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ORIGINAL RESEARCH



Supracondylar Humerus Fractures in Infants and Early Toddlers; Characteristics, Clinical and Radiological Outcomes Compared with Older Children

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ABSTRACT

Background: Supracondylar humerus fractures (SCHF) are rarely seen in the youngest age groups (1-3 years). Although there is no difference in the context of treatment options, it has been shown that younger age groups have different characteristics. Few studies have examined toddlers, which have notably different characteristics. This study is the first to report the characteristics, diagnosis, treatment and functional results of SCHF in infants and early toddlers.

Methods: A retrospective analysis was made of the data of patients younger than 30 months old, who were operated on in our clinic for SCHF between 2012 and 2020 with at least 2 years of follow-up. Patient demographic and surgical data, and the functional and radiological results were documented.

Results: Evaluation was made of a total of 52 patients comprising 30 females (58%) and 22 males (42%), with a mean age of 20.75 ± 5.4 months (range, 6-30 months). The injury was in the right elbow in 24 (46%) patients. The mechanism of injury was a fall from an object at home (table, chair, bed, etc.) in 41 (79%) patients. Patients who fell from a height of more than 4 meters had additional injuries (liver laceration, vertebral fracture, etc.). Only 1 patient had anterior interosseous nerve (AIN) damage before the operation, but the final follow-up neurovascular examinations for all patients were normal. The median follow-up period was 4 years (range, 2-7 years). Flynn outcome scores were (88.5%) excellent and variant Hospital for Special Surgery scores were (82.7%) excellent.

Conclusions: With appropriate treatment of SCHF, the clinical outcomes in infants and early toddlers are excellent. Using a medial pin to achieve and protect stability in this age group does not increase the risk of iatrogenic ulnar nerve damage. Patients younger than 20 months tend to have more varus malalignment but similar functional results.

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KEYWORDS

Toddlers; infants; supracondylar fracture; humerus fracture; pediatric fracture

Introduction

Supracondylar humeral fractures (SCHF) are the most commonly seen fractures in the pediatric population, and are primarily treated with surgery [1]. It is essential for pediatric and general orthopedic surgeons to better understand this type of injury because of possible complications and problems [2, 3]. The peak age for SCHF is between 5 and 7 years, although they can be seen between the ages of 0 and 14 years, and the widely accepted treatment is closed reduction and percutaneous pinning for displaced fractures [3-5]. SCHF in the infant and toddler age group are less common due to different trauma mechanisms than in the older age group⁶. Although there is no difference in the context of treatment options, it has been shown that younger age groups have different characteristics including female predominance, more varus malalignment, and more loss of reduction (LOR) without bicolunar fixation [7, 8]. There are many studies in the literature on SCHF, exploring topics from diagnosis to treatment. However, these fractures are

rarely seen in infants and early toddlers and few studies have examined treatment results for this age group [8].

The aim of this study was to present the midterm radiological and functional results of pediatric supracondylar humeral fractures in infants and early toddlers who were operated on in our clinic and to identify factors affecting clinical outcomes. As there are fewer data in literature for this group, the results obtained in this study will help pediatric orthopedic surgeons to predict treatment outcome.

Methods

Approval for the study was granted by the Institutional Ethics Committee. Inclusion criteria were defined as patients with SCHF aged <30 months, who were treated surgically in our clinic between 2012 and 2020 with the diagnosis code of S42.4 according to the International Statistical Classification of Diseases and Related Health Problems (ICD-10; S42.40: closed, S42.41: open). The threshold of

30 months was selected because gross motor skill development reaches a plateau at this age, so it was thought that this might be helpful in making a more precise functional evaluation.

Patients were excluded from the study if the postoperative follow-up time was < 2 years, if they had a pathological fracture, any other disease that may cause pathological fracture, an intra-articular fracture, or if they were followed up conservatively after a Gartland type 2 fracture.

The mechanism of trauma, orthopedic and systemic traumas were documented. Waiting times before surgery due to other traumas and surgical results were evaluated.

The mean age of the enrolled patients was calculated as 20 months, so two groups were then formed as younger (≤ 20 months) and older (> 20 months) than 20 months.

From standard anteroposterior and lateral radiographs, the Johns Hopkins classification was used for the fracture pattern (Figure 1) and the Gartland classification was used to measure fracture displacement [9, 10]. Whether the fracture was flexion-type or extension-type was also noted.

All surgeries were performed under fluoroscopy guidance with the patient in the supine position. Six different orthopedic surgeons (pediatric and adult trauma surgeons) who had more than 6 years of experience with pediatric and adult trauma performed the operations. No operations were performed during the night shift.

Pin configurations were categorized as isolated lateral, single lateral + medial, and multiple lateral + medial (Figure 2). Translation, Bauman angle, and anterior humeral line crossing the capitellum were evaluated from early postoperative

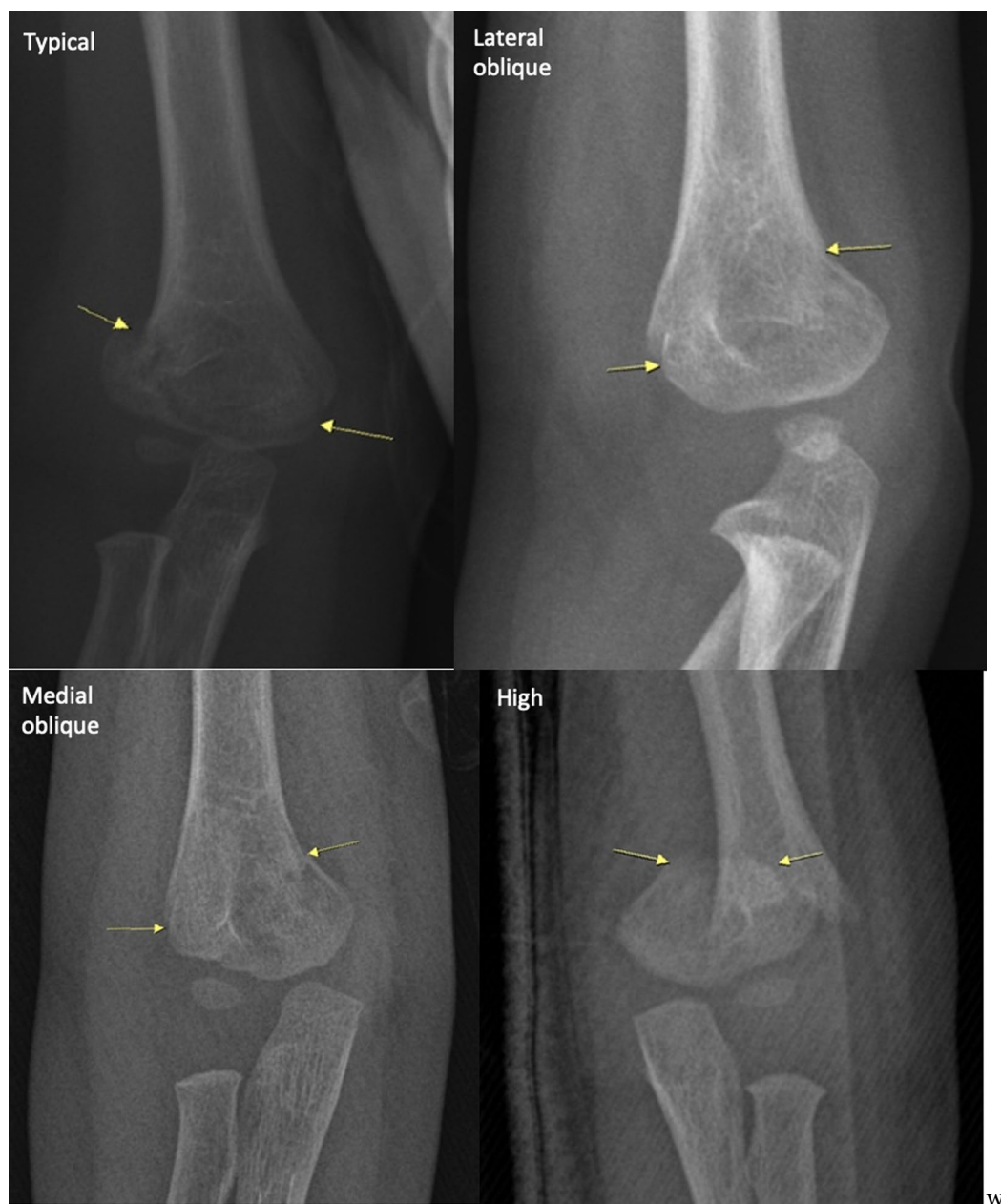


Figure 1. Supracondylar humeral fracture patterns according to the Johns Hopkins fracture classification system, with patients listed in Table 2 from left to right (#42, #43, #50, #26).

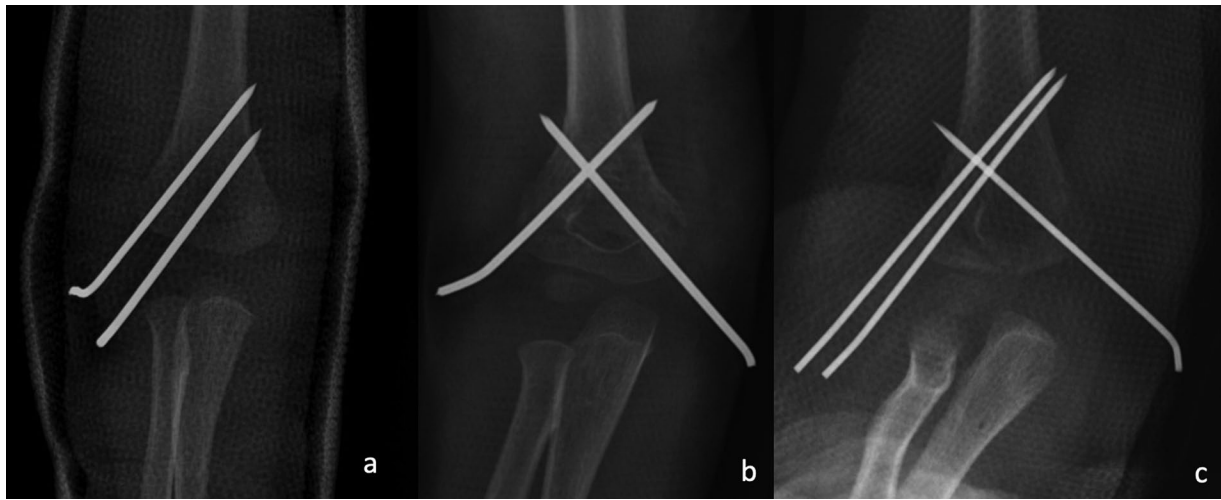


Figure 2. Radiographic images demonstrating study pin configuration: **(a)** Only lateral entry, multiple pinnings; **(b)** 1 lateral pin and 1 medial pin; **(c)** 2 lateral pins and 1 medial pin. The patients are listed in [Table 2](#) from left to right (#40, #19, #51).

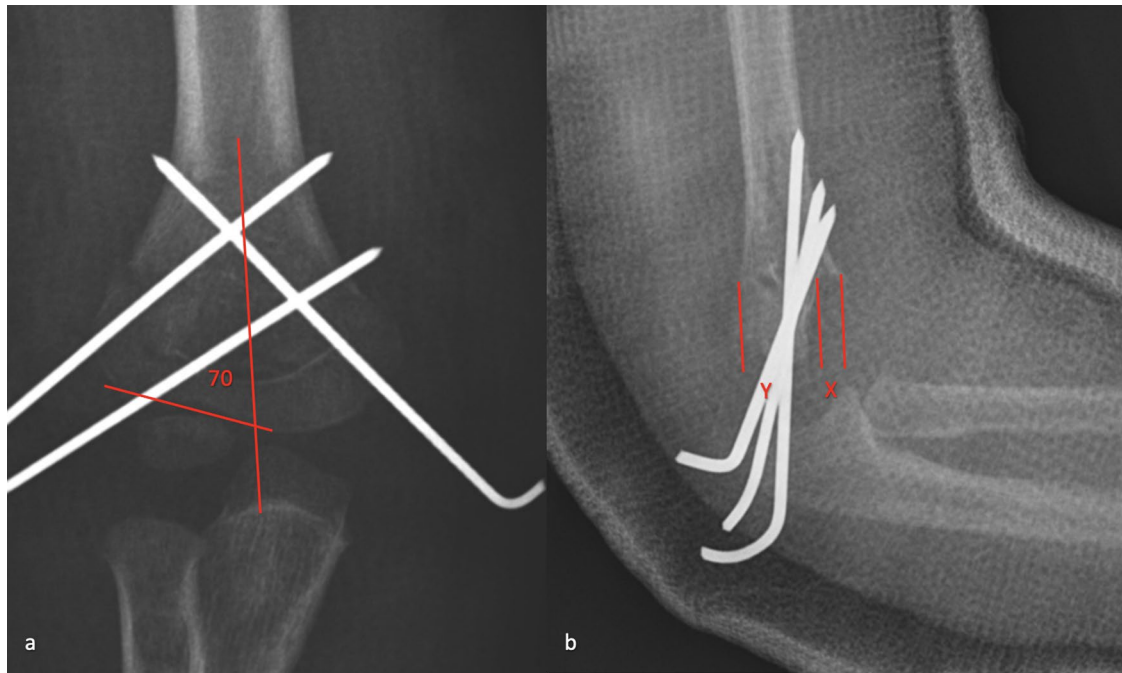


Figure 3. Images demonstrating the radiological measurement parameters used in this study: **(a)** Bauman angle; **(b)** Gordon index. The patients are listed in [Table 2](#) from left to right (#34, #52).

radiographs and radiographs taken during the clinic visit when the pins were removed [11] ([Figure 3](#)).

Bauman angle between 64° and 81° , no translation, and anterior humeral line crossing the capitellum were taken as acceptable results. Postoperative reduction quality and LOR during follow-up were determined with these evaluations according to the Skaggs criteria (a change of Bauman angle of $>10^\circ$ on anteroposterior view, or anterior humeral line not crossing the capitellum on lateral view) [12]. It was determined whether bicolunar fixation was achieved or not [7].

Fixation pins were removed in an average of 30 days in outpatient clinic conditions. At the same time, the splint or cast was removed from the patient and the patients and caregivers were encouraged to do active and passive range of motion exercises. During these exercises, caregivers only gently helped

elbow motion of the child while avoiding any excessive force to improve range of motion. Additional physical therapy was not applied for any of the patients in the postoperative period.

Patients were called to a final follow-up visit and physically examined for functional scoring ([Figure 4](#)). Varus-valgus, flexion-extension, and neurovascular statuses were evaluated and documented in these physical examinations. Limitations of functional range of motion according to Morrey et al. (30° to 130°) were also noted [13]. The outcomes were evaluated with the Flynn elbow criteria (cosmetic and/or functional factors) and variant Hospital for Special Surgery (HSS) scores [14].

The relationships between the two outcome scores, functional and radiological results, and preoperative and perioperative factors were evaluated statistically.

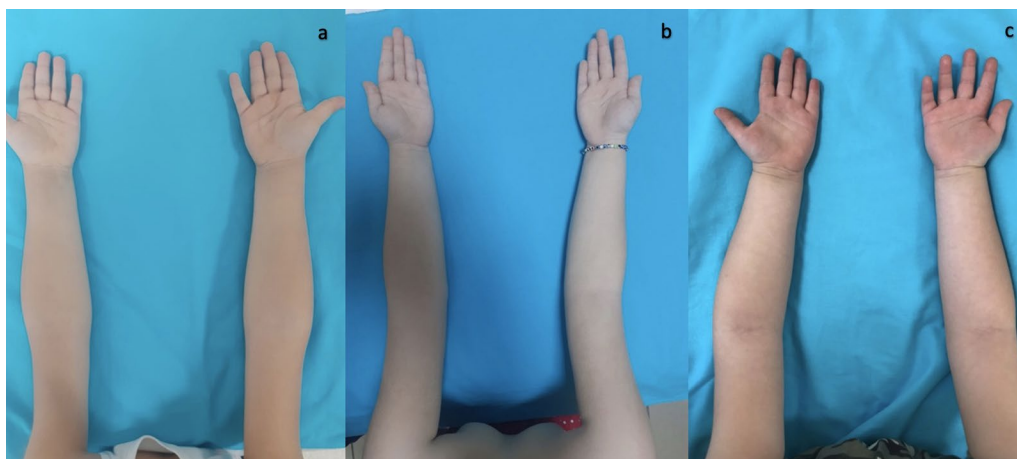


Figure 4. Clinical photographs from the final follow-up examinations of the patients. The patients are listed in Table 2 from left to right (#21(2-year follow-up), #10 (5-year follow-up), #9 (5-year follow-up)).

Statistical analysis

Data analysis was carried out using SPSS 22.0 software (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to determine whether quantitative variables were normally distributed. Results were presented as median (interquartile range) values for continuous variables and number (percentage) for nominal/categorical variables. Comparisons between groups were performed using the Chi-square test, Mann-Whitney U test, or Fisher exact test as appropriate. Values of $p < 0.05$ were considered statistically significant [15].

Result

A total of 52 patients surgically treated in our clinic, comprising 30 females (58%) and 22 males (42%) met the inclusion criteria. The characteristics and additional data of patients included in the study are shown in Tables 1 and 2.

With the exception of some patients who had fallen from a height of more than 2 meters, patients were operated on within the first 36 hours of admission to the hospital. One patient (patient #2) who was referred from another clinic on the 10th day of the fracture underwent surgery on the same day. The surgical data are shown in Table 3.

Associated fractures or injuries were detected in 4 of 6 patients who fell from a height of more than 4 meters. Three of those 6 patients were hospitalized in the pediatric intensive care unit and, consequently, the waiting time before surgery was prolonged. Three of those 6 patients had a high fracture pattern according to the Johns Hopkins classification (Table 4).

No neurological findings such as neuropraxia or nerve palsy related to the operations were detected. It was determined from the outpatient clinical notes that the findings of the only patient who had preoperative anterior interosseous nerve (AIN) damage continued into the early postoperative period and regressed in the 4th month of the follow-up period (patient #34). Figure 5 shows the X-Ray images of patient 34.

While examining radiographs taken at the time of pin removal, 8 patients were seen to have radiologic LOR.

Neurovascular examinations of all 52 patients were normal at the final follow-up. Limitations of flexion and extension that would restrict functional joint movement (30° to 130° flexion) were not observed in any of the patients (5 patients had 10° of flexion limitation and 1 patient had 5° of flexion limitation). Varus deformity between 10° and 20° was observed in 5 patients. Data from the evaluations at the final follow-up visit are shown in Table 5.

Younger patients (≤ 20 months) were more likely to have a varus deformity and a lower Flynn outcome score but there was no difference in variant HSS scores (min-max 75-100) (Table 6). Factors with statistically significant effects on the outcome scores are shown in Table 7.

Discussion

LOR was determined in 6 patients. These patients had worse outcome scores than the other patients, which underlines the importance of achieving and maintaining anatomic reduction in cases of pediatric SCHF. All x-rays outside the acceptable limits were considered as "Loss of Reduction", although some might have been "Poor reduction". Perioperative x-ray images were not available due to the retrospective nature of our study. To minimize confusion, patients with suspicion of poor reduction were not used as separate data for statistical analysis.

Of the total 52 patients, 5 (9.6%) had average varus malalignment of 14° at the final follow-up, and of those 5 patients with varus malalignment, 3 had medial pins while 2 had pin configurations with isolated lateral pins and bicolunar fixation. Bahk et al. reported a rate of 0.5% among all age groups, while other studies have obtained rates ranging from 3% to 57% [9, 16]. In a retrospective study, Striano et al. reported that children younger than 3 years of age had more varus malalignment [8]. Patients younger than 20 months in the current study cohort also had more varus malalignment than patients older than 20 months. It might be harder to achieve and maintain acceptable coronal plane

Table 2. General data of all patients.

Number	Demographic		Fracture definition		Pinning		Evaluation	
	Age (month)	Type (Gardland)	John Hopkins	Configuration	Bicolumnar fixation	Follow up (years)	Flynn score	Variant HSS score
1	19	2	High fractures	Multiple lateral	Yes	9	Excellent	Excellent
2	17	2	Typical	Multiple lateral	Yes	9	Excellent	Excellent
3	22	3	High fractures	Multiple lateral	No	9	Fair	Fair
4	6	3	High fractures	2 lateral + 1 medial	Yes	8	Excellent	Excellent
5	29	3	High fractures	2 lateral + 1 medial	Yes	8	Excellent	Excellent
6	23	3	Typical	multiple lateral	No	6	Excellent	Excellent
7	19	3	Typical	1 lateral + 1 medial	Yes	6	Excellent	Excellent
8	18	3	medial oblique	2 lateral + 1 medial	Yes	5	Excellent	Excellent
9	15	2	Typical	multiple lateral	Yes	6	Fair	Fair
10	25	2	Typical	1 lateral + 1 medial	Yes	5	Excellent	Excellent
11	29	3	High fractures	multiple lateral	Yes	5	Excellent	Excellent
12	18	2	Typical	1 lateral + 1 medial	Yes	5	Excellent	Excellent
13	13	3	Typical	multiple lateral	No	4	Excellent	Excellent
14	17	3	Typical	1 lateral + 1 medial	Yes	4	Excellent	Excellent
15	17	3	medial oblique	1 lateral + 1 medial	Yes	4	Excellent	Excellent
16	30	2	Typical	multiple lateral	Yes	3	Excellent	Excellent
17	24	2	Typical	2 lateral + 1 medial	Yes	3	Excellent	Excellent
18	29	3	Typical	2 lateral + 1 medial	Yes	2	Excellent	Excellent
19	24	2	Typical	1 lateral + 1 medial	Yes	2	Excellent	Excellent
20	16	3	Typical	multiple lateral	Yes	2	Fair	Fair
21	24	2	Typical	2 lateral + 1 medial	Yes	2	Excellent	Excellent
22	15	2	Typical	1 lateral + 1 medial	Yes	2	Excellent	Excellent
23	25	3	High fractures	multiple lateral	Yes	1	Excellent	Good
24	24	2	medial oblique	1 lateral + 1 medial	Yes	1	Excellent	Good
25	26	3	Typical	2 lateral + 1 medial	Yes	2	Excellent	Excellent
26	11	3	High fractures	2 lateral + 1 medial	Yes	2	Fair	Good
27	17	3	High fractures	multiple lateral	No	1	Excellent	Excellent
28	27	2	Typical	1 lateral + 1 medial	Yes	9	Excellent	Excellent
29	14	3	Typical	1 lateral + 1 medial	Yes	8	Excellent	Excellent
30	16	2	Typical	multiple lateral	Yes	9	Excellent	Excellent
31	28	2	Typical	multiple lateral	Yes	5	Excellent	Excellent
32	23	2	medial oblique	1 lateral + 1 medial	Yes	3	Excellent	Good
33	24	3	Typical	1 lateral + 1 medial	Yes	2	Excellent	Excellent
34	25	3	Typical	2 lateral + 1 medial	Yes	3	Excellent	Excellent
35	28	2	Typical	multiple lateral	No	8	excellent	Excellent
36	15	2	Typical	1 lateral + 1 medial	Yes	6	Fair	Fair
37	21	2	medial oblique	2 lateral + 1 medial	Yes	6	Excellent	Excellent
38	17	2	Typical	1 lateral + 1 medial	Yes	1	Excellent	Excellent
39	14	3	High fractures	multiple lateral	No	8	Excellent	Excellent
40	26	2	Typical	multiple lateral	Yes	7	Excellent	Excellent
41	27	3	Typical	2 lateral + 1 medial	Yes	1	Excellent	Excellent
42	21	2	Typical	1 lateral + 1 medial	Yes	5	Excellent	Excellent
43	17	2	lateral oblique	1 lateral + 1 medial	Yes	1	Excellent	Excellent
44	15	2	lateral oblique	1 lateral + 1 medial	Yes	1	Excellent	Excellent
45	16	2	medial oblique	2 lateral + 1 medial	Yes	1	Fair	Good
46	19	3	Typical	2 lateral + 1 medial	Yes	1	Excellent	Excellent
47	20	3	lateral oblique	2 lateral + 1 medial	Yes	1	Excellent	Excellent
48	22	2	Typical	2 lateral + 1 medial	Yes	1	Excellent	Excellent
49	21	3	High fractures	2 lateral + 1 medial	Yes	1	Excellent	Excellent
50	29	2	medial oblique	1 lateral + 1 medial	Yes	2	Excellent	Excellent
51	21	3	Typical	2 lateral + 1 medial	Yes	1	Excellent	Excellent
52	21	3	Typical	2 lateral + 1 medial	Yes	1	Excellent	Excellent

Table 1. Characteristics about fractures.

Sex	30 female %57,7		22 male %42,3	
Age	20,75 ± 5,4 (Mean ± Sd), 6–30 month (min–max)			
≤20→>20 months	≤20 24 patients (%46,2)		>20 28 patients (%53,8)	
Fractured side	24 right 46,2		28 left %53,8	
Compartment syndrome	None			
Neurovascular injury	AIN damage- 1 patient %1,9			
Gartland Classification	Type 2: n=26 (%50)		Type 3: n=26 (%50)	
Flexion- Extension type	Extension type n=48 %92,3		Flexion type n=4 %7,7	
John's Hopkins Classification	Typical n=32 (61,5%)	High fracture n=10 (19,2%)	Medial oblique n=7 (13,5%)	Lateral oblique n=3 (5,8%)
Trauma mechanism	Household falls n=41 (78,8%)	Fall from high level (≥3 m) n=6 (11,5%)	Fall from arms of an adult n=1 (1,9%)	Playground Injury n=4 (7,7%)

reduction in this young age group. Determining this malalignment might be also difficult on X-Rays, and because of the limited varus valgus remodeling of the distal humerus,

this malalignment may persist at the final follow-up examination. In contrast, there were no differences in functional results between patients younger and older than 20 months

of age. This highlights the need for additional studies to test factors for adaptation beyond remodeling after fractures in pediatric patients.

With a mean follow-up period of 4 years, 46 patients had excellent Flynn outcome scores and 43 patients had excellent variant HSS scores. To the best of our knowledge, no other studies have investigated functional results of

Table 3. Surgical data about fractures.

Reduction	Open n = 4 (7,7%)	Closed n = 48 (92,3%)	
Pin configuration	Isolated lateral n = 16 (30,8%)	1 medial+ 1 lateral n = 18 (34,6%)	Medial + multiple lateral n = 18 (34,6%)
Bicolumnar fixation	(+) n = 46 (88,5%)	(-) n = 6 (11,5%)	
Postoperative immobilization	Long arm cast n = 29 (55,8%)	Long arm posterior slab splint n = 23 (44,2%)	
Revision	(+) 2 (%3,8)	(-) 50 (%96,2)	
Pin remove	30 day (25–33) Median (Min–Max)		

Table 4. Data about patients with high energy fractures.

	Limb fracture	Craniovertebral fracture	Other pathologies	Waiting time before surgery (days)	HSS	Outcome score
Patient 3	Pelvis fracture	Cranial fracture	Subarachnoid hemorrhage	10	Fair	Fair
Patient 5	None	None	Liver laceration	2	Excellent	Excellent
Patient 13	Distal radius + Tibial fracture	Cranial fracture	Liver laceration	1	Excellent	Excellent
Patient 25	None	None	Subarachnoid hemorrhage	0	Excellent	Excellent
Patient 36	Femoral shaft fracture	None	None	2	Fair	Fair
Patient 39	Distal radius + proximal humeral fracture	Cervical vertebra fracture	Liver laceration	13	Excellent	Excellent

SCHF in this age group. A recent study reported by Mehlman et al., evaluated early radiological results in infants younger than 2 years of age [7], and although the patient group was larger than that of the current study, the midterm functional results are also reported in this study. Several other studies have considered the functional outcomes of SCHF in all age groups. For example, Ernat et al. reported overall excellent results and low rates of disability, concluding that the amount and direction of displacement had no effect on outcomes, parallel to the current study

Table 5. Final follow-up data of patients.

	Excellent	Good	Fair	Poor	Mean Score
Flynn outcome score	46 (88,5 %)	N/A	6 (11,5%)	0	N/A
Variant HSS	43 (82,7%)	5 (9,6%)	4 (7,7%)	0	94,3
Varus malalignment	+ 5 (%9,6)		-47 (%90,4)		
Limitation	+ 6 (%11,5)		-46 (%88,5)		
Follow-up time	4 year (2-7)		Median(Min-max)		

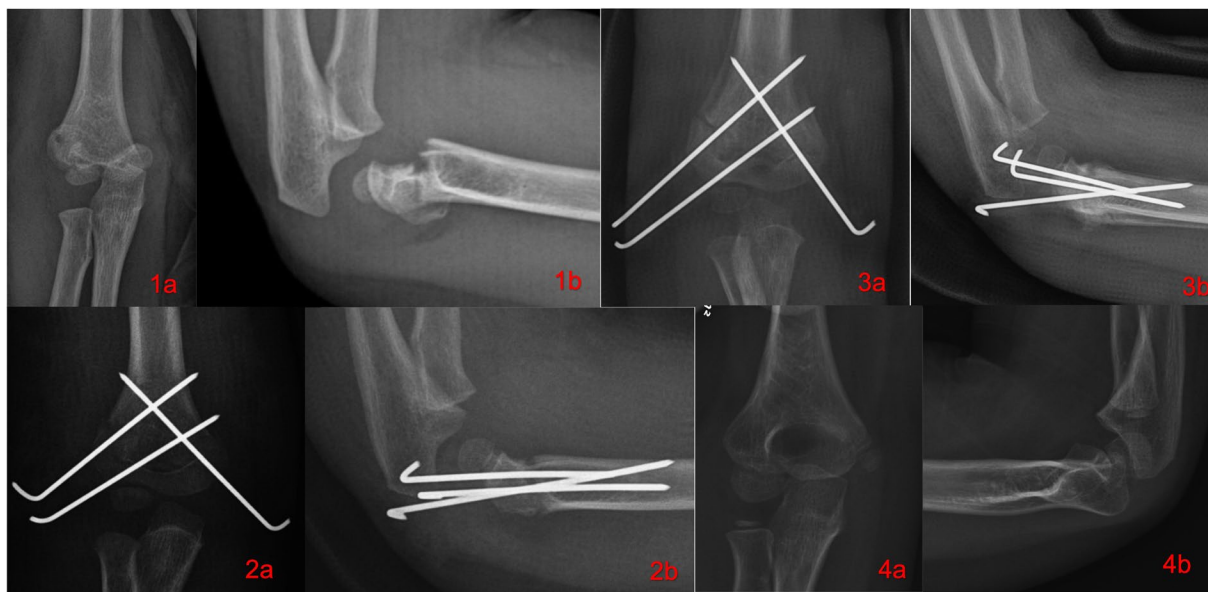


Figure 5. Supracondylar humerus fracture in a 25-month-old female patient, as a result of a fall from a chair.1a/b: Preoperative X-ray (Typical pattern Gartland tip 3 fracture)2a/b: Early postoperative X-ray (Treated with 2 lateral, 1 medial pin)3a/b: Before pin removal X-ray (32 days after surgery)4a/b: 3-year follow-up X-ray (Full range of motion)

findings [17]. Isa et al. reported good results for 94 patients with 3 to 5 years of follow-up, but there were only 3 patients younger than 30 months in that study [18].

There was no statistically significant difference in the context of functional results between patients with different pin configurations in the current study. Although there is debate about the “best” pin configuration, some clinical and biomechanical studies support these findings [19, 20]. In a retrospective study, supporting the current study data, Striano et al. reported that toddlers were more likely to be treated with a medial pin [8], in contrast to Mehlman et al., who used only isolated lateral pin fixation for their patients [7]. Mehlman et al. did not achieve bicolumnar fixation in 45 of 101 cases. This rate was 4 in 16 of the current study

patients in the isolated lateral fixation group and 4 in 52 overall. As previously stated, the current study data are contrary to the tendency of not using a medial pin to avoid ulnar nerve damage, but this resulted in more bicolumnar fixation and normal ulnar nerve examinations in the final follow-up visits. Flexion-type fractures had worse variant HSS scores (p=0.009) than extension-type fractures in the current cohort, parallel to previously published studies concluding that this type of fracture is more challenging [21]. However, the statistically significant results obtained in this study are not powerful enough to draw a precise conclusion, although this is mainly due to the relatively small cohort.

The female-to-male ratio was 3:2 in this age group in this study, in contrast to the ratios generally seen for SCHF among all age groups. When all age groups are examined, SCHF is 2 times more common in males. LiBrizzi et al. reported that girls sustained SCHF at younger ages than boys [22]. This ratio was also consistent with that previously reported by Mehlman et al. and Farnsworth et al. [7, 23].

Household trauma was the primary injury mechanism, seen in 41 of the current cases. This finding was similar to the data reported by Mehlman et al. and Striano et al. [7, 8]. There was only 1 patient who had fallen from a caregiver’s arms, in contrast to the study by Chaudhary et al. [6] Again in contrast to those previous findings, there were no cases of child abuse caused by non-accidental trauma in the current cohort of 52 patients. However, our institution’s pediatric emergency department has a strict algorithm for investigating that issue and identified several cases of non-accidental trauma for different fractures in the same period. As there were many falls from household items (table, chair vs) and one fall from the arms of an adult in this patient group, this could indicate abuse by neglect [24].

In the current cohort, the injuries of 6 patients were the result of a high-energy fall. In this patient group, there were some delays in surgical fracture treatment because of additional injuries and surgeries (cervical fracture, intracranial hemorrhage, or solid organ damage). According to the Johns Hopkins classification, there was a remarkable number of high fracture patterns in this group of injuries. Due to all of these factors, the number of LOR was higher in this group. High fracture patterns might result in more LOR because of the narrower fracture contact surface [25]. With further comparative studies of larger groups of patients it might be possible to show different characteristics and results among such patients.

Lower variant HSS scores were obtained for patients with associated injuries (p=0.009), although 1 patient, who

Table 6. Data about information >20months and <20months.

		Age		P value
		≤20 months	>20 months	
Sex	Female	15	15	p=0,516 ¹
	Male	9	13	
Trauma mechanism	Household falls	19	22	NA
	Fall from high level	3	3	
	Fall from arms of an adult	1	0	
	Playground Injury	1	3	
Fractured side	Right	10	14	p=0,548 ¹
	Left	14	14	
Associated injuries	Yes	3	1	p=324 ²
	No	21	27	
Flexion-extension type	Flexion	2	2	p=1,000 ²
	Extension	22	26	
Gartland	2	11	15	p=0,578 ¹
	3	13	13	
	Open	2	2	
Operation	Close	22	26	p=1,000 ²
	Isolated lateral	8	8	
Pin configuration	1 Medial + 1 lateral	6	12	P=382 ¹
	1 Medial+ multipl lateral	10	8	
	Bicolumnar fixation	21	25	
Revision	Yes	3	3	p=1,000 ²
	No	0	2	
Immobilization	Yes	24	26	p=493 ²
	No	10	19	
Reduction	Cast	14	9	p=0,058 ¹
	Splint	18	26	
Varus-Valgus malalignment	Normal	6	2	p=0,123 ²
	Loss or Unacceptable	5	0	
Limitation	Yes	19	28	p=0,016²
	No	3	3	
Flynn	Yes	21	25	p=1,000 ²
	No	19	27	
Variant Hss	Excellent	5	1	P=0,084 ²
	Fair	19	24	
	Exellent	5	4	
	Good-Fair	19	24	p=716 ²
		5	4	

¹Pearson chi square test.

²Fisher exact test.

Table 7. Factors affecting outcome scores.

		Variant HSS				Flynn outcome score		
		Excellent	Good-Fair	P value		Excellent	Fair	P value
Limitation	No	42	4	P<0.001 ¹	No	43	3	p=0.016 ¹
	Yes	1	5		Yes	3	3	
Varus malalignment	No	43	4	P<0.001 ¹	No	46	1	p<0.001 ¹
	Yes	0	5		Yes	0	5	
Reduction	Normal	39	5	P=0.023 ¹	Normal	42	2	p=0.003 ¹
	Loss or unacceptable	4	4		Loss or unacceptable	4	4	

Immobilization method, Revision, Operation, Gartland, Flexion-Extension type, Fracture side, Age (>20 months or <20 months), Pin configuration; all p>0,05.

¹=Fisher exact test.

underwent surgery on the 13th day after injury, had excellent results. The number of such patients with associated injuries in this study is obviously not sufficient for proper statistical conclusions.

Despite using medial pins, no postoperative iatrogenic ulnar nerve damage was encountered. Ulnar nerve damage is a reported complication of medial pin fixation, and in a review by Slobogean et al., the overall risk of ulnar nerve damage was reported to be 1:28. Interestingly, this complication rate was zero in the current study cohort [26]. The operations were performed by 6 different surgeons and the utmost care was taken to avoid this particular complication. Some damage may have been overlooked because of the difficulties in conducting proper postoperative neurovascular examinations for infants, even in early postoperative follow-up visits. Nevertheless, on neurovascular examinations with better patient compliance, all 52 patients were reported to have normal results. This suggests that even if any minor ulnar nerve damage had been present postoperatively, it resolved in the follow-up period, parallel to the findings reported by Kalenderer et al. [27].

Previously published studies about functional results in cases of SCHF in all age groups have primarily used two different outcome scores. The scoring system used alongside the Flynn outcome score is usually the QuickDASH score or the Mayo score [17, 28, 29]. The current study used the variant HSS score, which is less complicated and easier to use with the help of parents of young patients who have problems answering questions in the QuickDASH score. Some differences were expected between the two scores, as the Flynn score is an outcome scoring system mostly based on radiological findings and range of motion, while the variant HSS system is a more functionally based scoring system, which also assigns cases to 4 groups (excellent, good, fair, poor) based on the points obtained from the survey. It can be considered that such differences do not suggest that one of these systems is better than the other for this group of patients and the functional status of these patients during adolescence or adulthood cannot be predicted with the current data. Such questions could be explored with a longer follow-up period (maybe 15 years or more) and a larger patient group, particularly with patients who have different scores with both scoring systems. While Morrey defined functional elbow range of motion as between 30° to 130° flexion, the Flynn scoring system classifies patients with >15° flexion loss as “poor. This difference could be also controversial in respect of the Flynn scoring system.

The current study evaluations used the Baumann angle and lateral translation on anteroposterior view, the anterior humeral line crossing the capitellum, and the Gordon rotation percentage on lateral view X-Rays [30]. These measurements were made with radiographs from the early postoperative period, but Gordon rotation percentage measurements could not be performed again in follow-up after pin removal because of callus formation, especially in patients with higher percentages. Although numerous studies have used this parameter, it was not possible to make consistent measurements for the reason noted here and therefore this variable was removed from the statistical analysis.

The main limitation of this study was the retrospective design, which prevented the acquisition of data such as the contralateral Baumann angle. The difficulties of making radiological measurements on relatively small children with immature bones was another limitation. There was also no data about the dominant hand, because ambidexterity is normal during the first 18 to 24 months of life [31]. The relatively small numbers of patients in some subgroups prevented the drawing of more detailed conclusions from the results. There is a need for further studies to compare different age groups, fracture types and fracture mechanism with larger series to be able to provide more precise results for this fracture.

Conclusion

The results of this study demonstrated that radiological LOR and clinical outcome were correlated. A younger age does not mean more remodeling. While the functional results obtained were similar to those presented in past studies that included older patients, there are some important points to be highlighted from this study, despite its limitations. Using a medial pin to achieve and protect stability in this young age group does not increase the risk of iatrogenic ulnar nerve damage. Patients with flexion-type fractures and those who underwent additional surgeries due to other injuries had worse outcomes. Younger patients tended to have more varus malalignment but similar functional results. High-energy fractures have different characteristics, and further studies of this kind of trauma are still needed.

Ethical review committee statement

This study was approved by the institutional ethics committee (Marmara University Medical School, Ethic Committee for Clinical Research: 13/07/2020-58).

Contributions

Concept-A.H.A.; Design-A.H.A., B.E.; Materials-Ö.B., Y.Ş.; Data Collection and/or Processing-A.H.A., H.K.; Analysis and/or Interpretation- A.H.A., Ö.B., B.E., Y.Ş.; Literature Review-A.H.A., Y.Ş., Writing and Original Draft- A.H.A., Y.Ş.

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