ORIGINAL ARTICLE

Does the fracture line position relative to the olecranon fossa affect surgical difficulty and outcomes in pediatric supracondylar humerus fractures?

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ABSTRACT

BACKGROUND: This study aimed to investigate whether the level of the fracture line relative to the olecranon fossa influences surgical difficulty, complication rates, and radiological outcomes in pediatric supracondylar humerus fractures (PHSF).

METHODS: A retrospective review was conducted of 822 children who underwent surgical treatment for PHSF. Patients were categorized according to the location of the fracture line relative to the apex of the olecranon fossa: high-level (proximal to the fossa, n=163) and low-level (at or distal to the fossa, n=659). High-level fractures were further classified as oblique (n=40) or transverse (n=123), based on the angle between the fracture line and the transepicondylar line. Patient demographics, fracture characteristics, surgical parameters, complications, radiographic findings, and revision rates were analyzed.

RESULTS: There were no significant differences between groups in terms of patient demographics, fracture side, open versus closed fracture status, neurovascular injury, or associated trauma ($p>0.1$). High-level fractures were significantly more unstable, required longer surgical durations, and showed a greater number of K-wire cortical scars compared to low-level fractures ($p<0.05$). K-wire configuration, number, and diameter showed no significant differences. Subgroup analysis demonstrated that oblique high-level fractures more often required divergent pin configurations and had significantly higher revision rates compared with transverse high-level fractures ($p=0.049$ and $p=0.004$, respectively).

CONCLUSION: Fractures located proximal to the olecranon fossa are more unstable and technically demanding, resulting in longer operation times and more intraoperative pinning attempts. Among high-level fractures, oblique types are especially prone to technical challenges and increased revision rates, highlighting the importance of fracture morphology in surgical planning.

Keywords: Humerus fracture; elbow fracture; pediatric supracondylar humerus fracture.

INTRODUCTION

Supracondylar humerus fractures are the most common type of elbow fracture in the pediatric population, typically occurring between the ages of 5 and 7 years and usually resulting from a fall on an outstretched hand.[1] The vast majority (95–98%) are extension-type fractures, whereas flexion-type injuries are relatively uncommon.[1] The modified Gartland classification, consisting of four subtypes, is widely used for diagnostic categorization.[2] Type I fractures are nondisplaced and managed conservatively, while displaced fractures (Types II–IV) generally require surgical intervention.[3]

As the trend toward operative management of displaced fractures has increased, new clinical questions have emerged. There is ongoing debate regarding the optimal reduction method (open vs. closed), K-wire configuration, and the man-

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agement of associated neurovascular injuries.[4,5]

Some previous studies have examined the potential influence of fracture line level on clinical and radiographic outcomes in pediatric supracondylar humerus fracture (PHSF). Fayssoux et al.[6] proposed the concept of high-level fractures involving the metaphyseal-diaphyseal junction. However, their analysis included only 14 such cases, suggesting a need for further exploration. Kang et al.[7] emphasized the prognostic significance of fracture morphology, reporting that in Gartland type III fractures, a fracture line distal to the humeral isthmus correlated with poorer functional and radiological results.

The present study aims to assess whether the location of the fracture line relative to the olecranon fossa impacts surgical difficulty, complication rates, and radioclinical outcomes. By evaluating this anatomical landmark, we hope to contribute meaningful insights into the surgical planning and management of pediatric supracondylar humerus fractures.

MATERIALS AND METHODS

This retrospective study was conducted following approval from the local ethics committee (Institutional Review Board of S.B.U. İzmir Tepecik Research and Training Hospital, Date: 22/02/2021, Decision No: 2021/02-18) and in accordance with the Declaration of Helsinki. Patient data were retrieved using the Probel Hospital Automation System (Probel Software and Information Systems Inc., Izmir, Türkiye). All patients included in the study were operated on between January 2013 and December 2020 at a tertiary care center by different orthopedic surgeons.

Figure 1. Fracture line in relation to the apex of the olecranon fossa.

Figure 2. High-level supracondylar humerus fracture.

Inclusion Criteria:

1. Age between 1 and 13 years

2. Surgically treated supracondylar humerus fracture

3. Availability of adequate preoperative and postoperative elbow radiographs

4. Minimum follow-up until radiological bone union.

Exclusion Criteria:

1. Lateral condyle fractures coded as distal humerus fractures

2. Medial epicondyle fractures coded as distal humerus fractures

3. Miscoded fractures not involving the distal humerus.

Out of 874 screened patients, 52 were excluded (42 with lateral condyle fractures, seven with medial epicondyle fractures, and three with unrelated fracture codes). A total of 822 patients with PHSF (94% of the initial cohort) were included.

The olecranon fossa is a depression located on the posterior cortex of the distal humerus, directly proximal to the trochlea, and is the largest of the three fossae found on the humerus.[8]

Patients were categorized according to the location of the fracture line relative to the apex of the olecranon fossa (Fig. 1). Fractures proximal to the fossa were classified as high-level (n=163) (Fig. 2), while those at or distal to the fossa were classified as low-level (n=659) (Fig. 3).

The transepicondylar line was created by connecting the most extreme points of the medial and lateral epicondyles (Fig. 4). The high-level group was further subdivided based on the angle between the fracture line and the transepicondylar line into:

Figure 3. Low-level supracondylar humerus fracture.

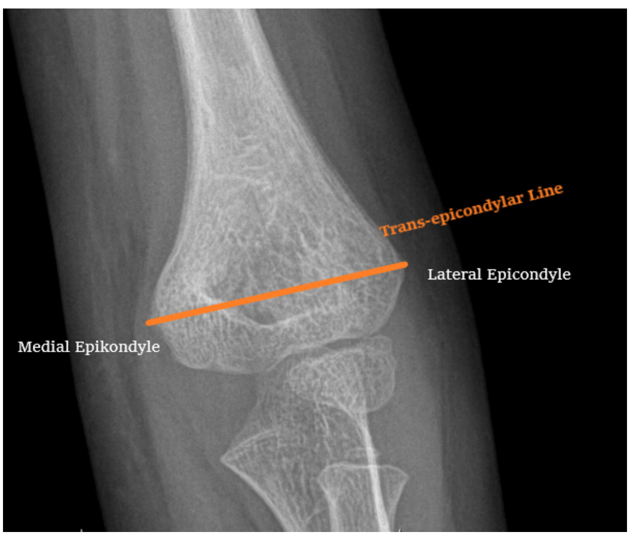

Figure 4. Transepicondylar line.

• Oblique fractures: angle >30° (n=40) (Fig. 5)

• Transverse fractures: angle ≤30° or parallel orientation (n=123) (Fig. 6).

Radiological assessments and data collection were conducted using PACS (Picture Archiving and Communication System) and the Probel database. Radiographic measurements were performed by the senior author, a pediatric orthopedic surgeon with over 15 years of experience.

Collected parameters included demographic data, fracture side, duration of surgery, method of reduction (open or

Figure 5. High-level oblique-type supracondylar humerus fracture.

Figure 6. High-level transverse-type supracondylar humerus fracture.

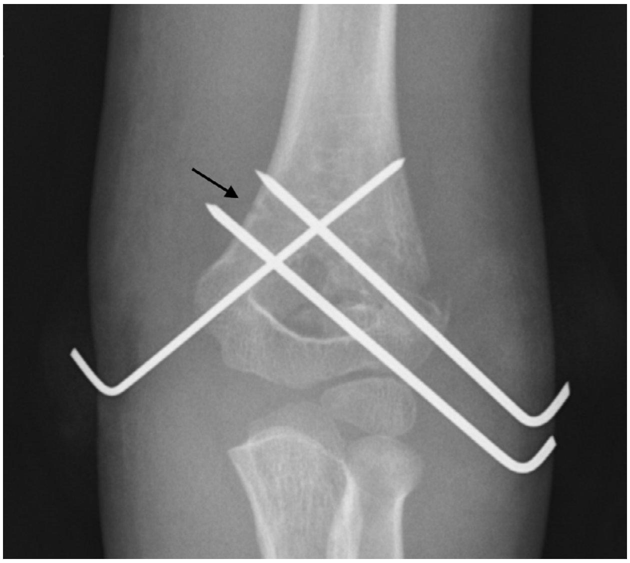

Figure 7. K-wire cortical scars.

closed), fracture type (open or closed), presence of vascular and nerve injury, systemic trauma, complications, and the requirement for revision surgery.

Radiographic analysis included fracture type (modified Gartland classification),[9] location relative to the olecranon fossa, sagittal displacement, number and diameter of K-wires, wire configuration, number of cortical scars (indicative of repeated pinning attempts) (Fig. 7), postoperative translation and rotation, anterior humeral line alignment on immediate and final radiographs, and follow-up duration.

Statistical Analysis

All statistical analyses were performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables were compared using the independent samples t-test or analysis of variance (ANOVA), while non-normally distributed variables were compared using the Mann-Whitney U test or Kruskal-Wallis test. Chi-square or Fisher's exact tests were applied for categorical variables, depending on expected frequencies. A p-value less than 0.05 was considered statistically significant.

RESULTS

The mean age of all patients was 6.5±3 years (range, 1–13). In the low-level fracture group (n=659), the mean age was 6.5±3 years, while in the high-level group (n=163), it was 6.7±2.9 years (p=0.618). Males comprised 62% (411/659) of the low-level group and 64% (105/163) of the high-level group (p=0.348). Right-side fractures accounted for 38% (248/659) in the low-level group and 34% (55/163) in the high-level group (p=0.570) (Table 1). Of the 822 fractures, 802 (98%) were closed. Fourteen of the 20 open fractures (70%) were low-level (p=0.118). Vascular compromise was present in 49 patients (6%), with 16 showing filiform pulses, 29 having no pulse but good capillary refill, and four requiring vascular repair (p=0.102). Nerve injuries were observed in 79 patients (10%), including anterior interosseous nerve (AIN) injury in 39, ulnar nerve injury in 18, posterior interosseous nerve (PIN) injury in 11, combined ulnar and AIN injuries in six, combined ulnar and PIN injuries in four, and both AIN and PIN injuries in one (p=0.141). Additional trauma was seen in 34 patients (4%), including fractures in other regions or head trauma (p=0.221) (Table 2). Modified Gartland fracture types included 7 type 1b, 177 type 2, 441 type 3, 143 type 4, and 54 flexion-type fractures. Unstable fractures were significantly more common in the high-level group (p<0.001). Among extension-type fractures (n=768), posteromedial displacement occurred in 402 patients (49%) and posterolateral displacement in 366 patients (44%) (p=0.164) (Table 2). Mean surgery duration was 52.6±30.6 minutes for low-level fractures and 58.9±30.1 minutes for high-level fractures (p=0.006). The average number of K-wires used was similar between groups (2.7±0.6 for low-level and 2.69±0.6 for high-level; p=0.478), as was the average wire diameter (1.8±0.11 mm vs. 1.8±0.13 mm; p=0.997). High-level fractures had a significantly higher mean number of K-wire cortical scars (p=0.042). K-wire configuration showed no significant difference: cross-wire was used in 77%, divergent in 21%, and parallel in 2% of cases (p=0.58). Open reduction was required in 4% of patients, with no significant difference between groups (p=0.114) (Table 3). Postoperative translation occurred in 157 patients (120 low-level, 37 high-level; p=0.942). Rotational deformity was observed in 246 patients (193 low-level, 53 high-level;

Table 1. Demographic data of the patients

	Below Olecranon Fossa	Above Olecranon Fossa	p-value
Age mean±SD (min-max)	6.5±3	6.7±2.9	0.618
	(1-13)	(1-12)	
Gender (male/female)	411/248	105/58	0.348
Side (right/left)	248/411	55/108	0.570
n	659	163	

SD: Standard deviation.

Table 2. Comparison of preoperative data

	Below Olecranon Fossa	Above Olecranon Fossa	p-value
Open fracture	14	6	0.188
Vascular injury	33	16	0.102
Nerve injury	55	24	0.141
Additional trauma (fracture/head trauma/fracture+head trauma)	17/4/3	9/1/0	0.221
Fracture type (1b/2/3/4/flexion)	7/164/354/91/43	0/13/87/52/11	**<0.001**
Sagittal plane displacement direction (posteromedial/posterolateral)	316/299	86/67	0.164
N	659	163	

Table 3. Comparison of intraoperative data

	Below Olecranon Fossa	Above Olecranon Fossa	p-value
Open Surgery	23	8	0.114
Wire configuration (crossed/divergent/parallel)	505/138/16	129/32/2	0.58
Operation time (minutes) mean±SD (min-max)	52.6±30.6 (10-458)	58.9±30.1 (15-210)	**0.006**
Number of Kirschner wires mean±SD (min-max)	2.7±0.6 (1-5)	2.69±0.6 (2-5)	0.478
Number of wire scars	1±1.4 (0-6)	1.2±1.6 (0-6)	0.042
Wire thickness (mm) mean±SD (min-max)	1.8±0.11 (1.5-2)	1.8±0.13 (1-2)	0.997
N	659	163	

SD: Standard deviation.

Table 4. Comparison of postoperative data

	Below Olecranon Fossa	Above Olecranon Fossa	p-value
Complication	16	7	0.621
Revision surgery	22	6	0.492
Follow-up (months)			
mean±SD (min-max)	5±9.3 (1-72)	5.7±9.4 (1-65)	0.276
Translation	120	37	0.942
Rotation	193	53	0.229
Anterior humeral line (anterior/anterior 1/3/mid 1/3/posterior 1/3/posterior)	40/157/326/102/34	17/29/77/32/8	0.121
N	659	163	

SD: Standard deviation; ant: Anterior; post: Posterior.

Table 5. Comparison of peroperative data of high-level fractures

	Transverse Fracture	Oblique Fracture	p-value
Fracture type (1b/2/3/4/flexion)	13/60/43/7/0	0/27/9/4/0	0.037
Open surgery	4	4	0.064
Wire configuration			
(crossed/divergent/parallel)	102/19/2	27/13/0	0.049
Operation time (minutes)			
mean±SD (min-max)	57.9±28	61.8±35.9	0.746
	(20-180)	(15-210)	
Number of Kirschner wires			
mean±SD (min-max)	2.7±0.6	2.7±0.6	0.899
	(2-5)	(2-4)	
Number of wire scars	1.2±1.5	1.3±1.8	0.946
	(0-6)	(0-6)	
Wire thickness (mm) mean±SD (min-max)	1.8±0.1	1.8±0.1	0.688
	(1-2)	(1.5-2)	
Complication	6	1	0.878
Revision surgery	1	5	0.004
Translation	30	7	0.419
Rotation	38	15	0.278
Anterior humeral line			
(anterior/mid/posterior)	33/60/30	13/17/10	0.706
n	123	40	

SD: Standard deviation.

p=0.229). Analysis of the anterior humeral line relative to the capitellum on early postoperative radiographs showed no significant differences between groups (p=0.121). Complications occurred in 23 patients (3%), including K-wire migration, pin tract infections, loss of reduction, refracture, and iatrogenic nerve injury, with no significant difference between groups (p=0.621). Revision surgery was needed in 28 patients (3%), similarly distributed between groups (p=0.492). Mean follow-up duration was comparable (5±9.3 months for low-level and 5.7±9.4 months for high-level; p=0.276) (Table 4). Within the high-level fracture group, oblique fractures (n=40) had a higher incidence of unstable (modified Gartland) types than transverse fractures (n=123) (p=0.037). Surgery duration, number of K-wires, and wire diameter did not differ significantly between these subgroups. However, oblique fractures more frequently required divergent pin configurations (p=0.049) and had a significantly higher revision rate (p=0.004). There were no significant differences in postoperative translation, rotation, need for open reduction, or complication rates between oblique and transverse fractures (Table 5).

DISCUSSION

Most pediatric fractures can be treated conservatively; however, displaced pediatric humeral supracondylar fractures typically require surgical fixation. Among pediatric fractures, supracondylar humerus fractures are the most frequently operated on, due to the distal humerus contributing approximately 20% to longitudinal growth.[10,11] Moreover, since the elbow's flexion-extension axis lies in the sagittal plane, coronal plane deformities cannot be reliably corrected through remodeling.[12,13]

The preferred fixation technique involves the placement of divergent or crossed K-wires after achieving adequate reduction, whether open or closed.[14] Many studies have focused on the relationship between wire configuration and fixation stability in PHSF.[15] High-level fractures, located proximal to the olecranon fossa, pose challenges due to limited proximal bone stock for fixation.[16] Our study found that operation times were significantly longer in high-level fractures compared to low-level fractures (p=0.006), supporting this difficulty. Additionally, these high-level fractures were more frequently unstable based on the modified Gartland classification (p<0.001). The greater number of K-wire-induced cortical scars in high-level fractures (p=0.042) further reflects the technical challenges during fixation.

Previous literature reports the incidence of high-level PHSF (also termed distal humerus metaphyseal-diaphyseal fractures) as approximately 3.3% of all PHSF.[17,18] In contrast, our study observed a higher rate of 19.8%, likely due to inclusion criteria limited to surgically treated unstable fractures.

The narrow cross-sectional area in the metaphyseal-diaphyseal region complicates fracture reduction and fixation, increasing the risk of loss of reduction postoperatively.[19-21] Additionally, the periosteum is thinner in this region, making closed reduction more difficult and often necessitating open reduction.[19] These factors collectively contribute to prolonged surgery duration for high-level fractures, as confirmed in our study and by Fayssoux et al.[6]

Although open reduction was slightly more frequent in high-level fractures (4.9% vs. 3.5%), this difference was not statistically significant (p=0.114), possibly reflecting the surgeons' expertise. Achieving stable fixation in high-level fractures is challenging because K-wires often remain within the medullary canal rather than engaging the far cortex, reducing stability.[6,22] Additionally, the required spacing of wires at the fracture site, typically one-third of the fracture length or at least 13 mm, is difficult to maintain in high-level fractures.[6] Despite these technical challenges, the revision surgery rate and postoperative translation did not differ significantly between groups (p=0.492 and p=0.942, respectively), suggesting that with careful technique, outcomes can be comparable.

High-level fractures can be further categorized as transverse or oblique. In our cohort, 75% were transverse and 25% oblique, differing from Fayssoux et al.'s.[6] study, in which oblique fractures predominated (57%). Age distribution was similar to the known peak incidence of PHSF (5-8 years),[23] although our study showed oblique fractures presenting at a slightly higher mean age than transverse fractures (7.1 vs. 6.5 years). Operation times did not differ significantly between fracture types (p=0.746), but the need for divergent K-wire configuration was higher in oblique fractures (p=0.049). Furthermore, oblique fractures had a significantly higher revision rate (p=0.004), highlighting their increased technical complexity.

Hai Zou et al.[19] suggested that intramedullary K-wire insertion after coronal plane reduction facilitates rotational and sagittal alignment in metaphyseal-diaphyseal fractures; however, we did not utilize this technique. Postoperative rotational deformities were more common in high-level fractures, but without statistical significance (p=0.229).

Neurovascular injury rates did not differ significantly between fracture levels, although anterior interosseous nerve and ulnar nerve injuries tended to be slightly more frequent in high-level fractures (4.4% and 6.1%, respectively). The lack of significant difference in associated injuries suggests that high-level fractures do not necessarily result from higher-energy trauma.

Intraoperative multiple K-wire insertion attempts may increase cortical damage, seen radiographically as wire-induced scars. Our finding of significantly more K-wire scars in high-level fractures (p=0.042) underscores the technical difficulties encountered during fixation.

Limitations of this study include its retrospective design and the fact that surgeries were performed by multiple surgeons, which could introduce variability. However, the large sample size strengthens the validity of our findings.

CONCLUSION

This study demonstrates that pediatric supracondylar humerus fractures with a fracture line proximal to the olecranon fossa present greater surgical challenges, including increased instability, longer operative times, and a higher number of intraoperative pinning attempts. Among these, oblique high-level fractures are especially prone to technical challenges and exhibit significantly higher revision rates compared to transverse fractures.

Clinically, recognizing the fracture line's position relative to the olecranon fossa can aid surgeons in preoperative planning and patient counseling by anticipating potential difficulties and the need for more meticulous fixation strategies. This anatomical landmark should be integrated into the assessment protocol for pediatric supracondylar fractures to optimize surgical outcomes.

Our findings extend the existing literature by quantitatively establishing the olecranon fossa as a practical and relevant threshold for predicting surgical complexity and prognosis in these fractures. This contributes valuable insights that may influence decision-making and improve management strategies for pediatric supracondylar humerus fractures.

Ethics Committee Approval: This study was approved by the S.B.U. İzmir Tepecik Research and Training Hospital Ethics Committee (Date: 22.02.2021, Decision No: 2021/02-18).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Pediatrik suprakondiler humerus kırıklarında kırık hattının olekranon fossaya göre pozisyonu cerrahi zorluğu ve sonuçları etkiler mi?

AMAÇ: Bu çalışmanın amacı, pediatrik suprakondiler humerus kırıklarında (PSHK) kırık hattının olekranon fossaya göre seviyesinin, cerrahi zorluk, komplikasyon oranları ve radyolojik sonuçlar üzerindeki etkisinin araştırılmasıdır.
GEREÇ VE YÖNTEM: PSHK tanısıyla cerrahi tedavi uygulanmış 822 olgu retrospektif olarak incelendi. Kırık hattının olekranon fossa apeksine konumuna göre hastalar iki gruba ayrıldı: Yüksek seviye (fossanın proksimalinde, n=163) ve düşük seviye (fossada veya distalinde, n=659). Yüksek seviye kırıklar, kırık hattı ile trans-epikondiler çizgi arasındaki açıya göre oblik (n=40) ve transvers (n=123) olarak sınıflandırıldı. Demografik veriler, kırık özellikleri, cerrahi parametreler, komplikasyonlar, radyografik bulgular ve revizyon oranları değerlendirildi.
BULGULAR: Gruplar arasında demografik özellikler, kırık tarafı, açık-kapalı kırık durumu, nörovasküler yaralanma veya eşlik eden travma açısından anlamlı fark saptanmadı ($p>0.1$). Yüksek seviye kırıklar, düşük seviye kırıklara kıyasla anlamlı derecede daha instabildi, daha uzun cerrahi süreye sahipti ve daha fazla K-teli kortikal izi sergiledi ($p<0.05$). K-teli konfigürasyonu, sayısı ve çapı açısından anlamlı fark bulunmadı. Alt grup analizinde, oblik yüksek seviye kırıkların diverjan pin konfigürasyonuna daha sık ihtiyaç duyduğu ve transvers yüksek seviye kırıklara göre anlamlı derecede daha yüksek revizyon oranına sahip olduğu görüldü (sırasıyla, $p=0.049$ ve $p=0.004$).
SONUÇ: Olekranon fossanın proksimalinde yer alan kırıklar, daha instabil olup teknik olarak daha zorludur; bu durum daha uzun ameliyat süresi ve daha fazla intraoperatif pinleme girişimine yol açmaktadır. Yüksek seviye kırıklar arasında oblik tipler, teknik güçlükler ve artmış revizyon oranı açısından özellikle risklidir. Bu bulgular, cerrahi planlamada fraktür morfolojisinin önemini vurgulamaktadır.

Anahtar sözcükler: Dirsek kırığı; humerus kırığı; pediatrik suprakondiler humerus kırığı.

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