomy fixed by 2 lateral cortical screws with figure of eight tension band wiring(18) , while other 14 cases (93.3%) had excellent outcome. The mean flexion loss in group A was 8.3º (ranging from 0.5º to 15.5º), in group B, mean flexion loss was 11.25º (ranging from 0.8º to 21.5º) and the difference between two groups was not significant (P value =0.51). Mean extension loss in group A was 6.25º (ranging between 2º –16.40º) while in group B, mean extension loss was 7º (ranging between 3.75º –18º) and the difference was not significant (P value =0.36).Considering functional outcome, 9 patients of group A was excellent (60%), good in 2 patients (13.3%), fair in 4 patients (26.7%) without poor outcome. In group B, 10 patients (66.7%) were excellent, 1 patients (6.7%) were good and 4 patients (26.7%) were fair and again without poor outcome. 2 patient in group A developed iatrogenic ulnar nerve injury (13.3%) that resolved spontanously after about 3 months without perminant damage, in group B, no iatrogenic nerve injury developed and the difference between two groups was statistically not signigicant (P value =0.41). 3 patients (20%) in group A developed pin tract infection and in group B, there was 2 cases (13.3%). Both infection types were superficial healed by clearing pus around pinning area, cleansing, daily dressing and oral antibiotcs. One female patient in group B (6.7%) developde trochlear osteonecrosis after 2 years postoperatively as shown in figure (5) below that was painless and identified by radiographic view of the involved elbow.

Figure (5): Demonsrating antero posterior radiographic view of elbow joint for 11 years old girl with trochlear osteonecrosis treated 2 years ago with 2 lateral pinning due to extension type III supracondylar fracture.

Figure (6) table below demonstrating all patients' data obtained before operation.

Data of the patients	Group A	Group B	P-value
No of patients	15	15	
Age of patients	7.02	6.44	0.25
Sex:			
male	11(73.3)	9(60)	0.43
female	4(26.7)	6(40)	
Mechanism of injuy:			
fall while running	12(80)	13(86.7)	
fall from heigt	1(6.7)	2(13.3)	
road traffic accident	2(13.3)	0	
Affected side:			
left	10(66.7)	11(73.3)	0.69
right	5(33.3)	4(26.7)	
Displacement:			
posteromedial	9(60)	12(80)	0.27
posterolateral	4(26.7)	3(20)	
posterior	2(13.3)		
Baumann`s angle of unaffected elbow(mean)	74.2º		
Carrying angle of unaffected elbow(mean)	9.5º		

Figure 7 table below demonstrating results obtained from patients after operation and subequent follow up.

	Group A	Group B	P-value
Mean follow-up period (months)	2.4±3.2	3.1±1.7	0.47
Baumann`s angle difference(degrees)	5.46±1.65	4.96±2.74	0.58
Carrying angle loss(degrees)	2.10±0.47	2.73±1.01	0.65
Elbow flexion loss(degrees)	8.3±5.7	11.25±2.4	0.51
Elbow extension loss(degrees)	6.25±5.1	7±6.7	0.36
Flynn grade(cosmetic outcome):			
excellent	15	14	0.3
good	0	1	
Flynn grade(functional outcome):			
excellent	9	10	0.38
good	2	1	
fair	4	4	
Iatrogenic ulnar nerve injury	2	0	0.14
Pin tract infection	3	2	0.62
Trochlear osteonecrosis	0	1	0.3
Re-operation	0	1	0.3

Discussion:

The mean age of group A was 7.02±1.61years, while in group B, it was 6.44±1.07 years. And this was comparable to a study done by Carvalho RA et al., on 20 children by a cross sectional study from April 2008 to August 2010, they found that mean age of children was 5.9 years [19], and this is because at this age period, supracondylar region is weak, remodeling and with thinner cortex [15]. Male gender and left sided involvement predominance over female gender and right side also found in the current study and this is also observed by Anjum R et al., in their study on 263 and found that a total of 157(59.70%) cases were males and 106(40.30%) cases were females. Non-dominant extremity was more commonly involved, constituting (65%) of supracondylar fractures in their series patients [20], these results may be because male children are more prone to trauma than females and left sided elbow is weaker than right side makes it more vulnerable to fracture. Ulnar nerve injury usually has been of a major concern in crossed type pinning. These results also seen by Catena N et al., including 1541 patients underwent a closed reduction and cross-pinning in supine position in 2005, 69 patients (4.5%) suffered from ulnar nerve injury but they also concluded that 606 patients treated in prone position, none ulnar nerve lesions were reported [21]. This also has been shown by Krusche-Mandl I et al., while studying in a retrospective cohort study on a series of 78 paediatric patients from September 1992 to June 2004 [22], They stated that about 1 patient (1.3%) developed ulnar nerve injury who regained full recovery after 13 weeks. A meta-analysis done by Na Y et al., by reviewing literatures that have been published, including prospective studies, retrospective studies, and randomized controlled trials up to May 2017 which included 24 studies from electronic databases Google Scholar, PubMed, and Chinese National Knowledge Infrastructure that involved 1163 patients with lateral pinning and 1059 patients with crossed pinning [23]. Of the 24 included studies, 9 were randomized control trials, 5 were prospective studies, and 10 were retrospective studies. They stated that iatrogenic ulnar nerve injury developed in 6 (0.5%) of 1124 patients managed by lateral pinning technique and in 50(4.9%) of 1020 patients managed by crossed pinning and incidence of nerve damage in the crossed pinning patients was significantly higher than that in the lateral pinning patients ($P < 0.0001$). In the present study, there were 2 case in group A (13.3%) who developed iatrogenic ulnar nerve injury that resolved spontanously after three months postoperatively. this is due to course of ulnar nerve behind medial epicondyle makes it vulnerable to injury while inserting medial pin.Both groups show no significant difference regarding Baumann`s angle which means that both fixation techniques were similar to each other. These results were identical to the study made by Anwar W et al., from January 2008 to July 2009 using a randomized controlled trials on fifty patients with displaced supracondylar fracture humerus and by comparing Baumann`s angle of two groups, found no significant difference between both techniques of fixation types [24]. A study done by Sapkota K et al., using 34 patients suffering extension type III supracondylar humeral fractures from July 2015 to July 2018, they also

concluded that there was no significant difference between two groups regarding Baumann`s angle fixed either by crossed pinning or lataral pinning [25]. In group A, there was 3(20%) patients who developed pin tract infection that didn`t extend into the bone and healed with oral antibiotics after about 1 week, while in group B, there was 2 patients (13.3%), and this was comparable to a study made by Elsaid S et al., on a series of 44 patients with extension type III supracondylar fracture from June 2012 to May 2013 using prospective randomized study who found that three patients treated by crossed pinning developed superficial infection and two patients with lateral pinning developed superficial infection [26]. In group B, there was one female patient (6.7%) who developde trochlear osteonecrosis with pain free and full range of motion after two years of fixation. In 2007, Bronfen CE et al., reported dissolution of trochlea after displaced supracondylar fractures treated with percutanous pinning despite of good anatomical reduction and their ages at time of fracture were between 4 years 6 months to 6 years 11 months and developed trochleear osteonecrosis abetween 7 months and 4.5 years post injury [27]. Etier B et al., also reported five cases of trochlear osteonecrosis [28], four of them were females and the other was male and four of these cases were Gartland type III and their ages were between five to ten years at time of injury, represented at 6 months to seven years later with elbow pain or loss of motion and trochlear osteonecrosis. The cause of this complication is due to interruption of trochlear blood supply as claimed by these articles.Both types of fixation regarding carrying angle, showing no significant difference in between, this was comparable to a study done by Prashant K et al., by conducting a prospective, single-blinded randomized controlled trial in a one year duration on 62 patients aged between 3 and twelve years suffering extension type III supracondylar humeral fracture [29], they found out mean carrying angle loss in two lateral pinning was 4.12 degrees and crossed pinning angle was 3.80 with no significant difference between (p value =0.54) and this means that both fixation types were efficient in sagittal plane. Elbow flexion and extension limitation presented in both groups of fixation types and gradual returning to full flexion and extension was seen in both groups by subsequent follow up with no elbow stiffness concluded in the present study, and there was no significant difference between two groups in relation to flexion extension loss, this was comparable to a study made by Lewis E et al., on their study on 141 cases aged between (1.6 to 13.8 years old) with extension type III elbow injuries fixed with either two or three lateral pinning [30], and none of these patients participated in formal physical therapy, they concluded that elbow range of motion returned to (72%) of the uninjured elbow after 1 month and a half, this ratio increased to (86%) after three months, this furtherly increased to (94%) after six months, and after 1 year following pinning, it reached about (98%) and more improvement in elbow range of motion occurred after 1 year following surgery. A prospective randomized study done by Khairy., on 44 children with extension type III supracondylar fracture from June 2012 and May 2013, he concluded that flexion loss was 7.6, while extension loss was 8.2 in crossed pin fixation,

flexion loss in two lateral pinning was 7.6 and flexion loss was 8.2, also they stated that these differences were not significant [31]. This limitation of movement may be due to fracture haematoma and cast effect.So, consideringing Flynn criteria system, there was no significant difference between two groups of fixation types which was comparable to a study made by Sapkota K et al., [25]. A study done by Yousri et al., used a systematic review of 4 randomized controlled trials to compare the efficiency of crossed entry pins over lateral entry pins for fixation of Type III supracondylar fractures [32], they stated that there was no statistical significant difference in means of stability and incidence of encountered complications in both groups.

Limitation:

Power analysis was not done in this study, so smaller sample size produced.

Conclusion:

From this prospective study, we concluded that apart from the susceptibility of the ulnar nerve injury, there was no significant difference between crossed pin configuration and lateral pinning in the treatment of type III supracondylar fracture humerus in children as regarding postoperative clinical results and complications, so, both are equal in terms of stability, outcomes and post operative complications.

References:

[1]. Herring JA. Tachdjian's Pediatric Orthopaedics. 3rd ed. Vol. 3. Philadelphia: W.B. Sanders, Fracture about the elbow; 2002. pp. 2139–221.

[2]. Solomon L, Warwick D, Nayagam S. Apley's System of Orthopaedics and Fractures, 9th ed. Florida: CRC Press; 2010. 758 p.

[3]. Pellegrin DM, Brivio A, Pescatori E, Tessari L. Supracondylar humerus fractures in children: Closed reduction and cross pin fixation in prone position. GIOT. 2008;34:199-204.

[4]. Wilkins KE. The operative management of supracondylar fractures. The Orthopedic clinics of North America. 1990 Apr;21(2):269-89.

[5]. Williamson DM, Coates CJ, Miller RK, Cole WG. Normal characteristics of the Baumann (humerocapitellar) angle: an aid in assessment of supracondylar fractures. Journal of pediatric orthopedics. 1992;12(5):636-9.

[6]. Kocher MS, Kasser JR, Waters PM, Bae D, Snyder BD, Hresko MT, et al. Lateral entry compared with medial and lateral entry pin fixation for completely displaced supracondylar humeral fractures in children. A randomized clinical trial. J Bone Joint Surg Am. 2007 Apr;89(4):706–12.

[7]. Ramachandran M, Skaggs DL, Crawford HA, Eastwood DM, Lalonde FD, Vitale MG, Do TT, Kay RM. Delaying treatment of supracondylar fractures in children: has the pendulum swung too far?. The Journal of bone and joint surgery. British volume. 2008 Sep;90(9):1228-33.[PubMed].

[8]. Krusche-Mandl I, Aldrian S, Köttstorfer J, Seis A, Thalhammer G, Egkher A. Crossed pinning in paediatric supracondylar humerus fractures: a retrospective cohort analysis. International orthopaedics. 2012 Sep 1;36(9):1893-8. [PMC free article] [PubMed].

[9]. Brauer CA, Lee BM, Bae DS, Waters PM, Kocher MS. A systematic review of medial and lateral entry pinning versus lateral entry pinning for supracondylar fractures of the humerus. Journal of Pediatric Orthopaedics. 2007 Mar 1;27(2):181-6. [PubMed]

[10]. Canale ST, Beaty J. Campbell's Operative Orthopaedics , 12th ed. Canada: Patricia Tannian; 2012. 1405 p.

[11]. Dua A, Eachempati KK, Malhotra R, Sharma L, Gidaganti M. Closed reduction and percutaneous pinning of displaced supracondylar fractures of humerus in children with delayed presentation. Chinese Journal of Traumatology (English Edition). 2011 Feb 1;14(1):14-9. [PubMed].
[12]. Woratanarat P, Angsanuntsukh C, Rattanasiri S, Attia J, Woratanarat T, Thakkinstian A. Meta-analysis of pinning in supracondylar fracture of the humerus in children. Journal of orthopaedic trauma. 2012 Jan 1;26(1):48-53. [PubMed].
[13]. Wilkins KE. Fractures in children. 3rd ed. Philadelphia: JB Lippincott; 1991. Fractures and dislocations of the elbow region. In: Rockwood CA Jr, Wilkins KE, King RE, editors; pp. 526–617.
[14]. Ryan LM. Evaluation and management of supracondylar fractures in children. UpToDate, Waltham, MA (accessed on june 15, 2015). 2009. [Google Scholar].
[15]. Kasser JH. Supracondylar fractures of the distal humerus. U: Beaty JH, Kasser JH, ur. Rockwood and Wilkins fractures in children, 5 izd. [Google Scholar].
[16]. Kirschner Wire Is Used in Surgery to Hold Broken Bones [Internet]. Verywell Health. 2019 [cited 22 January 2019]. Available from: https://www.verywellhealth.com/what-is-a-kirschner-wire-2548523.
[17]. Flynn JC, Matthews JG, Benoit RL. Blind Pinning of Displaced Supracondylar Fractures of the Humerus in Children: SIXTEEN YEARS'EXPERIENCE WITH LONG-TERM FOLLOW-UP. JBJS. 1974 Mar 1;56(2):263-72. [PubMed].
[18]. Srivastava AK, Srivastava DC, Gaur SC. Lateral closed wedge osteotomy for cubitus varus deformity. Indian journal of orthopaedics. 2008 Oct;42(4):466.
[19]. Carvalho RA, Franco Filho N, Castello Neto AB, Reis GD, Dias MP. Fratura supracondiliana de Ãºmero em crianÃ\Sas: fixaÃ\SÃ\poundso com dois fios de Kirschner cruzados. Revista Brasileira de Ortopedia [Internet]. 2012;47:705–9. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-36162012000600005&nrm=iso.
[20]. Anjum R, Sharma V, Jindal R, Singh TP, Rathee N. Epidemiologic pattern of paediatric supracondylar fractures of humerus in a teaching hospital of rural India: A prospective study of 263 cases. Chinese journal of traumatology = Zhonghua chuang shang za zhi [Internet]. 2017 Jun;20(3):158–60. Available from: https://www.ncbi.nlm.nih.gov/pubmed/28511800
[21]. Catena N, Calevo M, Fracassetti D, Moharamzadeh D, Origo C, De Pellegrin M. Risk of ulnar nerve injury during cross-pinning in supine and prone position for supracondylar humeral fractures in children: a recent literature review. 2019.
[22]. Krusche-Mandl I, Aldrian S, Köttstorfer J, Seis A, Thalhammer G, Egkher A. Crossed pinning in paediatric supracondylar humerus fractures: a retrospective cohort analysis. International orthopaedics [Internet]. 2012 Sep;36(9):1893–8. Available from: https://www.ncbi.nlm.nih.gov/pubmed/22729665.
[23]. Na Y, Bai R, Zhao Z, Han C, Kong L, Ren Y, et al. Comparison of lateral entry with crossed entry pinning for pediatric supracondylar humeral fractures: a meta-analysis. Journal of Orthopaedic Surgery and Research [Internet]. 2018 Apr 3;13(1):68. Available from: https://doi.org/10.1186/s13018-018-0768-3.
[24]. Anwar W, Rahman N, Khan MA, Idrees M. Radiological Evaluation of The Stability of Crossed-Pins Versus Lateral-Pins Fixation in Displaced Supracondylar Fractures of Humerus. Journal of Surgery Pakistan (International). 2013 Jul;18:3.
[25]. Sapkota K, Wahegaonkar K, Ranjeet N, Thapa P, Thapa U, Onta P. Comparison of cross pinning versus lateral three pins in type three supracondylar fracture of distal humerus in children. AJMS [Internet]. 1Mar.2019 [cited 18May2019];10(2):58-1. Available from:

https://www.nepjol.info/index.php/AJMS/article/view/22034.
[26]. Said EA. Crossed-Pin Configuration Versus Lateral Pins In Treatment Of Supracondylar Humeral Fracture In Children. 2015. [Research Gate]
[27]. Bronfen CE, Geffard B, Mallet JF. Dissolution of the Trochlea After Supracondylar Fracture of the Humerus in Childhood: An Analysis of Six Cases. Journal of Pediatric Orthopaedics [Internet]. 2007;27(5):547–50. Available from: https://journals.lww.com/pedorthopaedics/Fulltext/2007/07000/Dissolution_of_the_Trochlea_After_Supracondylar.12.aspx.
[28]. Etier B, Scott Doyle J, R Gilbert S. Avascular Necrosis of Trochlea After Supracondylar Humerus Fractures in Children. Vol. 44. 2015. E390 p.
[29]. Prashant K, Lakhotia D, Bhattacharyya TD, Mahanta AK, Ravoof A. A comparative study of two percutaneous pinning techniques (lateral vs medial-lateral) for Gartland type III pediatric supracondylar fracture of the humerus. J Orthop Traumatol [Internet]. 2016 Sep;17(3):223–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/27312248
[30]. Zionts LE, Woodson CJ, Manjra N, Zalavras C. Time of return of elbow motion after percutaneous pinning of pediatric supracondylar humerus fractures. Clinical Orthopaedics and Related Research®. 2009 Aug 1;467(8):2007-10. [Google Scholar].
[31]. Khairy A. Fixation of Supracondylar Humeral Fracture in Children By Medial and Lateral Pinning Versus Lateral Pinning. MOJ Orthop Rheumatol. 2016;6(7):00248.
[32]. Yousri T, Tarassoli P, Whitehouse M, Monsell F, Khan WS. Systematic review of randomized controlled trials comparing efficacy of crossed versus lateral K-wire fixation in extension type Gartland type III supracondylar fractures of the humerus in children. Ortop Traumatol Rehabil. 2012 Oct;14(5):397–405.