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Kirschner Wire Fixation for Lateral Condylar Humerus Fracture in Children

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Abstract

Background: Lateral condyle humeral fractures are relatively common in developing regions of the world. Lateral condyle humeral fractures in the pediatric age group, most commonly distal humeral head injuries, are often associated with late presentation to medical professionals at the end of the course.

Materials and Methods: Twenty-one children with lateral condyle humeral fractures with a duration of injury 1-3 weeks and greater than 3 weeks were included in a prospective study. Of the 21 patients, 14 were male and 7 were female. All patients had Milch type II injuries. Patients were treated with open reduction and internal fixation with Kirschner wires. The outcome was assessed using the scoring system proposed by Dhillon., *et al*.

Results: Mean age (months) at surgery was 81.5 months (range 64-112 months); 8 right/13 left; Reason for admission: Pain, swelling in 12 patients; Pain, Decreased elbow mobility in 7 patients, Stiffness of elbow joint in 2 patients. Mean time from fracture to surgery was 6.34 weeks; ≤ 3 weeks in 13 patients and > 3 weeks in 8 patients; Previous treatment: Casting in 15 patients and No treatment in 6 patients; Mean follow-up time: 66 months; Mean age at last follow-up was 11.6 years (range 8.4-15.0). Overall results: Total result, 38.1% in Excellent, 38.1% in Good, 14.3% in Fair, and 9.5% in Poor. Comparative results were accepted at ≤ 3 weeks initial fracture to surgery and > 3 weeks with PValuate 0.001387. There was 1 case of AVN, and Nonunion in 1 case.

Conclusion: Kirschner wire fusion without bone grafting can provide a secure bone union and improve elbow function. However, this technique cannot completely prevent angular deformity. Orthopedic surgery should be considered in patients with valgus or varus deformity.

Keywords: *Late Presentation; Lateral Epicondyle Fracture; Acute Operation; Surgical Technique; Surgical Management*

Introduction

Lateral condyle humeral fractures in children are a common condition. This injury is essentially a fracture of the epiphysis; therefore, in the long term, it is often associated with potential problems such as growth arrest, premature epiphyseal closure, limited range of motion, elbow angle deformity, and neurological complications. Current literature recommends surgical treatment for displaced fractures less than 3 weeks old. However, orthopedic societies have conflicting views on the treatment of the same fracture lasting more than 3 weeks. Lateral condyle humeral fractures are the second most common fracture in children, accounting for 16.9% of all upper extremity fractures [1]. Prompt treatment with precise reduction, Kirschner wire fixation, and regular follow-up will yield good results [1]. However, if diagnosis is delayed or reduction in casting is lost after initial conservative treatment, poor or nonunion may occur, leading to persistent pain and reduced range of motion (ROM) of the elbow [2]. The surgical approach for these patients remains controversial. In 1975, Jakob., *et al*. [3] reported the results of open reduction in seven patients after three to 12 weeks, describing a mean loss of range of motion of 34°, and concluding that open reduction was no more effective than medical treatment in these patients. Opponents of surgical treatment have argued that surgical treatment may jeopardize the already unstable vascular supply of the surgically displaced fragment, threatening avascular necrosis of the fragment; furthermore, the fracture surfaces no longer conform to each other and the small amount of soft tissue attachment is shortened and contracted, making accurate reduction difficult. It has also been reported that anatomical reduction is difficult in cases of nonunion and that the surgery itself may lead to avascular necrosis (AVN) of the bone fragment [3-5]. Several authors have reported surgical results in delayed cases where AVN was avoided [5-11]. Nonunion results in good functional outcomes, except in some cases of joint instability and angular deformity. Delayed ulnar nerve palsy and deformities can be treated separately without any attempt at fusion. While advocates of surgical intervention for lateral condyle humeral fractures in children maintain that this is a metaphyseal injury, precise reduction and internal fixation are required to prevent long-term complications. Since the lateral condyle also participates in the development of the lower humerus, underdevelopment of the trochanter and the head may lead to osteosynthesis deficiency and, consequently, fishtail deformity, radial head underdevelopment/dysplasia, joint instability, limited forearm rotation, and nerve palsy.

We report the results of surgical treatment for 21 pediatric lateral condyle humeral fractures presenting ≤ 3 weeks and more than 3 weeks after the initial fracture. Our hypothesis was that open reduction and internal fixation (ORIF) could improve elbow function without increasing the incidence of complications such as humeral dysplasia, AVN. and premature closure of the physeal.

Materials and Methods

A retrospective study was performed to evaluate the outcomes of surgical techniques performed between December 2013 and December 2021 in 25 patients with lateral condyle of the humerus in children. The surgeries were performed by a single surgeon (Author).

The study was approved by the Ethics Review Committee of our Institution and was conducted in accordance with the principles of the Declaration of Helsinki.

The patients underwent "*In-situ* bone grafting without bone grafting" for the treatment of LCF that developed > 3 weeks after fracture. According to the criteria of Flynn., *et al*. [12], if the fracture did not unite within 3 months, it was defined as nonunion. Between 2013 and 2021, 25 patients presented to our institution with present of LCF and underwent the index procedure. One patient was lost to follow-up and three were excluded because the time to surgery was <3 years, leaving 21 patients in this study. All patients with metabolic bone disease, skeletal dysplasia, and lateral condyle fractures with superior condyle dislocation, medial condyle dislocation, and elbow dislocation were excluded from the study.

All patients were transferred from other hospitals and presented with lateral elbow pain and pain on elbow movement at the time of examination. None of the children had signs of ulnar neuropathy. All patients had varying degrees of elbow mobility impairment. Most patients had some degree of elbow flexion contracture and pain on elbow movement, making it impossible to accurately assess the bearing angle and elbow instability.

Diagnosis

Physical examination

Most patients presented with localized pain and swelling on the lateral aspect of the distal humerus, along with functional impairment manifested as limited upper limb mobility. During the initial physical examination, it is important to assess the neurovascular status of the elbow joint, checking for the presence of hematoma, which may indicate a displaced fracture and instability [13].

Imaging

Radiography

Currently, radiography remains the gold standard for diagnosing LHC fractures in children, with general recommendations including anteroposterior (AP) and 4/13 lateral radiographs. While some experts recommend additional lateral radiographs in uncertain cases, others recommend their routine use as they may provide a clearer picture of fracture displacement (Case 3 - Figure 1). This should be emphasized to residents and young surgeons, and emphasizes the need to suspect LHC fractures in patients with elbow pain and functional impairment. If necessary, comparison with contralateral radiographs can be performed.

Figure 1: *Non-displaced LHC fracture, for which conservative treatment is recommended. A: An AP view, where the fracture is vaguely visible. B: A lateral view, where the fracture is not appreciable. C: An internal oblique view, where the characteristics of the fracture are clearly distinguishable.*

Ultrasound

Ultrasound offers advantages in assessing articular cartilage, cortical bone damage, and distinguishing stability from unstable fractures. With a sensitivity of 92.9% to 98% in pediatric elbow fractures, ultrasound is an effective and rapid alternative diagnostic method, as it is easily available in emergency situations.

However, the limitation of ultrasound lies in its dependence on the skill of the sonographer. Although it is not currently a complete replacement for radiography, it remains a valuable diagnostic tool, helping to avoid patient radiation exposure [14].

Magnetic resonance imaging (MRI)

MRI provides high-resolution images of soft tissues, a capability that is particularly valuable in this setting as it allows visualization of incompletely ossified epiphyses.

MRI is particularly useful in patients with non-displaced or minimally displaced fractures, assisting in assessing the integrity of the articular cartilage and classifying fractures as stable or potentially unstable [15].

However, the disadvantages of this modality include limited availability, the need for anesthesia in patients under 6-7 years of age, and high cost. Therefore, our recommendation is to reserve MRI for complex cases.

Radiographic diagnosis can be difficult due to factors related to the patient's age. Painful pediatric patients may not be fully cooperative during the scan, while incompletely ossified epiphyses can complicate the identification of fractures, especially when there is no or minimal displacement.

Computed tomography (CT)

CT has emerged as a useful tool for determining fracture classification and displacement.

Although it has the disadvantages of high radiation exposure. However, the advent of multi-detector CT (MDCT) scanning in many centers offers the potential to reduce radiation dose to the elbow joint. This advanced technology allows rapid assessment of cartilage damage through a painless procedure, eliminating the need for patient anesthesia [16].

CT assessment is particularly beneficial in fractures where localization of displacement may be difficult with other imaging methods, especially in cases where treatment decisions depend on assessing the location of displacement (e.g. fractures with displaced bone fragments of less than 2 mm) [26]. However, the use of CT remains limited, and like MRI, it is reserved for cases that are difficult to examine with more conventional diagnostic methods.

Arthrography

Arthrography, although providing visual images of structures within the joint, is increasingly being used in diagnosis. Its invasive nature promotes the preference for MRI or CT when detailed soft tissue evaluation is required. However, it remains a widely used intraoperative method for assessing articular cartilage adequacy [17].

Imaging test selection

The unique anatomy of pediatric patients requires careful consideration of radiation exposure. Therefore, given the complexity of each case, a balance must be struck between maximizing diagnostic accuracy and minimizing exposure, where previously described alternatives may be used [14]. However, we are mindful of the practical challenges we face in the clinical setting, including cost, equipment availability, and time constraints. Therefore, in clinical practice, we rely mainly on anteroposterior (AP) and lateral radiographs for diagnosis, reserving the oblique view for cases of diagnostic uncertainty to minimize radiation exposure to the patient. specifically, we recommend the use of the internal oblique view for non-displaced or minimally displaced fractures, as this provides a better visualization of the true displacement of the bone fragments, which aids in the decision between conservative and surgical treatment. In more complex cases, we conduct an individual assessment of the diagnostic needs to determine which imaging modality will be used.

At the time of examination, the radiographs showed a clear fracture gap between the distal humerus and the lateral condyle fragments, and no bone callus over the fracture gap. All patients had lateral condyle fragments. All fractures were Milch II type, with varying degrees of superolateral displacement. Displacement was measured from the medial and lateral metaphyseal ends of the lateral condyle fragments to the original position of the distal humerus on the anteroposterior or internal oblique radiographs. The measurement with the greatest displacement was considered the amount of medial and lateral displacement. The amount of displacement of the lateral epicondyle was measured to be 3 to 9 mm, with a mean of 5.2 mm medially, and 4 to 10.4 mm, with a mean of 6.8 mm laterally.

The indication for surgery was intra-articular displacement > 2 mm and decreased elbow range of motion. The procedure included open reduction, Kirschner wire fixation, and cast fixation.

Classification

The correct classification of LHC osteophytes can be crucial in determining the optimal treatment for each case. There are several systems that have been validated and are widely used in clinical practice, each based on different criteria. Although all are accepted, their simplicity of application, reproducibility and guidance adjustment differ, so the latest research evidence can help to choose between them [18].

Reload sample

Milch classification: The Milch classification [19] divides LHC osteophytes into two types based on the protective entertainment lights that trace the frame impact.

- Type I bone fragments exit the fight on the outside of the purge. We represent the type IV bone forging system according to Salter-Harris (the next classification of the osteochondral system) and are considered to be the stable frame system.
- In type II bone, the most common type, the fight line crosses the meshwork. We are considered a Salter-Harris type II steel frame and are likely to be unstable.

Wall translation and concordance

Jakob classification: The Jakob classification [20] identifies that the bone originates from the lateral aspect of the condyle, with three classifications based on the translation of the bone fragment.

- In a type 1 bone frame, there is a non-translated bone fragment (<2 mm), the contour is not united. This is to reproduce a raw material requirement that acts as an aid to correct the bone fragment.
- In a type 2 bone frame, there is a minimal translation of 2-4 mm and the rail passes through the joint but there is no bone fragment.
- In a type 3 bone, there is a translation greater than 4 mm with a rotational component and loss of radiocapitellar concordance.

The Weiss classification [21] is primarily based on bone fragment translation and was developed with the goal of establishing treatment recommendations and predicting complications.

- In type 1 osteotomy, there is a shift <2 mm, with the articular surface. Value maintenance exists.
- In type 2 osteotomy, there is a drift ≥2 mm, maintaining the atomic articular surface. Gap and fixation.
- In wave 3, there is a drift ≥2 mm and loss of articulation. Gain and internal fixation.

Type, deviation and stability

Song classification: The Song classification [22] combines the assessment of the metal fragments, technique and stability rate, thereby combining the criteria used by other systems and making it the most comprehensive classification.

- In stage 1, there is a 2 mm deviation, with the curve located at the bone activity and stability; all four radiographs are required for assessment.
- In stage 2, there is a 2 mm deviation, and the line extends to the epiphyseal fragment with a small gap on the outside. Its stability is not well defined and requires four radiographs to be assessed.
- Stage 3: Displacement >2 mm, with a gap that widens medially and laterally. The fracture is unstable and can be found on any radiograph.
- Stage 4: Displacement >2 mm, with intra-articular joint fusion, no bone fragment rotation. The fracture is unstable and can be found on any radiograph.
- Stage 5: Displacement >2 mm, with intra-articular fusion, with bone fragments. The fracture is unstable and can be found on any radiograph.

Selection of a classification system

Currently, there is no consensus on a recommended classification system for LHC bones in clinical practice. However, individual recommendations have been published based on inter- and intra-observer correlations, which were found to be lower in the Milch classification than in the Weiss classification [23], with acceptable values in the Jakob classification-although lower than for bones with rotational components and high values in the Song classification. However, the latter classification may cause difficulties in the separation of subtypes 2-4 [18]. We believe that the final choice of classification system should depend on the expert, hospital setting, and available clinical practice of the center, using the selected systems for all patients to ensure consistency. In clinical practice, we often accompany the Jakob and Milch classifications, while acknowledging the broader applicability of the Song classification in scientific contexts.

Surgical technique

The surgical approach is performed through the lateral elbow. Dissection is made through the plane between the triceps and brachioradialis. Dissection is made through the lateral fascia to the fracture site. The bone fragment is often displaced, and fibrous tissue often makes it difficult to assess the fracture orientation. Careful debridement of the fibrous tissue is performed, sparing the posterior attachments. Thorough irrigation is performed to remove fibrinous debris. Any surgery required on the lateral epicondyle and humerus is performed anteriorly to avoid the posterior blood supply and minimize the risk of avascular necrosis. The displaced bone fragment is reduced under direct vision, usually with the aid of forceps, Kirschner "joystick" wires, or manual pressure by an assistant. We use 1.4 mm Kirschner wires for patients under five years of age, 1.6 mm wires for patients between five and eight years of age, and 1.8 mm wires for patients over eight years of age. No patients received bone grafting. Postoperatively, all patients underwent a common protocol of 3 weeks of cushioned Cramer wire immobilization followed by 3 weeks of intermittent knee range of motion exercises.

After 6 weeks, the Kirschner wire was removed. Patients were allowed to perform knee range of motion exercises without the brace after 6 weeks. All patients were followed up for a year and to date, according to Dhillon., *et al.* [24].

Radiographically, avascular necrosis, poor union, nonunion, and anisotropic ossification were specifically considered. Union was assessed on anteroposterior and lateral radiographs of the elbow. Union was considered to have occurred when the fracture was obliterated by trabeculae or callus. Radiographic findings were evaluated for lateral bone overgrowth, fishtail deformity, presence of osteonecrosis, and valgus or varus deformity at the latest follow-up.

To assess function, elbow range of motion and signs of ulnar neuropathy were examined and the presence of pain and tenderness on elbow motion and fatigue during strenuous activities such as sports were examined. To assess cosmetic problems, the bearing angle was measured and compared with the contralateral side and the development of a bony humerus on the outside of the distal humerus after surgery was examined.

To assess outcome

To assess overall outcome, the scoring system proposed by Dhillon., *et al.* [24] was used. This scoring system includes pain on activity, range of motion and bearing angle (Table 1).

Statistical analysis

Paired-sample t tests were used to compare preoperative and postoperative elbow function. Univariate regression analysis was performed to determine whether there was a statistically significant association between each surgical and preoperative variable and the final increase in function changes by time group from initial fracture to surgery ≤ 3 weeks and > 3 weeks, and to compare the results

Function		Carrying Angle (Degree)	Score Points Each Column
Pain	Range of Motion (Deg,)		
None	0-140	Valgus 7-10	3
Occasional	>15-125	Valgus < 20 Varus < 0	2
After heavy work (or activities)	>30-110	Valgus 20-30 Varus 0-15	1
With normal activity (morto or sensory loss)	>30-110	Valgus > 30 Varus > 15	0

Table 1: *Scoring system for the outcome of fractures of the lateral humeral condyle in children [25].*

Functional grading (points): Excellent 6, Good 5. Fair 4, Poor < 4. Overall grading (points): Excellent 9, Good 7-8. Fair 5-6, Poor < 4.

of the two time groups. All analyses were performed using SPSS software, version 12.0 (SPSS Inc., Chicago, Illinois), and a P value < 0.05 was considered statistically significant.

Results

Total of 21 patients were included in our study (Table 2). There were 14 Male and 7 Female. 81.5 months (range, 64-112 months). Time from injury to Operation 1 weeks - ≤ 3 weeks with 13 Patients (Case 3-Figure 2), and > 3 weeks with 8 patients. Union was achieved in 19 of them (90.5%) patients at average 9 weeks (range, 7 to 11 weeks) (Case 9-Figure 3). The average duration of follow-up was 66 months (range, 38 to 89 months). In one patient had evidences of osteonecrosis on the latest follow-up radiographs. In 5 patients, variable degrees of lateral bony hump were shown on anteroposterior radiographs. It originated from the superolaterally displaced metaphyseal fragment of fractured lateral humeral condyle, which was fixed *in situ*. Although lateral bony hump was shown on radiographs, it was hardly detectable on gross clinical examination and no patients complained about mild bony protrusion on lateral side of elbow. In one patient (case 14), bony hump had remodeled completely on the latest follow-up radiographs, and the size of bony hump had decreased with time in the remaining patients.

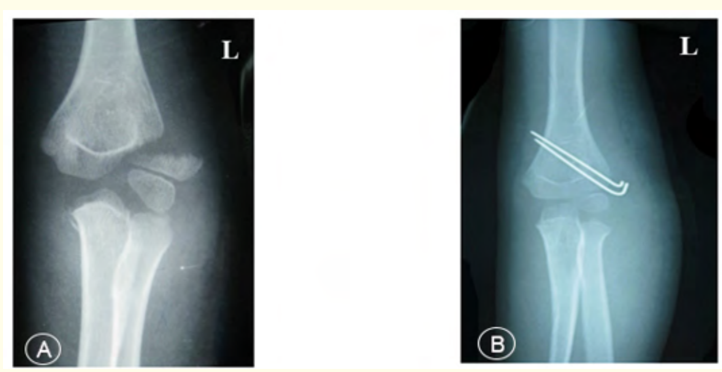

Figure 2: *(Case 3) Initial injury 5 weeks; A: Pre-operation, B: Post-operative 5 weeks.*

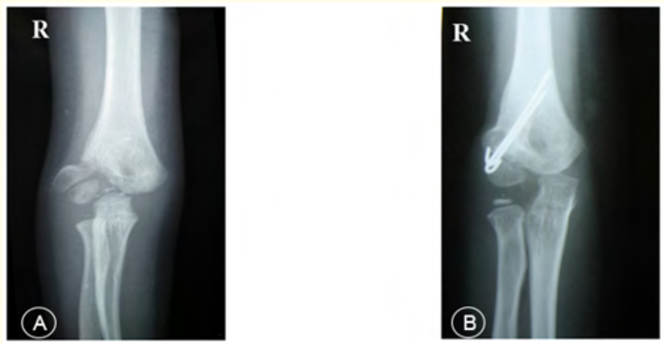

Figure 3: *(Case 9) Initially 6 weeks. A: Pre-operation, B: Union postoperative 6 weeks.*

Case	Gender	Age at Operation (Months)	Side	Reason for presentation	Time Inj-Ope. (Weeks)	Previous treatment	Follow-up (Moths)	Age at last Follow-up (Yrs, Months)
1	Female	64	R	Pain, swelling	1	No Treat-ment	94	8, 4
2	Male	89	R	Pain, Decreased elbow motion	7	Plaster	76	13, 8
3	Male	74	L	Pain, swelling	2	Plaster	85	13, 3
4	Male	91	L	Pain, swelling	3	Plaster	86	14, 7
5	Male	70	R	Pain, swelling	3	Plaster	78	12, 3
6	Female	68	L	Pain, swelling	2	Plaster	46	12,0
7	Male	86	R	Pain, swelling	3	Plaster	48	11, 2
8	Male	76	R	Pain, swelling	3	Plaster	89	13, 7
9	Male	98	R	Restriction of the elbow flexion	3	Plaster	81	14, 9
10	Female	78	L	Pain, swelling	3	No Treat-ment	68	12, 1
11	Male	95	R	Pain, Decreased elbow motion	9	Plaster	53	12, 2
12	Male	78	R	Pain, Decreased elbow motion	8	Plaster	74	12, 6
13	Male	112	R	Pain, swelling	3	Plaster	38	15, 0
14	Male	85	L	Pain, swelling	2	Plaster	69	12, 8
15	Female	76	L	Pain, Decreased elbow motion	7	Plaster	46	10, 2
16	Female	64	L	Pain, Decreased elbow motion	8	No Treatment	45	9, 1
17	Male	81	R	Pain, swelling	2	Plaster	75	13, 0
18	Male	106	R	Pain, swelling	2	Plaster	56	13, 5

19	Male	78	L	Pain, Decreased elbow motion	7	No Treatment	47	10, 4
20	Male	74	L	Restriction of the elbow flexion	8	No Treatment	71	12, 2
21	Female	68	L	Pain, Decreased elbow motion	9	No Treatment	63	10, 9

Table 2: *General information of the patient.*

There are 13 male and 8 female (61.6%), Mean age (months) at operation 81.5 months (range, 64-112 months); 8 right/13 left; Classification according to Milch, all patient in type II; Reason for presentation: Pain, swelling in 12; Pain, Decreased elbow motion in 7, Restriction of the elbow flexion in 2. Time from injury to Operation with mean 6.34 weeks, 1 week - 3 weeks with 13 Patients with 13 Patients, and > 3 weeks with 8 patients; Previous treatment: Plaster cast in in 15 Patients, and No treatment in 6 Patients; Mean time of Follow-up: 66 Months; Mean Age at last Follow-up was 11,6 (range, 8,4-15,0). There were 2 cases with nonunion (cases 2 and 21); AVN in 1 case (case 9).

Cubitus valgus was seen in 4 patients (range, 12° to 18°) and cubitus varus in 5 patients (range, 10 to 8 degrees) by the criteria of scoring system proposed by Dhillon., *et al*. [4] which defined the ideal carrying angle as 7 to 10 degrees of valgus. However, in 7 patients who had angular deformities, the difference of carrying angle between the affected side and contralateral side was within 5 degrees at the latest follow-up. The parents and patients were satisfied with the alignment of upper extremity in 11 patients. In the remaining 3 patients, cubitus varus deformity of 21 degrees or more than contralateral side developed in 1 patient**.** One cubitus valgus deformity (case 12) with a carrying angle of 18 degrees was not found to be substantially improved at the latest follow-up, and both the patient and the parents refused to undertake the corrective osteotomy. The other one patient with cubitus valgus deformity (Case 7 - Figure 4) did not want corrective osteotomy.

Figure 4: *(Case 7) Patient have left cubitus valgus.*

At the latest follow-up, tenderness over the lateral aspect of the elbow had disappeared. All the children were pain free at the elbow upon strenuous activities, and there were no signs or symptoms suggestive of ulnar nerve dysfunction. Range of motion was remarkably improved in most of the patients. The average flexion contracture of the elbow joint decreased from 25 degrees (range, 0° to 52°) before surgery to 4.6 degrees (range, 0 to 14 degrees), and the range of elbow flexion increased from 118 degrees (range, 90 to 135 degrees) to 136 degrees (range, 125 to 140 degrees). Pronation and supination were full in all patients with initial fracture under 6 weeks (Case 8 - Figure 5). Overall outcome according to the scoring system proposed by Dhillon., et al. [4] in time from injury to operation ≤ 3 weeks was excellent in 8 patients (61.5%), good in 5 patients (39.5%); in time from injury to operation > 3 weeks was, good in 3 (37.5%) patients, fair in 3 patient (37.5%), and poor in 2 patient (25.0%) (Table 3). Total results Excellent 8 (38.1%), Good 8 (38.1%). Fair 3 (14.3%), Poor 2 (9.5%).

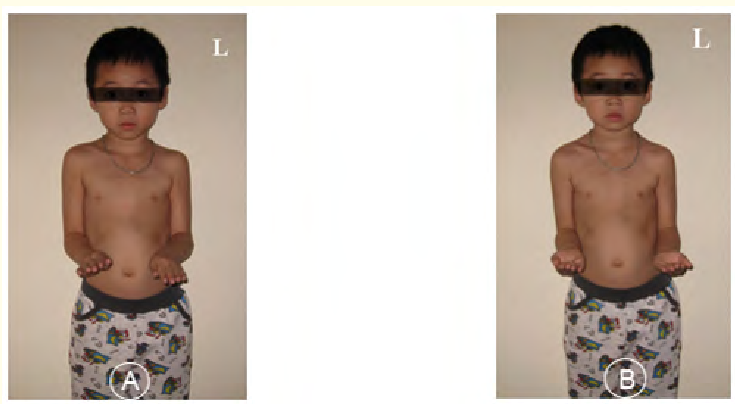

Figure 5: *(Case 8) Function of the elbow with A: Full Pronation and B: Full Supination.*

Fracture presentation Time	Outcome according to Dhillon's scoring system			
	Excellent (%)	**Good (%)**	**Fair (%)**	**Poor (%)**
≤3 Weeks n =13	8 61.5%	5 39.5%		
> 3 Weeks n = 8		3 37.5%	3 37.5%	2 25.0%
Total	8 38.1%	8 38.1%	3 14.3%	2 9.5%

Table 3: *Compare latest results of operation according to fracture presentation time.*

Accepted result (Excellent and good) was all patients 100% in time of fracture to operation ≤ 3 weeks and 25% in time > 3 weeks. Total result, 38.1% in excellent, 38.1% in good, 14.3% in fair, and 9.5% in poor (Two cases of complications in the group from fracture to surgery > 3 weeks). Comparison of accepted result in time of initial fracture to operation ≤ 3 weeks better than > 3 weeks with PValuate 0.001387. There were AVN in 1 cases, Nonunion in 1 case.

Discussion

Displaced lateral condyle humeral fractures are rare and are considered one of the most difficult pediatric injuries to treat due to the difficulty of surgery and the risk of postoperative complications. Recently, several studies have demonstrated significant improvement in postoperative outcomes and advocated several surgical techniques that preserve the vascularity of the lateral condyle fragment and provide acceptable reduction during surgery [26]. However, the techniques mentioned above do not provide a clear reference for correction of longitudinal deformity, and studies have also failed to demonstrate a correlation between longitudinal axis deviation and postoperative functional outcome.

In developing countries, patients with lateral condyle humeral fractures often present late [27]. Diagnosis is sometimes missed due to incorrect interpretation of radiographs, as the fragment is partly cartilaginous; radiographs are also often of poor quality. A prospective cohort study showed that lateral oblique radiographs were more sensitive than conventional anteroposterior (AP) radiographs in diagnosing displaced or minimally displaced fractures. Recently, 20° AP radiographs have been proposed to demonstrate fragmented dislocations more accurately than standard radiographs. High-resolution ultrasound [28] or MRI [29] can also demonstrate articular cartilage and displacement; however, these tools may not be available in rural and suburban areas in most developing countries. Therefore, the diagnosis of minimally displaced fractures is often missed in the early stages, often performed late or only after more significant displacement has occurred.

Lateral condyle fractures of the humerus are among the most common injuries encountered by orthopedic surgeons. Henry Milch distinguished between two types of fractures. Type 1 condylar fractures are type 1 and type 2 condylar fractures are type 2, Milch type I fractures are Salter type IV head injuries and Milch type II fractures are Salter type II injuries. In most injuries, the degree of displacement depends on the preservation of the joint. If the joint is intact, the condylar fragment is only tilted to one side. If the fracture is complete, the bone can rotate completely close to 180 degrees.

Undisplaced Milch type I fractures are usually treated with cast immobilization. There is a risk of delayed displacement and nonunion if the injury is not monitored regularly with radiographs. We believe that delayed displacement is a relevant sequela of any fracture as this can lead to prolonged use of a cast, causing discomfort to the patient, increasing costs and resource utilization, and increasing the risk of elbow stiffness.

Delayed displacement fractures require immediate open surgery and internal fixation of the fracture. Toh., *et al*. [30] looked at the long-term functional outcomes of condylar nonunion in children and concluded that a Milch type I fracture causes more functional disability due to the loss of the normal radius-capillary relationship due to the partial separation of the head. Therefore, what initially appears to be a small, stable fragment, if displaced, may result in more functional disability than a potentially unstable Milch type II fracture.

Treatment options

Nonoperative treatment is the preferred option for fractures with minimal displacement (<2 mm) and no additional damage [31]. Close follow-up is mandatory to exclude secondary displacement in the cast. Follow-up should be performed within one week of injury in the outpatient clinic and should include conventional radiographs in the AP, lateral, and oblique views. If the fracture is displaced >2 mm, with articular surface damage, reduction and fixation of the fracture is recommended.

The authors of each lateral condyle humeral fracture classification system have made recommendations for treatment options based on the severity of the fracture; these recommendations can be found in table 2. In cases of successful and uncomplicated union, the success rates for nonoperative and operative lateral condyle humeral fractures, as described in meta-analyses, range from 89.8-91.5%. Delayed diagnosis of these fractures (>3 weeks post-injury) should be made initially based on the time from injury to symptoms and the degree of displacement, according to the options described above. Unfortunately, late diagnosis of these fractures is quite common after 3 months [32]. The management of these complications requires a different approach depending on the degree of displacement, elbow position, and condylar stability.

	1 (A)	2 (B)	3 (C)	4	5
Jakob [3]	Cast/CRPP	CRPP	ORIF	-	-
Flynn [5]	Cast/CRPP	CRPP	CRPP/ORIF	-	-
Milch [19]	Cast/CRPP	CRPP/ORIF	-	-	-
Weiss [21]	Cast/CRPP	CRPP	ORIF	-	-
Song [22]	Cast	Cast/CRPP	ORIF	CRPP	ORIF

Table 4: *Classification of lateral condylar humeral fractures and corresponding preferred treatment options for pediatric patients.*

Cast = Above elbow cast, CRPP = Closed reduction and percutaneous pinning with Kirschner wires, ORIF = Open reduction internal fixation with Kirschner wires and/or cannulated screw.

Non-surgical/operative treatment options: Plastered cast therapy

The non-operative treatment of choice for lateral humeral condyle fractures in children is an above-elbow cast. This is used for non-displaced fractures, intact articular surfaces, and no additional trauma. The elbow should be flexed to 90 degrees, with the wrist and hand in a neutral position (Figure 6).

The patient should return after 4 weeks for cast removal if non-operative treatment fails to reveal secondary fracture displacement on long-arm cast radiographs obtained within the first week after injury [33]. If, after cast removal, the clinician doubts whether 4 weeks of cast treatment was sufficient, additional radiographs should be obtained. If radiographs do not demonstrate callus around the fracture, cast treatment should be continued for another 2 weeks. Secondary displacement of fractures, requiring surgical treatment (unstable fractures, see classification table 1), most commonly occurs between three and seven days after injury. Secondary displacement of lateral humeral condyle fractures treated with casting occurs in 4.8-29.4% of all pediatric cases [34].

Figure 6: *Digital picture of a left arm in an above-elbow cast in the recommended position (90-degree flexion and neutral rotation).*

Plaster casting for patients with malalignment or nonunion >3 months after initial diagnosis is delayed is only feasible if the malalignment is less than 5 mm, the condyle is stable, and there is evidence of bony bridging on CT scan [32].

Surgical treatment options

Closed reduction and internal fixation

Minimally invasive surgical techniques for reduction and fixation of lateral humeral condyle fractures are known as closed reduction and internal fixation (CRIF), or closed reduction and percutaneous pinning (CRPP). This technique is commonly used for unstable/displaced fractures with displacement ranging from 2 mm to 4 mm [35]. Most fractures without evidence of fragment rotation and/or other elbow fractures are treated with CRPP. Reduction of CRPP fractures is performed by flexing the elbow and supinating the wrist while applying pressure to the lateral aspect of the elbow. Concomitant imaging is required to deduce the effect of closed reduction. Successful reduction will demonstrate the anatomical articular surfaces on imaging. Fluoroscopy and ultrasound-guided reduction are suitable options to provide baseline imaging during surgery. Ultrasound-assisted reduction offers the opportunity to provide good baseline imaging while eliminating the negative effects of fluoroscopy radiation [36]. Image quality and surgical performance are related to the surgeon's ability to capture images using ultrasound. Ultrasound-assisted closed reduction is a relatively new technique with a learning curve for the surgeon. However, recent results suggest that complication rates are comparable to closed reduction using fluoroscopy and/or open osteotomy (ORIF). The impact of reduction can be inferred through simultaneous fluoroscopy. However, the diagnostic accuracy of joint reduction assessed on two-dimensional fluoroscopy used in the operating room has been found to be inferior to computed tomography (CT). The subjective image quality of fluoroscopy is a major factor contributing to poor diagnostic accuracy. Image quality is influenced by the degree of image convergence achieved during surgery. The most notable factor directly affecting image quality is the presence of bone graft material, which results in scatter and artifacts. A secondary factor affecting image quality is the relative thickness of cartilage, which is particularly pronounced in children compared to adults, compared to bone thickness. Cartilage and articular surfaces of the elbow in children are not as well visualized by fluoroscopy as they are by arthrotomy because fluoroscopy does not visualize cartilage as well as bone. Given these factors, along with the potential for overestimation of the amount of displacement seen on preoperative radiographs, it is best to visualize the reduction using arthrography, arthroscopy, or arthrotomy. The surgeon then performs percutaneous fixation of the reduced fracture by placing two smooth Kirschner wires perpendicular to the fracture line. Crossing the Kirschner wires may reduce fracture stability. A third Kirschner wire can be placed across the condyle, parallel to the joint, to increase fracture stability and minimize rotation. The Kirschner wire can be buried subcutaneously or left exposed for easy removal. Both methods have been shown to have low complication rates, low infection rates, and high rates of successful union.

The Kirschner wire is left in place for 4 weeks postoperatively. In addition, the patient receives a long-sleeve cast with an elbow support brace for 4 weeks. CRPP for patients with dislocation or nonunion >3 months after initial diagnosis is only deferred if the displacement is less than 5 mm, indicating an unstable condylar fragment, and there is no evidence of a bone bridge on CT scan [32].

Open reduction and internal fixation

Open reduction and internal fixation (Figure 7) is the preferred tactical treatment for bones with greater than 4 mm of torsion and/or rotation of the bone fragment. It is also the next tactical treatment when CRPP fails to return the frame to its resting position. A small incision is made on the anterior aspect of the compressed arm. This is followed by careful surgical dissection of the subcutaneous tissue, fascia, and joint capsule. The irregularity of the bone fragment and its size require careful dissection so as not to interrupt the distal humeral supply and/or injure the radial nerve bundle. Similar to CRPP, the neurologist stabilizes the bone by placing two Kirschner wires perpendicular to the glenoid line. Post-tactical treatment is similar to CRPP. Neurologists may choose to fix the fragment with a small AO frame combined with K-wires. However, researchers have found that screw fixation provides equivalent quality of life and range of motion after surgery, although there are disadvantages such as the need for a second surgery to remove the screws, limited range of motion, slowness, and wound infection.

ORIF is used for patients with malunion or nonunion after >3 months and after the initial normal alignment of the elbow [37]. If the patient has malunion, a corrective osteotomy with simultaneous anterior transposition of the ulnar nerve can be performed [32].

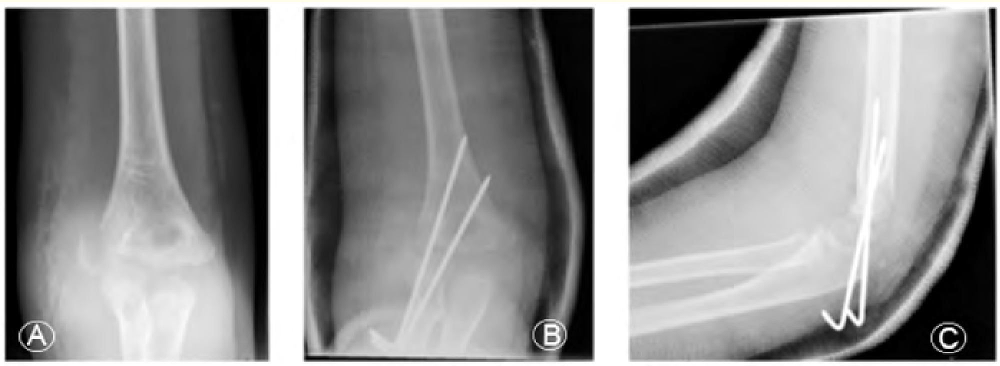

Figure 7A-7C: *A: Anterior-posterior view of a lateral humeral condyle fracture. B: Anterior-posterior and C: Lateral radiographic view of the elbow after open reduction and internal k-wire fixation.*

Surgical late lateral condylar humerus fracture

The surgical technique should not be too aggressive, affecting the vascular distribution of the condyle. To control the intra-articular contracture, it may be necessary to resect some parts of the joint capsule and synovial membrane [37]. Jakob., *et al*. suggested that surgical intervention in late cases does not improve the outcome compared to untreated patients. They pointed out the difficulties due to early scar formation. There is a general consensus that surgical intervention should be avoided in cases of persistent nonunion because osteosynthesis may reduce the range of motion of the elbow or the bone may not fuse, so surgical treatment for these patients is not preferred [38].

Local osteosynthesis allows displacement of the lateral condyle fragment, leading to disproportion of the articular surface of the distal humerus. Some authors suggest that the fragment should be reduced in anatomical or functional position for a good prognosis (Case 7 - Figure 4). Anatomic or functional reduction requires mobilization of the bone fragment and carries a relatively higher risk of osteonecrosis than local osteosynthesis. Many authors have emphasized the need for bone grafting for successful osteosynthesis [39]. However, Inoue., *et al.* [40] mentioned that bone grafting carries the risk of decreased elbow mobility due to obstruction of the distal humeral fossa or inadvertent displacement of the fracture fragment leading to radioulnar joint rupture. Previous studies have reported favorable results for the treatment of LCF nonunion without bone grafting [41]. In this study, complete bone union could be achieved by open debridement and firm fixation without bone grafting. Therefore, we believe that bone grafting is not mandatory to achieve bone union in local osteosynthesis and that the more important issue may be firm fixation and debridement of the fibrous bone. We did not perform bone grafting for all patients in this study. Several surgical techniques have been described for the treatment of LCF nonunions. These procedures are usually performed using an open technique, including pinning, bone grafting, anterior ulnar nerve transposition, and corrective humeral osteotomy for cubitus valgus deformity. However, there is still controversy as to whether the bone fragment should be fixed *in situ*, avoiding articular cartilage and joint deformity, or whether the bone fragment should be re-reduced anatomically. Anatomical repositioning of the bone fragment to restore the articular surface often requires extensive soft tissue dissection, which may lead to osteonecrosis of the lateral epicondyle of the humerus or postoperative loss of elbow range of motion [42].

The present study demonstrates significant biomechanical advantages of screw fixation over Kirschner wire fixation for lateral epicondyle fractures using a synthetic bone model. Displaced lateral condyle fractures in children have traditionally been treated with open reduction and internal fixation with Kirschner wires (Case 3 - Figure 1). There is a potential for pin loosening when fixation is lost, and if the pin is not securely fixed, additional casting is required during the period of fixation. Screw fixation has been advocated as an alternative technique with the potential advantages of applying compression to the fracture site and allowing continued fixation after the treating clinician feels that further casting is no longer necessary. This may theoretically result in better bone healing, reduced casting time, and faster recovery of range of motion. Potential disadvantages include the need for subsequent removal and the theoretical possibility of growth disturbance (although this has never been reported with screw fixation of lateral condyle fractures). Although several clinical studies have compared fixation methods, no previous biomechanical studies have provided a biomechanical comparison [43].

Previously, Bloom., *et al*. [44] performed a biomechanical evaluation of Kirschner wire fixation for lateral condyle fractures in children. They compared the stiffness and maximum force of Kirschner wire fixation constructs in the convergent, parallel, 30-degree divergent, and 60-degree divergent directions. Tests were performed in extension, flexion, varus, valgus, internal rotation, and external rotation. Statistically significant differences were noted in varus, internal rotation, and external rotation. Among the different 2-leg constructs, the K-wires placed 60 degrees apart were determined to provide the greatest biomechanical stiffness.

Two studies have compared the use of Kirschner wire and screw fixation in the treatment of lateral condyle fractures in children. Li., *et al*. [45] compared 30 lateral condyle fractures treated with Kirschner wires with 32 fractures treated with 3.5-mm cannulated screws at a mean follow-up of 39.4 months. No statistically significant differences in clinical outcomes were noted; however, five infections occurred in the Kirschner wire group compared with none in the screw group. Additionally, 11 patients in the Kirschner wire group and four patients in the screw group developed obvious lateral condyle growth. Nine fractures treated with Kirschner wires and two fractures treated with screws lost 10 degrees of elbow extension. Gilbert., *et al*. [46] in a series of displaced lateral condyle fractures requiring open reduction compared 41 patients treated with screw fixation and 43 patients treated with Kirschner wire fixation. They found shorter time to union, improved range of motion, and fewer complications in the screw fixation group. The present study compared the optimal 2-Kirschner wire configuration determined by Bloom., *et al*. [30] with lag screw fixation and showed that lag screws provided greater biomechanical stability at the fracture site. Tension testing was performed to simulate extensor muscle forces, a mechanism commonly thought to contribute to displacement and delayed healing of lateral condyle fractures. Under tension, screw fixation was biomechanically superior to Kirschner wire fixation in both stiffness and maximum force required to achieve displacement, as expected. Compression testing was performed to simulate the failure mechanism described by the distal radius "pushing" the fracture fragment. Compression testing showed a smaller increase in maximum force with screw fixation and no significant difference in stiffness. The more similar biomechanical performance of the two fixation methods under compression conditions was consistent with the expected characteristics [47].

Complications

The complication rate in pediatric LHC fractures is higher than in other types of elbow fractures, with up to 10% of patients experiencing events that significantly impact quality of life, which may arise during or after treatment.

Overgrowth and bone deformity

Lateral growth, defined as an increase in intercondylar width without signs of angular deformity, is a common complication observed in 70-100% of patients. Some experts even consider the development of lateral osteophytes to be an expected outcome, especially in surgically treated displaced fractures [48].

Due to clinical and radiological similarities, lateral growth may be confused with varus on initial examination. However, varus is defined as an increase in Baumann angle greater than 5° compared to the opposite side [48], with a lower incidence of 29-40%.

Although neither of these conditions typically results in elbow dysfunction or the need for surgical intervention, careful monitoring of varus elbow is warranted, as some cases may require corrective surgery [48].

Less common deformities include valgus, valgus, and coracoid.

Nonunion

Nonunion is a significant concern in pediatric elbow fractures, particularly LHC fractures, with its incidence varying widely between studies due to the lack of standardized timescales for its definition. While some authors describe nonunion as failure to union within 8 weeks, others classify it as delayed union within this timeframe and reserve the term nonunion for cases lasting up to 12 weeks [49].

Nonunion may arise from failed fixation, secondary fragment displacement in conservatively treated fractures, or delayed onset. Although more common in conservatively treated fractures, it has also been observed in patients treated surgically [50].

Treatment options for nonunion include closed reduction or open reduction and fixation. In a meta-analysis by Zhang [28], percutaneous fixation appeared to be associated with poorer outcomes than open reduction and internal fixation, although it may lead to improved mobility [51].

Arthrodesis

Joint fixation differs from nonunion in that it involves bone healing without maintaining the natural anatomical alignment, resulting in an abnormal joint shape, which can lead to pain and stiffness of the elbow.

The incidence of this condition can be as high as 12% and, if left untreated, often through arthroscopic surgery, can lead to the aforementioned deformities such as valgus and varus [52].

Avascular necrosis

AVN is one of the most feared complications due to its devastating long-term consequences, causing significant disability due to its impact on range of motion and joint function. Fortunately, its incidence is relatively rare, ranging from 1% to 3%.

Although open surgery carries a risk of AVN and surgeons must be careful not to tear the posterior soft tissue, this complication has also been reported in conservatively treated fractures, most likely due to trauma [52,53].

Infection

Infection is a relatively rare complication (0-8%) following treatment of LHC fractures in children and can be classified as superficial or deep. Superficial infections generally respond well to removal of the foreign body and treatment with oral antibiotics [49]. Deep infections are less common, tend to occur later, and if not managed properly can lead to serious complications, including recurrent infections. Treatment varies depending on the case, but irrigation and debridement should be considered, along with appropriate antibiotic therapy based on culture results.

Infection rates and the need for additional surgery to remove material are both slightly higher in cases treated with KW fixation [54].

Loss of range of motion

Loss of extension and flexion is common but does not usually lead to functional impairment. However, in extreme cases, where motion is restricted to more than 20°, capsulotomy has been used as a solution [55].

In contrast to all of the above, some authors have recently reported favorable results with osteosynthesis in cases of old lateral condyle fractures and nonunions in children, and advocate the treatment of fractures by reduction and fixation with bone graft before epiphyseal closure. Smith [34] treated lateral condyle nonunion with cubitus valgus deformity with the Ilizarov device and found 53.5% excellent results, 39.3% good results, and 2% fair results with a mean postoperative humeral angle of 6°. Roye., *et al*. [56] treated four cases of lateral condyle nonunion and found favorable results, and support that nonunion can be safely treated with osteosynthesis. Agarwal., *et al*. [57] retrospectively studied the results of attempted fixation in 22 children presenting late with lateral condyle humeral fractures. Their study showed a high union rate and normal elbow function in the late cases. There was a poor correlation between patient age, time of presentation, Milch type, and elbow function (Case 7 - Figure 4). Shimada., *et al*. [36] treated 16 patients with confirmed nonunions who presented with symptoms such as cubitus valgus deformity, fear of using the limb, muscle weakness, and lateral instability. Open reduction and internal fixation with bone grafting were performed with excellent results in 8 patients and good results in 7 patients. Milch [37] observed lateral humeral condyle nonunion for 17 years and reported good elbow function. Contrary to concerns that the dangerous condition of hyperextension and excessive traction could impair the vascular supply to the bone fragment, Gaur., *et al*. [58] proposed a technique of multiple incisions in the common extensor fascia to facilitate reduction of the bone fragment. This study included a patient with AVN (Case 15 - Figure 8).

Figure 8: *(Case 15) Post-operative 12 weeks with avascular necrosis.*

Ali and Tahir [59] fixed 18 lateral condyle fractures between 3 and 12 weeks of age with Kirschner wires at a mean follow-up of 15 months and reported excellent results in five patients, good in three patients, fair in six patients, and poor in four patients using the modified Aggarwal., *et al*. criteria. They concluded that open reduction and internal fixation is an effective treatment for lateral condyle humeral fractures in children occurring between 3 and 12 weeks after injury. In another local study, fifty children with neglected lateral condyle humeral fractures were fixed with Kirschner wires and the results were evaluated in terms of pain relief, range of motion, and bone union at the time of fracture. Two-month follow-up showed excellent results in 68% of patients, good in 14% of patients, fair in 10% of patients, and poor in 8%. Similarly, in another study, 22 patients with lateral condyle humeral fractures occurring within 12 weeks of injury were fixed with Kirschner wires and the results were evaluated according to the modified criteria of Aggarwal., *et al.* at 1 year follow-up. Excellent results were achieved in 12 patients, good in three patients, fair in three patients and poor in three patients and they concluded that open reduction and internal fixation is an effective treatment in all cases of displaced lateral condyle humeral fractures occurring within 12 weeks of injury based on low surgical complications and high bone union rates. All the participants in our study had lateral condyle humeral fractures between the ages of 3 and 8 weeks. In a series, Sarafand and Khare [40] analyzed their results on 16 patients with lateral condyle humeral fractures between 5 and 12 weeks of age using the criteria established by Agarwal., *et al*. They observed excellent to good results in 6 patients, fair results in 6 patients, and poor results in 4 patients. They concluded that open reduction and internal fixation is recommended for all displaced lateral condyle humeral fractures within 12 weeks of injury. However, the results become worse as time after injury and degree of displacement increases.

In our study, excellent results were achieved in 38.1%, good in 33.3%, fair in 14.3%, and poor in 14.3%. Comparing accepted outcomes by time of injury, surgery at ≤ 3weeks was better than at > 6 weeks with PValuate 0.001387 (Table 3).

The rate of bone union and satisfactory elbow function is high in pediatric lateral condyle fractures after attempted fixation. Studies have shown a poor correlation between patient age, late presentation or Milch type I or II, and final elbow function as determined by LES. Our study only reported one patient with postoperative lateral condyle AVN. Wattenbarger [41] fixed 11 children with fractures older than 3 weeks with K-wires and found no cases of AVN, although four of them had displacement of more than 10 mm. Three patients had occasional pain. The risk of AVN with lateral condyle reduction delayed after 3 weeks is reduced if tissue is not removed from the posterior fragment.

Even children with anatomical non-reduction had functional arms with little or no pain. Weiss [60] reported that 3.8% of patients had skin infections around Kirschner wires while Chao Li [61] reported 16.7%. In our study, skin infections around Kirschner wires occurred in 9 (36%) patients, while no patients had skin infections around cancellous screws. This suggests that infections are more common in patients with percutaneous Kirschner wires than screws. Therefore, skin care should be performed to prevent skin infections. Oral antibiotics and wound care should be used to treat infections. Mahmood., *et al*. [62] showed that five Kirschner wires in four fractures were found to be loose because the Kirschner wires did not pass through the bone cortex on the opposite side. Therefore, we recommend the use of double cortical fixation with smooth Kirschner wires when Kirschner wires are used for fixation. Mild local deformity was noted in 2 (8.6%) patients with Kirschner wire fixation while no patients with screw fixation in our study. Thomas [63] reported that 40% of patients with Kirschner wire fixation had a clear condyle at the lateral humeral epicondyle, while Chao Li [61] reported that this figure was 36.7% of patients with Kirschner wire fixation and 12.5% of patients with screw fixation, and they suggested that the relatively low rate of fracture fixation with Kirschner wire may be more bony callus than screws, which may promote more rigid fixation of the fracture and reduce the possibility of extrusion. On the other hand, extrusion may be due to extensive periosteal dissection and bony callus formation. Therefore, it is necessary to protect the periosteum of the metaphyseal fragment and avoid extensive dissection. Limitations of this study include the small sample size, heterogeneity, and shorter follow-up period for some cases. Since most of our patients had not yet reached the pubertal growth spurt, it is clear that longer studies are needed to understand the lateral condyle activity and functional changes due to remodeling. Longer follow-up of these patients is essential.

Although there is consensus on the treatment of fractures treated early, the treatment of late fractures remains controversial. Delayed presentation leads to difficulty in treatment due to displacement of the bone fragment due to traction of the common extensor muscles, uneven contraction of the articular surfaces, damage/premature closure of the epiphyseal growth plate, and possible vascular injury.

Lagrange and Rigault demonstrated that the blood supply to the lateral condyle passes through soft tissue attachments, especially posteriorly at the origin of the extensor longus muscle, and this disruption will destroy the blood vessels and cause ischemia of the condyle.

Jacob., *et al*. [64] reported that open reduction and internal fixation >3 weeks after fracture does not provide better results than no treatment at all and may lead to AVN of the bone fragment.

Intraoperative soft tissue dissection may be a factor affecting bone healing in these fractures. Since the blood supply to the lateral condyle passes through the posterior cortex, posterior soft tissue dissection should be avoided during surgery to prevent avascular necrosis.

Anatomical reduction is often not possible due to fragment remodeling, new bone formation, sclerosis, and flattening of the fracture line. For these various reasons, fracture reduction has become a concern in cases of long-standing untreated nonunions. With greater displacement, it is sometimes impossible to return the fragment to its normal position without stripping the soft tissue covering the displaced fragment. Because extensive soft tissue dissection can lead to avascular necrosis of the fragment, many physicians recommend leaving these fractures intact.

Complications of nonunion include cubitus valgus deformity, lateral elbow instability, limb weakness, radial condyle deformity, late ulnar nerve palsy, etc. This surgery can help avoid future osteotomy and anterior ulnar nerve transposition (Case 12 - Figure 9).

Cubitus varus/valgus deformities

Cubitus varus and lateral overgrowth are reported to be the most common deformities after lateral condyle fractures in children (40% and 70%, respectively) [65,66].

Distal humeral osteotomy is performed to correct cubitus varus or valgus malalignment. Cubitus varus is usually the result of supracondylar union, and cubitus valgus is usually the result of lateral condyle nonunion. Cubitus varus malalignment occurs after treatment of a historically displaced supracondylar fracture in approximately 4% to 57% of cases depending on the treatment method used. The varus is due to nonunion of distal humeral fractures rather than a developmental disorder. Cubitus varus combined with extension and internal rotation of the distal humerus is called a "gunstock deformity". The resulting abnormal appearance is cosmetically disfiguring.

Common complications of lateral condyle fractures include lateral epicondyle overgrowth, lateral osteophytes, and varus. Lateral epicondyle overgrowth or lateral osteophytes may appear as varus on general examination. Overall varus without actual angulation is pseudovalgus, while a difference in the angle of varus on radiographs of more than 5° is true varus. This study aimed to compare true varus and pseudovalgus.

The general indication for correction of three-dimensional deformities with good range of motion is cosmetic. Several osteotomies have been described for correction of this deformity, each with its own advantages and disadvantages. Several reports have described different osteotomies and their results in correction of these three-dimensional deformities, using methods such as cross pin fixation, screw fixation, and external fixation [67,68] or the Hung method for elbow osteoarthritis. Since each technique has its own advantages and disadvantages, there is no consensus on which method provides the best end result, especially in children. Suspension method for elbow deformities.

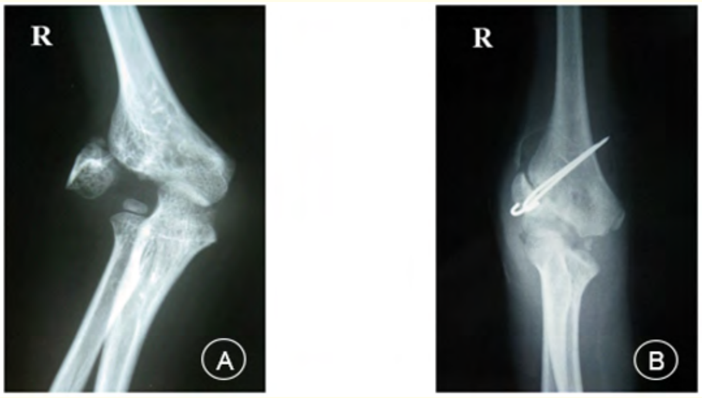

Figure 9: *(Case 12) Initial injury 10 weeks; A: Pre-Operation, B: Post-Operative 14 weeks.*

Dhillon., *et al*. [69], Zionts [70], Speed and Macey [71] all reported poor outcomes, including cubitus varus and valgus deformities, osteonecrosis, nonunion and abnormal union, and loss of mobility. They recommended that patients presenting late should be isolated and any sequelae evaluated at a later stage. Fractures operated on after a delay are also more complicated by the presence of fibrosis and scar tissue formation. The preoperative stiffness found in these cases may influence postoperative outcomes [69]. *In situ* fixation can prevent valgus or varus deformities in most patients. Early arrest of fracture progression may contribute to the development of cubitus valgus deformities. The underlying problem will be progressive cubitus valgus deformities with relative shortening of the lateral column [12]. In this study, there were no cases of premature growth arrest, fishtail deformity, and no patients with ulnar neuropathy at the final follow-up. Since all fractures were classified as Milch II, we were able to achieve fusion between the distal humeral fragments and the distal humerus without causing damage to the epiphysis. This result implies that premature growth arrest of the lateral condyle can be avoided by *in situ* osteosynthesis, especially in cases of nonunion of Milch II fractures. At the final follow-up, significant angular deformities were found in 4 patients.

This result may be due to the inability of *in situ* osteosynthesis to correct the angular deformity that was present at the time of surgery. However, this assumption cannot be proven because we were unable to accurately assess the initial angular deformities of these patients due to flexion contractures. In addition, we believe that these deformities were due to the surgical technique itself. If the fracture fragment does not fit properly with the distal humerus and a fracture gap remains even after tightening the Kirschner wire, a cubitus varus deformity will develop. If the Kirschner wire is tightened too much, a cubitus valgus deformity will occur. Therefore, we agree with the opinion of some authors that if the patient has an angular deformity at the last examination or follow-up, a simultaneous or staged corrective osteotomy should be considered [72]. Lateral kyphosis of the distal humerus is a common radiographic abnormality. Displacement of the lateral condyle fragments can cause lateral kyphosis of the distal humerus. Although some authors note that kyphosis is usually only significant on radiographs and does not affect function [73], some patients and parents are concerned about its appearance in cases of marked kyphosis. In this study, kyphosis of varying sizes was observed in 3 cases. Fortunately, no children or parents in our study complained about the overall appearance of the lateral kyphosis. Although lateral kyphosis rarely causes cosmetic problems, it should be noted that children and parents may be concerned about the overall appearance, especially in special cases [74]. It has been observed that nonunion and growth arrest are more common in less displaced fractures than in highly displaced and rotational fractures, possibly because severe fractures are treated more adequately surgically. Late presentation leads to difficulty in management due to displaced bone fragments due to traction of the common extensor muscles, inadequate reduction of the articular surface, trauma/premature closure of the epiphyseal growth plate, and possible vascular compromise due to loss of soft tissue attachments (Case 15 - Figure 8). For these reasons, when patients present at 3-8 weeks, there is still controversy over whether these fractures should be treated nonoperatively or surgically. Complications with nonoperative treatment include nonunion, poor union, local deformity, elbow instability, stiffness, cubitus valgus/varus, and late ulnar nerve palsy (Case 7 - Figure 4). In addition, the unstable blood supply to the fracture fragment due to excessive soft tissue dissection can lead to avascular necrosis of the fragment. Therefore, most advocate not treating established nonunions because the functional problems are not too severe [3,48]. It is easier to treat late varus/external torsion with corrective osteotomy or late ulnar nerve palsy with ulnar nerve transposition than difficult reduction. Although surgery carries inherent risks, there have been reports in the literature of successful outcomes with open surgery and internal fixation for these established nonunions. The current controversy regarding the management of lateral condyle humeral fractures occurring between 3 and 8 weeks prompted us to evaluate this approach.

Conclusion

Acute and late LHC fractures in children are common and can present challenges in both diagnosis and treatment. Lateral radiographs can aid in the diagnosis of complex cases, and the choice of fracture classification system ultimately depends on the specialist. Displaced fractures <2 mm can be treated conservatively with immobilization and regular follow-up. However, displaced fractures >2 mm often require surgical intervention. Both closed reduction and open reduction techniques, with KW or cannoid screw fixation, provide satisfactory results, with no method being superior to the other.

Kirschner suture fixation without bone grafting can provide secure union and improved elbow function. We have demonstrated that this technique is a safe and effective procedure for growing children with minimal relative displacement and new nonunion. However, it cannot completely prevent angular deformity. Orthopedic surgery should be considered in patients with valgus or varus deformities.

Limitations of this Study

The main limitation of this study is the literature review, meaning that although we conducted a comprehensive search, it was not exhaustive. Therefore, not all studies relevant to the topic were included, and not all referenced studies provided primary evidence. Furthermore, there was a certain degree of heterogeneity between studies, as our sources included a variety of study designs and assessments. We attempted to minimize this by supplementing the evidence with our own technical recommendations based on clinical experience.

Our study was retrospective in nature and included small case series. Furthermore, we included patients with open fractures and Milch II fractures. We were unable to draw any conclusions in patients with closed fractures or Milch I fractures. The index surgery was performed in patients with relatively recent nonunions, with a mean time from injury to surgery of 6.3 weeks (range, 1-11 weeks). Therefore, the present study does not imply that this technique can produce excellent results in children with long-standing fractures or nonunions after skeletal maturity. This article did not examine the long-term effects of local osteosynthesis because it was not possible to follow all patients into adulthood. Because growth potential still exists in these patients, monitoring progression into adulthood may be worthwhile.

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