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Evaluation of surgical or conservative treatment of forearm fracture in pediatric floating elbow injuries

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Abstract. – OBJECTIVE: Floating elbow, which refers to a humerus fracture in the supracondylar region and a forearm fracture, is a very unusual injury. The purpose of this study is to compare the clinical results of patients with "floating elbows" who underwent surgical therapy and who were given forearm immobilization with a splint as follow-up care.

PATIENTS AND METHODS: Fifteen patients who had been diagnosed with floating elbow owing to trauma were scanned retrospectively and followed up for at least a year. Eight individuals who suffered from broken forearms underwent surgical repair. After initial treatment, a lengthy arm splint was used to immobilize seven patients' arms. The modified Flynn criteria were used to analyze the data, and comparisons were made between the groups.

RESULTS: The median age and mean follow-up time for patients whose forearms were conservatively followed was 6.1 years and 13.8 months, respectively. The median age of the patients who underwent forearm surgery was 8.5 years, and the average follow-up was 14.2 months. Five of the seven patients whose forearms underwent conservative follow-up had outstanding clinical outcomes, while two had poor and moderate outcomes. Four individuals who got surgical treatment for their forearms had excellent and good clinical outcomes, while the other four had intermediate and poor outcomes. Between the two groups, there was no discernible difference ($p = 0.60$).

CONCLUSIONS: In the pediatric population with floating elbow injuries, using a cast for forearm fractures may not necessarily result in worse outcomes compared to surgical management.

Key Words:
Floating elbow, Supracondylar, Forearm Injuries, Pediatrics.

Introduction

Children seldom sustain ipsilateral injuries to the elbow and forearm[1], also referred to as a "floating elbow". The prevalence of this association ranges from 3% to 13%[2]. The term floating elbow was initially used by Stanitski and Micheli[3] to describe a combination of supracondylar and both bone forearm fractures in which the elbow is effectively disconnected from the remainder of the limb. In the past, this combination of wounds has been linked to high-energy trauma, a higher prevalence of open fractures, and significant neurovascular sequelae[4].

For this kind of injury, several different treatments have been recommended, including primary closed reduction of both fractures and application of a long arm cast, olecranon pin traction and delayed application of a long arm cast, percutaneous pinning of the supracondylar fracture and application of a short arm cast for the forearm bone injury, or closed reduction and percutaneous pinning for both injuries[5]. Supracondylar fractures, even when isolated, can be associated with many complications involving vascular and nerve damage, sometimes requiring urgent treatment. The risk of complications increases when combined with forearm fractures[6-8].

Because of the seriousness and rarity of the floating elbow, as well as the lack of studies determining the best way to treat this injury, we set out to compare the clinical and radiological outcomes of our patients who were treated surgically *vs.* those who were simply immobilized in a splint.

Patients and Methods

Patients and Design

This is a level III retrospective comparative study. Before starting this retrospective investigation, the institutional review board's approval was required. The Declaration of Helsinki's guiding principles were followed in conducting the study. A retro-

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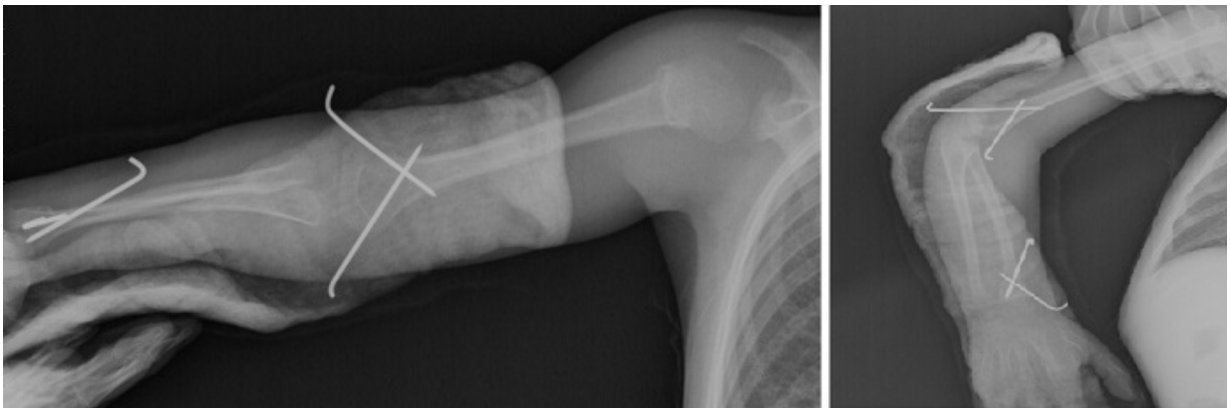

Figure 1. One of our patients who underwent surgery for both supracondylar and forearm fractures.

spective examination of medical case records was performed on all pediatric supracondylar fractures treated in our university hospital between January 2017 and July 2019. Among them, 15 kids with ipsilateral forearm bone injuries and supracondylar fractures were found. Based on their choice of surgical or conservative forearm therapy, the patients were split into two groups. Demographic information, the injured side, the injury mechanism, the kind of fracture, associated problems, the therapy given, and complications resulting from the treatment were the variables examined. The Gartland classification was used to categorize supracondylar humerus fractures. Patients with a Gartland type I fracture and those older than 15 years old were excluded from the study.

Treatment Technique

Before forearm fracture, supracondylar fractures were initially treated with reduction and stabilization. Depending on the degree of comminution and instability, the supracondylar fracture was reduced using the conventional procedure and stabilized with two or three cross Kirschner (K)-wires. Open maneuvers were used to reduce the fractures that were not amenable to closed operations.

Following the reduction of forearm fractures, a K-wire was applied proximally medially across the fracture through or just proximal to the radial styloid process to avoid the physis. All of the K-wires were bent so they could be easily removed at the clinic in 4-6 weeks. A splint was placed on the amputated limb for four to six weeks (Figure 1).

Forearm fractures were treated conservatively following recognized standards: fewer than 15 degrees of angulation, fewer than 45 degrees of malrotation, and less than 1 cm of bayonet apposition were acceptable requirements for children younger than 9 years old. The angulation was less than 10 degrees for proximal fractures and less than 15 degrees for distal fractures in children aged 9 years and older, with malrotation less than 30 degrees[9] (Figure 2). K-wires were taken

Figure 2. Another patient who had a supracondylar fracture was treated with percutaneous pinning, and a forearm fracture was managed with cast immobilization.

out of the surgically treated group at 4-6 weeks, and joint range of motion exercises were started. After an average of 6 weeks of treatment, the splint was taken off, and mobility was started in the group that received conservative care. At the very least, patients were monitored until all fractures had healed, their entire range of motion had returned, and all problems had disappeared. We assessed and compared the carrying angle, elbow, and wrist ranges of motion. Final results were assessed based on modified Flynn[9] standards (Table I).

Statistical Analysis

Data from the study were analyzed for demographic features using descriptive statistical methods (frequency and percentage analysis, mean and standard deviation values). The relationship between the variables of treatment type, elbow, wrist, and forearm functions, and postoperative complication was examined using the Chi-square test. The SPSS 22.0 (IBM Corp., Armonk, NY, USA) program was used to conduct the analysis. Statistical significance was defined as a p-value < 0.05.

Results

The study identified 15 patients who met inclusion criteria and had appropriate follow-ups. The average age was 7.4 years (SD = 3.58). 11 patients (73.3%) were male and 4 (26.7%) were female. The right side was affected in 8 patients (53.3%). The commonest mode of injury was falling from height in 7 patients (46.7%) and falling at ground level in 6 (40%) patients. One patient had fallen from a swing, while another patient had suffered an injury following a traffic accident. The mean follow-up time was 14 months (SD = 1.2). The patient who fell from the swing had a type 1 open fracture and presented with radial nerve symptoms on preoperative neurological examination. The other patient with an open fracture had been taken to a bonesetter one week before the presentation and had a 2x3 cm wound in the antecubital region upon arrival. Ten supracondylar fractures were Gartland type III extension injuries, and five were type II. Thirteen were treated by closed reduction and percutaneous K-wire stabilization. In one case (6.6%), it was necessary to perform an open reduction of the elbow, and in one case, open reduction and plate fixation were performed. Two of the patients with supracondylar fractures experienced K-wire migration, and one had a complication of malrotation (Table II).

Twelve children (80%) had a fracture of the distal meta-diaphyseal forearm, one had a Monteggia fracture, and one had a distal radius and olecranon fracture. Closed reduction and percutaneous fixation with K-wire (CRPP) were performed on all 8 patients (53.3%) who underwent surgery on the forearm. Seven patients (46.7%) who had acceptable reduction for the forearm were followed up conservatively with a long arm splint.

In the group of patients with forearm fractures, the median age of those who underwent surgical treatment was 8.5 years (IQR: 5.2 - 11.7), with a follow-up period of 14.2 months (SD = 1.3). In the conservative treatment group, the median age was 6.1 years (IQR: 3 - 8), and the follow-up period was 13.8 months (SD = 1). Surgical treatment resulted in 4 out of 8 patients being evaluated as excellent or good based on the modified Flynn criteria, while the remaining 4 were considered fair or poor. In the conservative treatment group, 5 out of 7 patients were evaluated as excellent or good, and 2 were considered fair or poor (p = 0.60). Carrying angle changed in 5 of 8 patients in the surgical group and 5 of 7 patients in the conservative group (p = 1.00). There was no significant difference between the two groups according to these criteria. Two patients in the surgical treatment group and one patient in the conservative treatment group had elbow range of motion (ROM) limitations (p = 1.00) (Table III).

Table I. The modified Flynn criteria. The biggest loss of function or change in carrying angle in degrees is used to grade the functional outcome when compared to the unaffected limb.

	Loss of elbow flexion/extension	Loss of forearm pronation/supination	Loss of wrist flexion/extension	Change in carrying angle
Excellent	0-5	0-15	0-15	0-5
Good	6-10	16-30	16-30	6-10
Fair	11-15	31-45	31-45	11-15
Poor	> 15	> 45	> 45	> 15

Table II. Patient demographics, injuries, and operation information.

Age	Sex	Mechanism of Injury	Side	Gartland type	Ipsilateral forearm injury	Treatment	
						Humeral	Forearm
3	F	Fall	Right	3	Monteggia fracture	crpp	Conservative
5	M	Fall from height	Right	2	Distal 3rd both bone	crpp	crpp
8	M	Fall from height	Left	3	Distal 3rd both bone	crpp	Conservative
3	F	Fall	Left	3	Distal 3rd both bone	crpp	Conservative
5	M	Fall from height	Right	3	Distal 3rd both bone	crpp	Conservative
6	M	Traffic accident	Right	3	Distal 3rd both bone	crpp	crpp
5	M	Fall from height	Left	3	Distal radius 3rd+olecranon	crpp	crpp
8	M	Fall	Left	3	Distal radius 3rd	crpp	crpp
3	M	Fall from height	Right	2	Distal 3rd both bone	crpp	Conservative
12	F	Play injury	Left	3	Distal 3rd both bone	orpp	crpp
12	M	Fall	Right	2	Distal radius 3rd	crpp	crpp
7	M	Fall	Right	3	Distal radius 3rd	crpp	Conservative
14	M	Fall from height	Left	2	Distal radius 3rd	orif	Conservative
9	F	Fall	Left	3	Distal 3rd both bone	crpp	crpp
11	M	Fall from height	Right	2	Distal 3rd both bone	crpp	crpp

crpp: closed reduction percutaneous pinning, orpp: open reduction percutaneous pinning, orif: open reduction internal fixation.

None of the patients needed re-reduction due to reduction loss. None of the patients experienced problems from the pins or pin-related infections. Both groups took the same amount of time to reach their final range of motion. No patient suffered from compartment syndrome. No patient was found to have a circulatory problem before surgery.

Discussion

A rare but serious injury in a developing child is a supracondylar fracture of the humerus combined with an ipsilateral forearm fracture. The literature supports the gender and trauma type preponderance that we discovered[3]. Additionally, distal radius and ulna fractures were the most typical forearm fractures in our analysis, which is consistent with previous research[1,10]. The most typical mechanism was a fall from a height. We agree with Templeton and Graham's theory[11] of fracture mechanism. When the forearm fracture is above the distal and middle third junction, it does not seem to provide sufficient moment force to produce an ipsilateral elbow fracture.

Table III. Comparative table of patients' clinical outcomes.

	Surgical treatment group		Conservative treatment group		
Age*	8.5 (5.2-1.7)	6.1 (3-8)			
Gender	Male	6	Male	5	
	Female	2	Female	2	
Side	Right	4	Right	4	
	Left	4	Left	3	
Follow-up, mean ± SD	14.2 ± 1.3	13.8 ± 1			
Modified Flyy criteria	Excellent + good	4	Excellent + good	5	$p = 0.60$
	Fair + poor	4	Fair+poor	2	
Carrying angle change	Yes	5	Yes	5	$p = 1.00$
	No	3	No	2	
Elbow ROM restriction	Yes	2	Yes	1	$p = 1.00$
	No	6	No	6	

*Median, (IQR).

The best course of treatment for pediatric floating elbow sufferers is still up for debate. In their study, Reed and Apple[12] recommended conservative follow-up for forearm and supracondylar humerus fractures. However, the outcomes demonstrated that casting done with the elbow in flexion could lead to cubitus varus development and compartment syndrome with swelling in the elbow. A medical device named the epibloc system has been discovered in Italy to protect against plaster immobilization and its complications, as well as to increase joint mobility after surgery. Patients with distal forearm fractures treated with this system were compared to those treated with traditional methods such as K-wires and cast immobilization. Individuals using the epibloc system showed higher degrees of range of motion[13]. These wounds are high-energy traumas and have a stronger deforming effect as a result. The increasing frequency of angular deformities seen in changes to the carrying angle may be explained by this effect[5]. In our study, there was no discernible difference in the altering of carrying angle between patients who had forearm surgery and those who did not, and no patients experienced compartment syndrome.

It was recommended in the studies by Tabak et al[14] and Ring et al[1] that surgery be done for both the supracondylar humerus and forearm fractures since there was no need for cast stabilization in excessive flexion, no increase in elbow swelling, and no reduction loss and need for re-reduction. They further claimed that because the forearm fracture was fixed with a K-wire, early mobilization could be started and superior results in terms of elbow ROM were obtained. Contrary to this, Blumberg et al[15] closed reduced forearm fractures and immobilized them with noncircumferential plaster casts after surgically stabilizing supracondylar fractures. They claimed that this technique is secure and has not been linked to the emergence of abnormally high compartment pressures or the requirement for repeated manipulation. They hypothesized that the post-operative immobilization technique might be more effective in preventing compartment syndrome. Studies[16] questioning the necessity of plaster due to potential complications of post-operative plaster application have been conducted. In a study by Passiatore et al[16] the treatment of pediatric distal radius fractures using the epibloc system was compared to K-wire short arm cast treatment. Patients treated with the epibloc system required less physiotherapy support. No significant differences were found in other complications. The authors noted that the epibloc system can be safely used. The debate regarding conservative *vs.* surgical treatment of supracondylar fractures has been discussed. In a study conducted by Umur et al[17] no significant difference was found in clinical and radiological outcomes between pediatric supracondylar fractures treated conservatively or surgically. The authors emphasized the importance of good reduction. After deciding on surgical treatment for forearm fractures, the choice of technique is sometimes debated. There are advantages and disadvantages to extramedullary or intramedullary implants. In a study by Güzel et al[18] four groups were compared in forearm fractures: double plates, intramedullary titanium elastic nail (TEN), intramedullary K-wire, and hybrid fixation. In the plate group, the surgical duration was longer, and the fluoroscopy time was shorter. In the K-wire and TEN groups, tourniquet time was shorter compared to other groups. The authors recommended all four treatment methods, highlighting that the hybrid fixation method with a plate for the ulna and TEN for the radius is also a suitable alternative. Uçar et al[19] also compared patients who underwent closed reduction and pinning with patients who underwent open reduction. Patients were also grouped according to the number of K-wires used. As a result, there was no significant difference between the groups, and they stated that the treatment of supracondylar fractures should be based on the patient's age, degree of deformity, and soft tissue condition. All supracondylar fractures were fixed with K-wires because we thought it would be dangerous to utilize high-energy mechanisms and conservative treatment for fractures proximal to the elbow and wrist. The majority of fractures were also given the Gartland type III classification, which also led us to perform surgery. Regarding the modified Flynn criterion, elbow, and wrist ROM, there was no discernible difference between the group that underwent surgery for forearm fractures and the group that received immobilization with a splint.

According to Ring et al[1] study, patients who had surgery for a supracondylar humerus fracture and then received a forearm cast experienced a loss of reduction and required re-reduction. As a result of cautious forearm follow-up, it has been reported in various trials[20] that re-reduction may be necessary at a rate of 7-15%. In our study, patients who were conservatively followed up with

a splint experienced no loss of reduction and no need for re-reduction.

In cases where proximal fractures accompany these fractures, complications can increase. In a case report presented by Basile et al[21] posterior interosseous and ulnar nerve injuries were detected in fractures of the proximal ulna and radius accompanying a distal humerus fracture. The nerve damage spontaneously resolved after treatment. According to the majority of research[12,22], children who suffer these fractures are not more likely to develop compartment syndrome. However, Blakemore et al[23] showed that 33% of ipsilaterally displaced supracondylar humeral and forearm fractures had compartment syndrome. Compartment syndrome was not noted in our investigation. However, we closely watched a patient who showed signs of compartment syndrome as a result of sequelae from bonesetter treatment. Our opinion is that the patient's time of admission to the hospital and the types of preoperative and postoperative immobility are more directly associated with the risk of compartment syndrome.

We acknowledge the limitations of our study, including its retrospective design and variable surgeon sample size. However, we are unable to control for the small sample size due to the rarity of the injury. Nonetheless, in our study, better patient homogeneity was achieved by performing the same surgical method on 86% of the supracondylar fractures. Applying the same treatment to most supracondylar fractures and randomly assigning participants to groups helped reduce the risk of selection bias.

Conclusions

There are various theories in the literature about how to treat a floating elbow, a rather uncommon pediatric trauma. In these patients, good outcomes can be achieved when forearm fractures are immobilized with a long arm splint. Additionally, depending on the patient's additional injuries and skin condition, surgical methods may also be applied. It should be kept in mind that these fractures are more high-energy compared to typical fractures, and careful perioperative management is essential.

Conflict of Interest
The authors declare that they have no conflict of interests.

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Ethics Approval
Ethical approval was obtained by the Dicle University Local Ethics Committee (number 239-2023).

Informed Consent
The protocol was performed in accordance with the Declaration of Helsinki, and the participants' legal guardians provided written informed consent.

Authors' Contribution
Conceptualization, E.Ö., Ş.Y., and R.A..; methodology, S.A.U., M.S.A., and S.D.; software, E.Ö., M.S.A., and S.A.U.; validation, Ş.Y., R.A., and S.D.; formal analysis, E.Ö., Ş.Y., and R.A.; investigation, S.A.U., and S.D.; data curation, M.S.A., and S.D.; bibliographic research, R.A., E.Ö., and S.D.; writing-original draft preparation, S.A.U., E.Ö., and R.A.; writing-review and editing, S.A.U., and Ş.Y.; visualization, E.Ö., and Ş.Y.; statistical analysis: S.A.U.; critical revision of the manuscript for important intellectual content, E.Ö., and S.A.U; supervision, Ş.Y, M.S.A., S.D., and R.A.; project administration M.S.A., E.Ö., and Ş.Y. All authors have read and agreed to the published version of the manuscript.

Data Availability
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