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CASE SERIES

Pediatric infrafossal fracture of the humerus: A case series

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Supracondylar fractures are the most common fractures of the distal end of the humerus in children,[1] while transcondylar fractures can be also seen rarely. Infrafossal fracture of the humerus is a type of fracture that has not been previously reported in the literature. The fracture pattern is different from the supracondylar fracture, as the fracture line passes under the olecranon fossa and extends toward the condyles. In supracondylar fractures, the fracture line is always located proximal to the condyles and it usually passes through the upper part of or proximal to the olecranon fossa. Infrafossal fracture of the humerus is also different from transcondylar fractures, since the fracture line usually passes through the olecranon fossa in transcondylar fractures. Infrafossal fracture of the humerus usually presents with a flexion-type fracture or neutral angulation in the sagittal plane. Difficulty in fracture reduction and fixation due to small intraarticular fragment also distinguishes

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ABSTRACT

Objectives: In this case series, we aimed to evaluate the clinical and radiographic outcomes of the patients with infrafossal fracture of the humerus and to evaluate the upper extremity and elbow function with the Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder, and Hand (QuickDASH) questionnaire.

Patients and methods: Between January 2005 and July 2020, the clinical data and radiographs of 2,443 children who were treated due to distal humerus fracture were retrospectively analyzed. A total of six patients (5 males, 1 female; mean age: 6.7±2.6 years, range, 3 to 11 years) treated due to an infrafossal fracture of the humerus were included. Radiographic measurements, such as Baumann's angle, lateral capitellohumeral angle, and carrying angle of the elbow, were performed. At the final follow-up, elbow joint range of motion (ROM) was measured, functional scores of the elbow and upper extremity were assessed. Complications were also recorded.

Results: The mean follow-up was 62.8±47.4 (range, 20 to 140) months. Two patients underwent open and three underwent closed reduction and internal fixation by different surgeons. One of the patients was treated with a long-arm cast. There was no major elbow ROM limitation. There was no significant deterioration in the lateral capitellohumeral and elbow carrying angles of the patients. Baumann's angle was normal for all the patients; however, it could not be measured in two patients, as their epiphyses were closed. Four patients had an excellent MEPS and two patients a good MEPS. The QuickDASH scores were low in all patients. There were two patients with cubitus varus who were treated surgically using lateral closing-wedge corrective osteotomy.

Conclusion: Infrafossal fracture of the humerus is a fracture type which is different from supracondylar and transcondylar fractures and has not been previously reported in the literature. Despite the cubitus varus developed in two of our patients, functionally satisfactory results were achieved in all patients at the end of the treatment. Due to the risk of developing cubitus varus, patients with infrafossal fracture of the humerus should be followed closely until the end of adolescence. Although the current study is very limited in terms of being a guide for the treatment, it may contribute to the literature in terms of defining a new fracture subtype.

Keywords: Baumann's angle, carrying angle, cubitus varus, elbow, infrafossal fracture, supracondylar.

these fractures from supracondylar fractures. Therefore, we present this case series to contribute to the literature by sharing our treatment experience.

In this case series, we aimed to evaluate the clinical and radiographic outcomes of the patients with infrafossal fracture of the humerus and to evaluate the upper extremity and elbow function with the Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder, and Hand (QuickDASH) questionnaire.

PATIENTS AND METHODS

This case series was conducted at Istanbul Metin Sabancı Baltalimani Bone Diseases Training and Research Hospital, Department of Orthopedics and Traumatology between January 2005 and July 2020. Clinical data of a total of 2,443 patients who were treated due to distal humerus fractures were retrieved from the medical records. Two senior orthopedic surgeons reviewed the radiographs of the patients to reach a consensus about the fracture pattern. When these radiographs were analyzed, six patients (5 males, 1 female; mean age: 6.7±2.6 years, range, 3 to 11 years) treated due to an infrafossal fracture of the humerus were included. A detailed history of the fracture formation mechanism was obtained from the families. After carefully evaluating the first radiographs taken in the emergency service (Figure 1), we determined the displacement positions of the distal fracture fragments.

Surgical data and patient follow-up

One of the patients was treated with a long arm cast, while the others were treated surgically. Five patients who were operated were given prophylactic first-generation cephalosporin 30 min before surgery. One patient was operated through the standard lateral approach with open reduction and internal fixation (ORIF), another was operated via the lateral and medial approach together with ORIF, and three patients were operated with closed reduction and internal fixation (CRIF). In patients with flexion angulation of the distal fragment, reduction was obtained with longitudinal traction. While the elbow was in extension, the distal fragment was reduced under fluoroscopy with a posteriorly directed force and, then, the coronal plane deformity (varus-valgus deformity) was corrected. In patients without angulation in the sagittal plane, only the coronal plane deformity was corrected under traction. After reduction, fixation was achieved with two or three divergent Kirschner wires (K-wire) inserted from the lateral side, or with medial and lateral crossing K-wires. The patients were applied a long arm splint after wound dressing and administered intravenous first-generation cephalosporin for 24 h postoperatively.

The patients who underwent surgery were examined at the postoperative second week for wound check, suture removal, and taking radiographs to ensure no displacement occurred, at the fourth week for pin removal and cast change, and at the sixth week for the evaluation of fracture union with radiographs, cast removal, and range of motion (ROM) check. At the third month follow-up, elbow ROM was checked and the need for physiotherapy was assessed. After the third month, the patients were followed quarterly, until the end of the first postoperative year and annually thereafter.

The patient who received conservative treatment with a long arm cast was examined weekly for two postoperative weeks to ensure no displacement occurred. The patient was followed at the fourth and sixth weeks for the evaluation of fracture union on radiographs. At the sixth week, fracture union was confirmed and the long arm cast was removed. Subsequently, muscle strengthening and ROM exercises were started. At the third month follow-up, the patient was examined for ROM and the need for physiotherapy was assessed. After the third month, the patient was followed quarterly, until the end of the first postoperative year and annually thereafter.

Outcome assessment

The patients' demographics, clinical characteristics, treatment data, and postoperative results were reviewed. Four of the six fractures were of the left humerus and two of the right one. The patients and their families were invited to the hospital for the study, and their elbow joint ROMs were measured compared to the contralateral side using a goniometer. All radiographic measurements, such as Baumann's angle (BA), lateral capitellohumeral angle (LCHA), and carrying angle (CA) of the elbow, were performed uniformly by two senior orthopedic surgeons. The BA was measured on a frontal radiograph, with the elbow in extension. A value between 65° and 82° is considered normal for BA.[2] Early post-treatment BA and CA were measured right after the cast or splint was removed. A value between 5° and 15° is considered normal for CA and 45° and 57° for LCHA.[3]

The functionality of the elbow was assessed using the MEPS and the upper extremity using the QuickDASH questionnaire.[4] The interpretation of the MEPS is presented in Table I. The QuickDASH

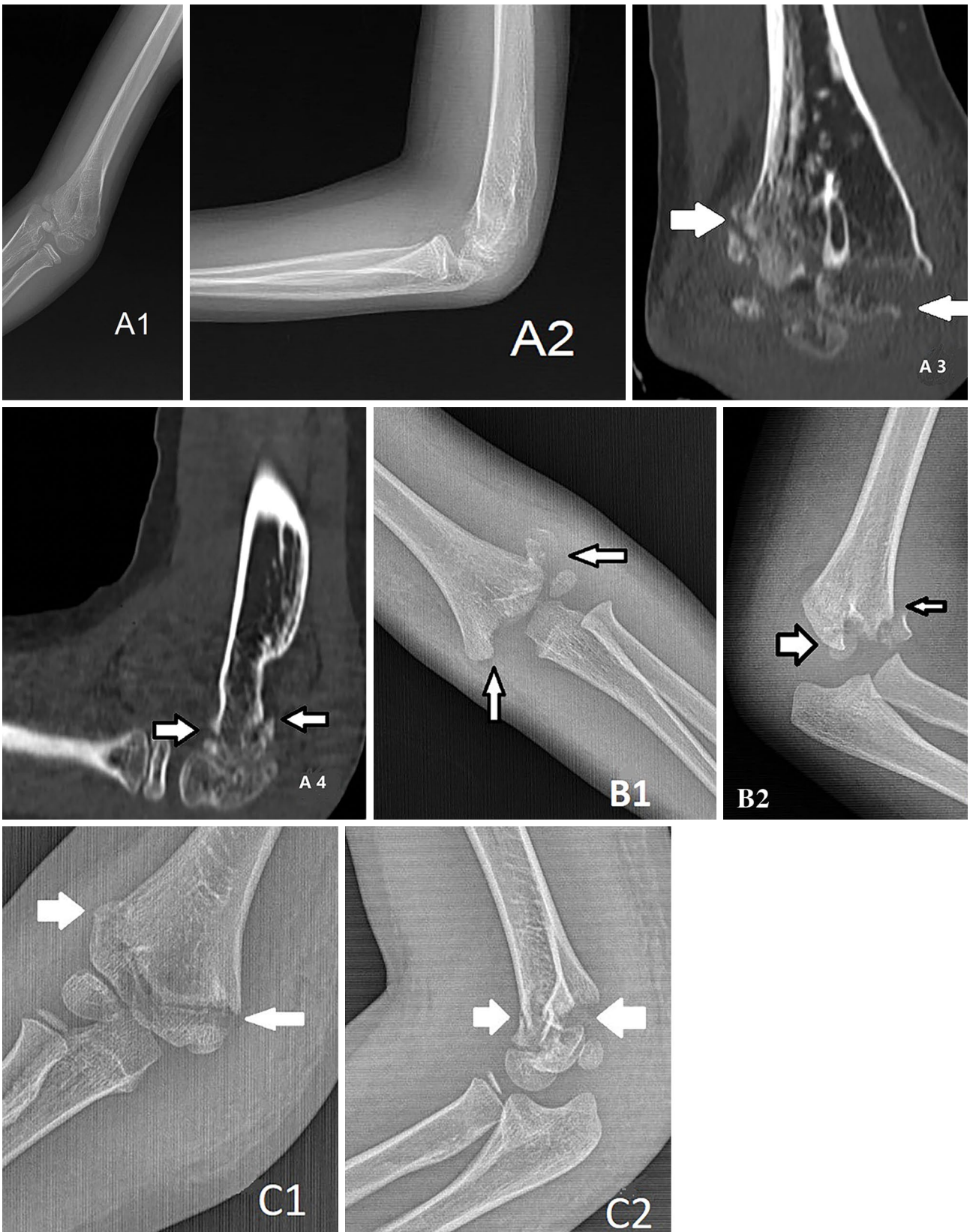

FIGURE 1. (A1) Anteroposterior and **(A2)** lateral radiographs of Patient 1 **(A3)** Coronal and **(A4)** sagittal computed tomography image of Patient 1. **(B1)** Anteroposterior and **(B2)** lateral radiographs of Patient 2. **(C1)** Anteroposterior and **(C2)** lateral radiographs of Patient 3.

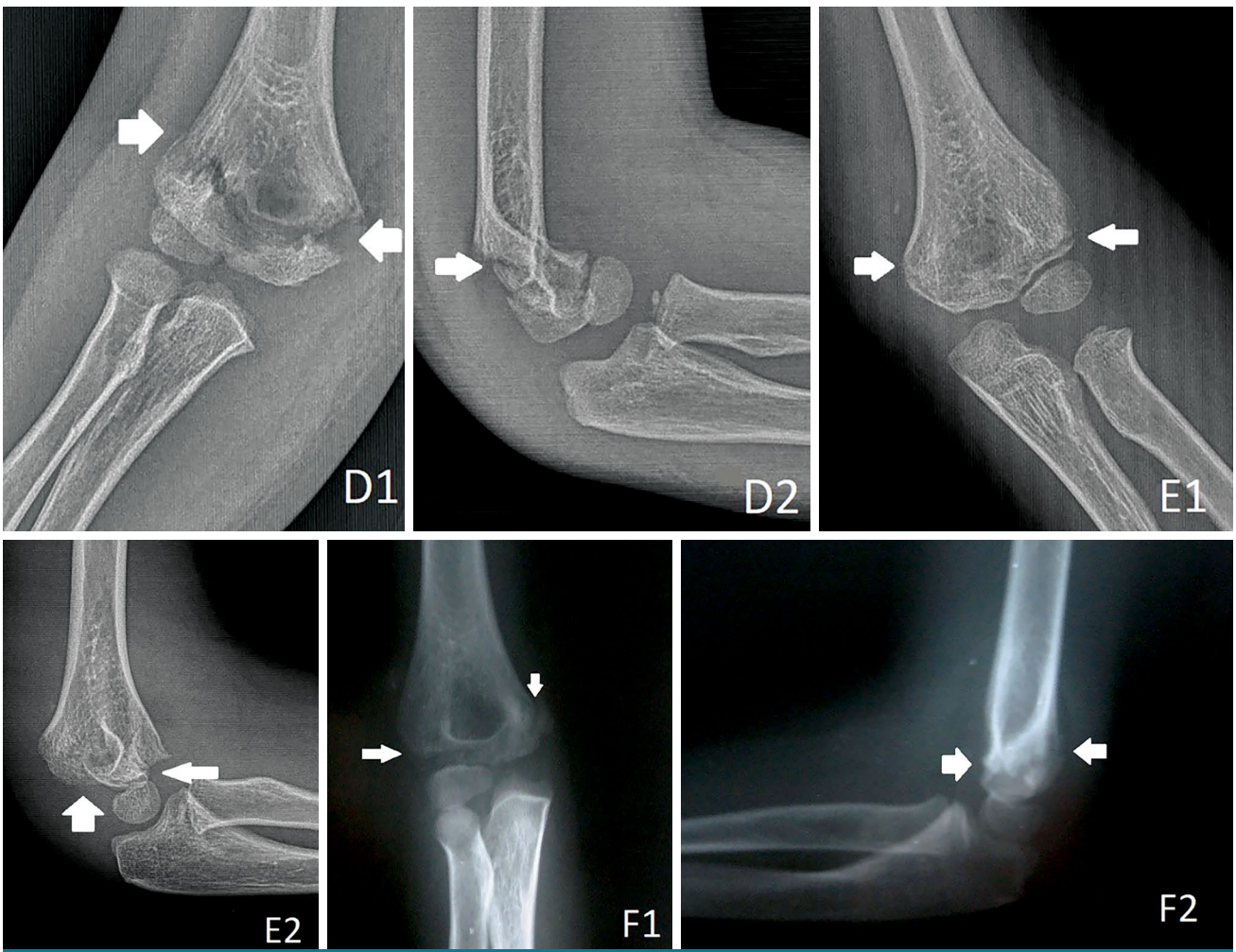

FIGURE 1. Continued.

(D1) Anteroposterior and **(D2)** lateral radiographs of Patient 4. **(E1)** Anteroposterior and **(E2)** lateral radiographs of Patient 5. **(F1)** Anteroposterior and **(F2)** lateral radiographs of Patient 6.

questionnaire contains 11 questions where the patient is asked to score disability in the affected arm. A total score ranging from 0 to 100, where 100 represents the worst possible disability, is calculated.[5] Higher scores indicate greater disability. Total follow-up time and complications were also recorded.

RESULTS

The patients were numbered from 1 to 6. Distal fracture fragment positions of the patients are given in Table II. Patients' clinical characteristics, treatment data, and postoperative results are given in Table III, and their postoperative radiological and clinical measurements in Table IV. The mean follow-up was 62.8±47.4 (range, 20 to 140) months. This fracture type had a prevalence of 0.25% (6/2,443) among all distal humerus fractures and was more common in males (83.3%). In five of the six patients, the fracture occurred due to low-energy trauma after falling directly on the affected elbow. Patient 4 and his family reported that they did not know the mechanism of falling exactly.

Two patients underwent ORIF and three underwent CRIF by different surgeons. A standard lateral incision was performed in Patient 5. For Patient 2, since the medial part of the fracture could not be reached, surgery was carried out via a medial and lateral incision together. Early postoperative radiographs of the first, second and fourth patient are given in Figure 2.

According to the literature, normal values for flexion are between 130° and 154°, extension between

TABLE I
Interpreting the Mayo Elbow Performance Score

Function	Definition	Points	Score classification
Pain	None	45	Excellent >90
	Mild	30	
	Moderate	15	
	Severe	0	
Motion	Arc >100°	20	Good 75-89
	Arc 50-100°	15	
	Arc <50°	5	
Stability	Stable	10	Fair 60-74
	Moderate instability	5	
	Gross instability	0	
Function	Comb hair	5	Poor <60
	Feed self	5	
	Perform hygiene tasks	5	
	Can put on shirt	5	
	Can put on shoes	5	
Total		100	

TABLE II
Patients' distal fracture fragment positions

No	Coronal plane angulation	Sagittal plane angulation	Rotation
1	Medial	-	-
2	Lateral	Flexion	Present
3	Lateral	Flexion	Present
4	Lateral	Flexion	-
5	-	-	Present
6	Medial	-	-

TABLE III
Patients' demographics, clinical characteristics, treatment data, and postoperative results

						Range of motion								
				Treatment		Flexion		Extension		Pronation		Supination		
No	Age/sex	Follow-up (months)	Side	Type	K-wires	I	CL	I	CL	I	CL	I	CL	Comp
1	9/M	94	L	CRIF	Lateral divergent 2 wires	135	142	10	12	82	84	77	85	Cubitus varus
2	3/M	37	L	ORIF with medial and lateral incision	Lateral 2 crossing wires, medial 1 and superolateral to medial 1 wire	135	136	4	9	75	85	76	85	-
3	6/F	20	R	CRIF	Medial 1 and lateral 2 crossing wires	125	137	9	9	76	89	80	85	-
4	8/M	20	R	CRIF	Lateral divergent 3 wires	130	131	14	15	80	80	81	83	-
5	7/M	66	L	ORIF	Medial 1 and lateral parallel 2 wires	134	146	1	4	79	75	80	80	-
6	7/M	140	L	Long arm cast	-	130	136	-11	3	75	84	85	86	Cubitus varus

L: Left; R: Right; CL: Contralateral side; I: Injured side; Comp: Complication; CRIF: Closed reduction-internal fixation; ORIF: Open reduction-internal fixation.

TABLE IV
Post-treatment radiological and clinical measurements of the patients

No	Radiological measurements						Before Cubitus varus operation	Outcome measures	
	Bauman's angle		LCHA		CA				
	Early post-treatment	Last follow-up	Early post-treatment	Last follow-up	Early post-treatment	Last follow-up		MEPS	QuickDASH
1	81	Closed GP	68	61	9	4	35	85	2.3
2	77	81	57	49	7	7	-	100	0
3	73	80	58	46	9	8	-	100	0
4	70	80	53	46	6	6	-	100	0
5	75	81	58	50	5	6	-	100	0
6	81	Closed GP	40	45	6	8	11	85	4.5

LCHA: Lateral capitellohumeral angle; CA: Carrying angle of the elbow; QuickDASH: Quick Disabilities of the Arm, Shoulder, and Hand; GP: Growth plate; MEPS: Mayo Elbow Performance Score.

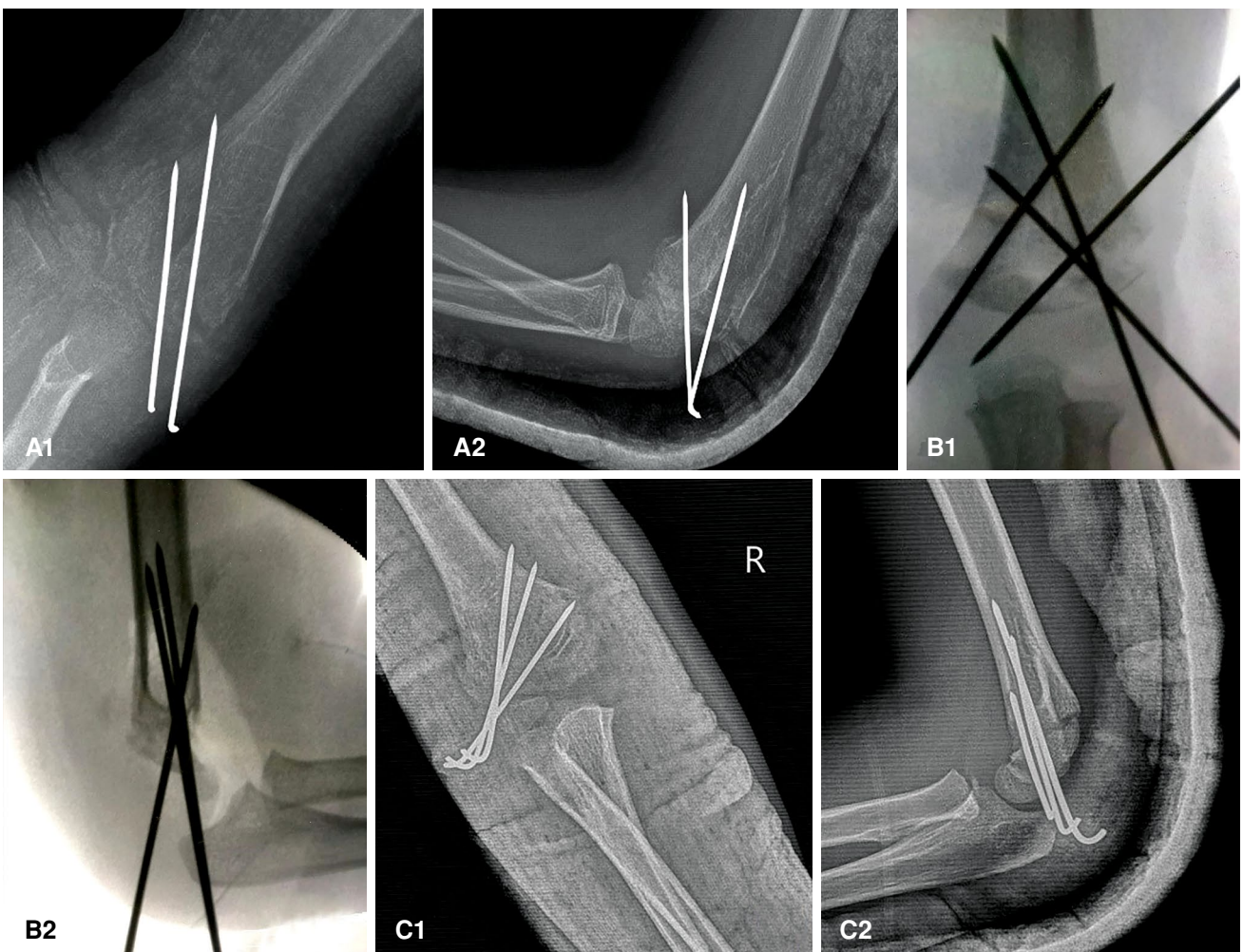

FIGURE 2. Postoperative **(A1)** anteroposterior and **(A2)** lateral radiographs of Patient 1. **(B1 and B2)** Postoperative fluoroscopic images of Patient 2. Postoperative **(C1)** anteroposterior and **(C2)** lateral radiographs of Patient 4.

FIGURE 3. Elbow range of motions of 1st Patient **(A1-A5)**.

FIGURE 3. Continued.
5th Patient **(B1-B5)**, 6th Patient **(C1-C5)**.

-6° and -11°, pronation between 75° and 85°, and supination between 80° and 104°.[6-9] According to these values and to contralateral elbow ROM, there was minimal flexion limitation in Patient 3 and a minor extension limitation in Patient 6. In addition, there was minimal supination limitation in Patient 1. No pronation restriction was observed in any patient. The elbow joint ROMs of the first, fifth, and sixth patient are given in Figure 3.

During the follow-up period, all patients' elbow CA values were normal. The LCHA of Patient 1 was high during the follow-up period. The LCHA of Patient 6 was low in the early period (the first six weeks), but normal at the final follow-up. The BA was normal for all of the patients; however, it could not be measured in Patients 1 and 6 at the final follow-up, since their epiphyses were closed. Four patients had an excellent MEPS and two patients a good MEPS.

Only two patients encountered complications, cubitus varus, in the current study. One of these patients was Patient 6, who was treated conservatively, and the other patient was Patient 1. We evaluated the medical records of Patient 1 retrospectively and noticed that the patient was treated with a long arm cast due to a distal humerus fracture when he was three years old and operated for a supracondylar fracture when he was seven years old. He underwent another surgery for an infrafossal fracture of the humerus, when he was nine years old. Cubitus varus deformity was observed in this patient during our follow-up. Both patients with cubitus varus deformity were treated surgically with lateral closing-wedge corrective osteotomy. Pre- and postoperative radiographs of the patients with cubitus varus are given in Figure 4.

FIGURE 4. Preoperative and postoperative radiographs of patients with cubitus varus.

(A1) Anteroposterior and **(A2)** lateral radiograph of Patient 1 before cubitus varus surgery. Early postoperative **(A3)** anteroposterior and **(A4)** lateral radiographs of Patient 1 after cubitus varus surgery. **(A5)** Anteroposterior and **(A6)** lateral radiographs of Patient 1 at the final follow-up.

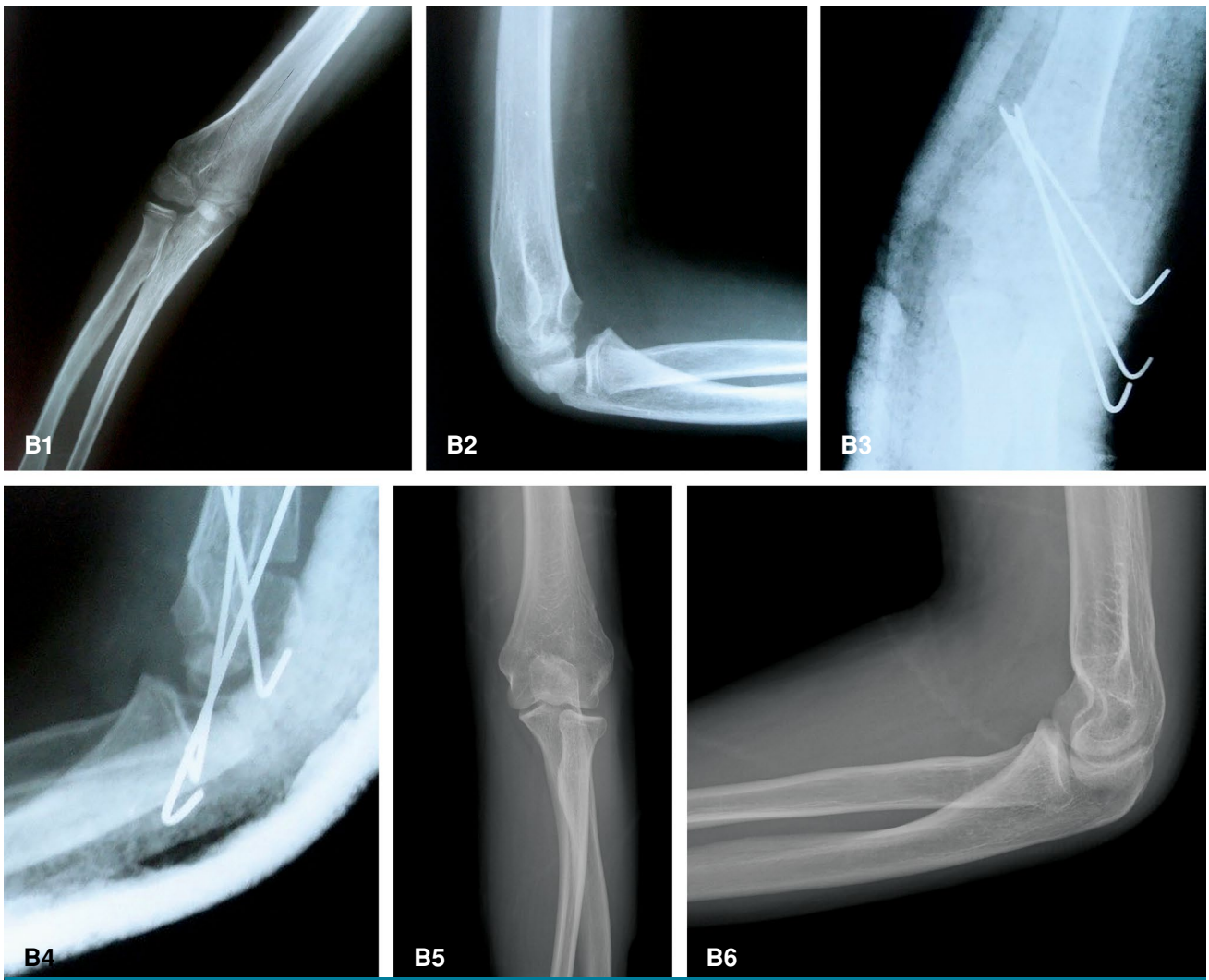

FIGURE 4. Continued.

(B1) Anteroposterior and **(B2)** lateral radiograph of Patient 6 before cubitus varus surgery. Early postoperative **(B3)** anteroposterior and **(B4)** lateral radiograph of Patient 6 after cubitus varus surgery. **(B15)** Anteroposterior and **(B6)** lateral radiographs of Patient 6 at the final follow-up.

DISCUSSION

In six of 2,443 patients who were treated for pediatric distal humerus fractures in the past 15 years, a special and quite rare (0.25%) fracture pattern that we had difficulty with, particularly in providing reduction during surgery attracted our attention.[10] This fracture pattern was different from the supracondylar fracture due to its anatomical features and the difficulty experienced during surgery. In supracondylar fractures, the fracture line passes through the upper part of or proximal to the olecranon fossa, whereas in infrafossal fracture of the humerus, the line always passes under the olecranon fossa and extends toward the condyles. The pattern was also different from distal humeral epiphyseal separation, as it is Salter-Harris type 1 injury in infants and type 2 in older patients.[11] The fracture type was unable to be classified as T-condylar fracture, as there was no second fracture line extending proximally.[12,13] In addition, this fracture type is also different from transcondylar fractures of the humerus, in which the fracture line traverses the olecranon fossa.[14] Therefore, we decided that it would be more appropriate to present the case series by defining the fracture as an "infrafossal fracture of the humerus", taking into consideration the anatomical location and characteristics of the fracture.

In five of the six patients, the fracture mechanism was falling directly on the affected elbow, as in flexion-type supracondylar fractures. When we examined the radiographs of the patients (Figure 1), three patients had flexion-type angulation in the sagittal plane in the distal fracture fragment, while there was no extension-type angulation. There were also three patients with distal fragment rotation. All these findings suggest that the possible mechanism in the formation of this fracture is a rotatory and a shearing force exerted on the distal humerus. Although the mechanism of fracture formation is similar to flexion-type supracondylar fractures, we cannot explain why the fracture occurs under the distal olecranon fossa, but not from a relatively weak supracondylar region. The reason may be the exertion of a more intense force on the distal than the force that causes a flexion-type supracondylar fracture. The rotational component of the force that emerges during falling directly on the elbow may also contribute to infrafossal fracture formation.

This type of fracture seems to be easily diagnosed with direct radiographs, but there is often diagnostic uncertainty with pediatric traumatic elbow injuries reflected by the highest diagnostic error rate in the elbow joint for pediatric trauma.[15] Unfortunately, this is also valid for the fracture type defined as infrafossal fracture of the humerus. Sometimes, it may be very difficult to recognize the fracture, particularly in patients who have it without displacement or whose anatomy has changed due to any other previous fractures. A preoperative computed tomography can provide better recognition of the fracture as in our first patient (Figure 1 A3 and A4). A preoperative magnetic resonance imaging may also be useful for better evaluation of the cartilaginous parts of the distal end of the humerus that have not yet ossified in younger children.

In this fracture type, due to the rarity of the treatment knowledge, the most optimal treatment option is not clear. Technical difficulties can be often encountered during closed and open reductions of these fractures. In this type of intracapsular fracture, since the distal part of the humerus is quite small, it is very difficult to achieve anatomical reduction at both the medial and lateral border of the fracture line with a single relatively small incision. Therefore, a combination of medial and lateral incisions may be required. Also, intense soft tissue edema makes it difficult to feel the medial and lateral condyles with palpation and, therefore, anatomical reduction of the distal humerus may not be achieved, properly. The fracture fragment is located at where the distal humerus is flexed anteriorly. The curve extended anteriorly in this region makes it difficult to maintain anatomical reduction during CRIF or ORIF. It should be also kept in mind that the ruptured joint capsule may sometimes enter the fracture line and prevent closed reduction (Figure 5). In fracture surgery, anatomical reduction is of great importance. To achieve an anatomical reduction in this fracture type, it is necessary to provide the cortical contour of the medial and lateral columns of the distal humerus and the BA within normal limits in the anteroposterior plane of the intraoperative fluoroscopic images. It is also important to preserve the eight-figure shape of the distal lateral humerus, together with the provision of anterior and posterior cortical contours in the lateral plane.

The prevalence of cubitus varus deformity following treatment of supracondylar humerus fractures is less common at a rate of 3.97%.[16] In the current study, cubitus varus deformity occurred in two of the six patients (33.3%; Patients 1 and 6). Patient 1 was previously treated with a long arm cast for a distal humerus fracture and operated

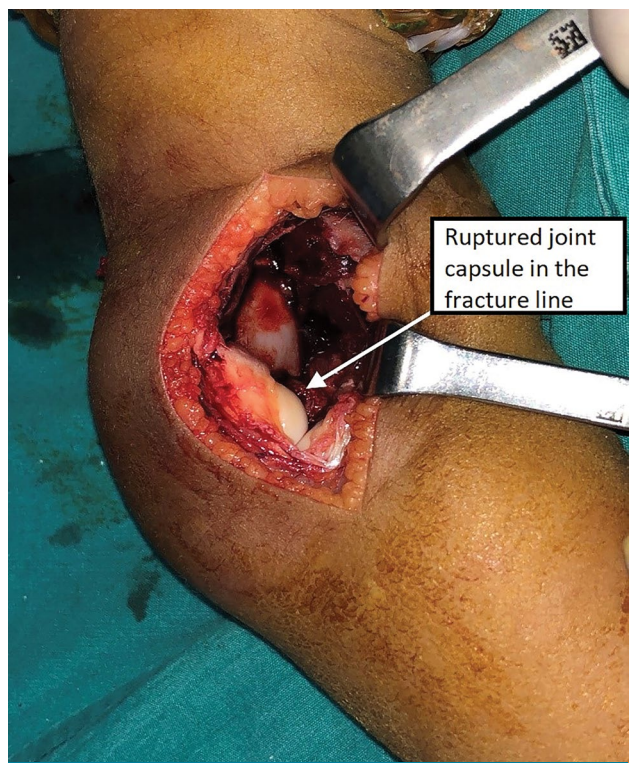

FIGURE 5. The ruptured joint capsule and the fracture line are seen. The ruptured joint capsule can be seen at the fracture line (Patient 2).

the same side for a supracondylar fracture before the development of the infrafossal fracture of the humerus. Patient 6 was treated conservatively. Patient 1 had a good fracture reduction postoperatively, while fracture displacement in Patient 6 was minimal. Although anatomical reduction was not achieved in the remaining four patients, we did not observe any cubitus varus deformity. Therefore, we believe that the cause of cubitus varus is an epiphyseal and physeal injury rather than failing to achieve anatomical reduction during surgery. Undoubtedly, the findings from a cohort of six patients are too small to drive this conclusion, but it is necessary to follow the patients closely assuming that they may develop cubitus varus until the end of adolescence.

There are some points that may be important in the fixation and immobilization of this type of fracture. Due to the distal location of the fracture fragment, K-wires may need to be placed more distally. Indeed, it may be necessary to send the K-wire through the joint to achieve a good fixation in the medial side. Also, it would be safer to place the K-wire using a mini-incision to avoid damage to the ulnar nerve in the medial side. The ideal K-wire configuration for a supracondylar fracture fixation has not yet been defined.[17] However, it can be speculated that, if better stability is desired, the most accepted method is to use two lateral and one medial K-wire crossing the fracture line.[18,19] Although different K-wire configurations were preferred by different surgeons in the current study, in our opinion both lateral and medial K-wire fixation is the most successful method in maintaining anatomical reduction.

At the final follow-up, we did not observe any ROM limitation in our patients. Two patients who were treated for cubitus varus had a good MEPS, while the others had an excellent MEPS. The QuickDASH scores were low in all patients. Although the current study was limited to six patients, the above findings reveal that clinically successful results can be achieved, even if cubitus varus deformity develops during the treatment of this fracture type.

In conclusion, infrafossal fracture of the humerus is a fracture type which is different from supracondylar and transcondylar fractures and has not been previously reported in the literature. Despite the cubitus varus developed in two of our patients, functionally satisfactory results were achieved in all patients at the end of the treatment. Due to the risk of developing cubitus varus, patients with infrafossal fracture of the humerus should be followed closely until the end of adolescence. Although the current study is very limited in terms of being a guide for the treatment, it may contribute to the literature in terms of defining a new fracture subtype.

Ethics Committee Approval: The study protocol was approved by the Health Sciences University Metin Sabancı Baltalimanı Bone Diseases Training and Research Hospital Medical Specialization Education Board (TUEK) (date: 20.08.2020, no: 61/436). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Study design, writing the article: O.Ç.; Study design, and last control: K.Ö.; Radiological measurement: H.E.A.; Clinical evaluations of patients: A.K.; Radiological measurements, writing the article: M.M.; Last control, evaluating the patients: D.K.

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