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Does the configuration of the K-Wires in the coronal plane affect the time to union in supracondylar humerus fractures?

Suprakondiler humerus kırıklarında K-Tellerinin koronal düzlemdeki konfigürasyonu kaynama süresini etkiler mi?

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ABSTRACT

Aim: Supracondylar humerus fractures (SHF) are among the most common bone fractures in the pediatric population. However, there is no consensus in the literature regarding the configuration of the K wires used in this method.

Materials and Methods: Patients who underwent closed reduction using two lateral and one medial percutaneous pins for SHF were included in the study. Measurements were made on the antero-posterior elbow radiographs of the patients taken on post-operative day 0. These measurements involved the angles of each K-wire with one another, the angles of the K-wires with the fracture line, and the angles between the K-wires and the humeral shaft. Postoperative complications, splint removal and pin removal times of all patients were recorded.

Results: A total of 167 patients were included in the study. Uneventful fracture healing was achieved in all remaining patients. No significant relationship or correlation was found between the above-mentioned angular parameters and fracture union time. However, the angle between the pins placed laterally, the angle between the medial pin, and lateral pin 2, and the angle between lateral pin 2 and the humeral shaft were found to be larger in patients with complications than in patients without complications (p=0.0001, p=0.017, p=0.0001).

Conclusion: The quality of fracture reduction is the basis for postoperative functional recovery. The results of this study that the main parameter affecting union in SHF is not the configuration of the pins in the coronal plane, but the anatomical fracture reduction and stable fixation obtained.

Keywords: Supracondylar humeral fracture, children, K-wire, coronal plane.

ÖZ

Amaç: *Suprakondiler humerus kırıkları (SHK), pediatrik popülasyonda en sık görülen kemik kırıkları arasındadır. Ancak bu yöntemde kullanılan K tellerinin konfigürasyonu konusunda literatürde fikir birliği yoktur.*

Gereç ve Yöntem: *SHK tanısıyla kapalı redüksiyon ile iki lateral ve bir medial perkütan pin fiksasyonu uygulanan hastalar çalışmaya dahil edildi. Hastaların ameliyat sonrası 0. günde çekilen ön-arka dirsek grafilerinde ölçümler yapıldı. Her bir K telinin birbiriyle olan açıları, K tellerinin kırık hattı ile olan açıları ve K tellerinin humerus şaftı ile olan açıları ayrı ayrı ölçüldü. Tüm hastaların ameliyat sonrası komplikasyonları, splint çıkarma ve pin çıkarma süreleri kaydedildi.*

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Bulgular: *Çalışmaya toplam 167 hasta dahil edildi. Tüm hastalarda sorunsuz kırık iyileşmesi görüldü. Yukarıda belirtilen açısal parametreler ile kırık kaynama süresi arasında anlamlı bir ilişki veya korelasyon bulunamadı. Ancak laterale yerleştirilen pinler arasındaki açı, medial pin ile lateral pin 2 arasındaki açı ve lateral pin 2 ile humerus şaftı arasındaki açı komplikasyonu olan hastalarda komplikasyonu olmayan hastalara göre daha büyük bulundu (p= 0,0001, p=0,017, p=0,0001).*

Sonuç: *Kırık redüksiyonunun kalitesi postoperatif fonksiyonel iyileşmenin temelini oluşturur. Bu çalışmanın sonuçları, SHK'da kaynamayı etkileyen ana parametrenin pinlerin koronal düzlemdeki konfigürasyonu değil, anatomik kırık redüksiyonu ve başarılı fiksasyon olduğunu göstermektedir.*

Anahtar Sözcükler: *Suprakondiler humerus kırığı, çocuklar, K-teli, koronal plan.*

INTRODUCTION

Supracondylar Humerus Fractures (SHF) account for approximately 15% of all pediatric fractures (1). SHF are the most common elbow fractures in children and accounts for approximately 70% of elbow injuries (2). SHF occur most frequently in children between the ages of 5 and 10 [2], with the non-dominant side of male children seeing the most reported cases (3).

This fracture pattern is usually caused by hyperextension of the elbow after a fall on one's open hand; and in more than 95% of fractures the distal fragment is displaced posteriorly (4). The method used for treatment of these fractures depends on the displacement of the fractured fragments. However, there is no consensus in the literature on treatment for this fracture (5,6).

SHF are classified according to the Gartland criteria (7). Closed reduction with percutaneous pinning is the standard treatment modality for Gartland Type 2 and 3 fractures (6). The two most common percutaneous pinning methods used in the treatment of SHF are medial-lateral crossed entry pinning and lateral only entry pinning (6). There is no clear consensus in the literature regarding the comparative strengths of these methods (8). Numerous biomechanical studies have evaluated the relationship between pin configuration and stability (9).

However, few studies have been put forth on the relationship between the angular configuration of K-wires between themselves, their angular configuration with respect to the fracture line and humeral shaft, and the fracture healing time and complication rates.

The aim of this study was to evaluate the relationship between the configuration of K-wires in the coronal plane and time to union and complications in supracondylar humerus fractures treated with closed reduction using one medial and two lateral percutaneous pins.

MATERIALS and METHODS

The study was designed as a single-centered retrospective study. The study commenced after ethics committee approval was obtained. Pediatric patients operated with closed reduction percutaneous pinning method for supracondylar humerus fractures between May 2016 and June 2022 were included in the study. Inclusion criteria mandated that the patients be between 3 and 10 years of age with Gartland Type 2 and Type 3 supracondylar humerus fractures. Patients with post-fracture neurovascular deficit, congenital neurovascular problems in the injured extremity, open fractures, trans-epiphyseal injuries, as well as those who were operated on with open reduction percutaneous pinning were excluded from the study.

All pediatric patients were operated under general anesthesia without a tourniquet. All patients received surgical prophylaxis using cephalosporin during induction of anesthesia. Traction was applied with elbow flexion of approximately 20°; varus and valgus alignment disorders were corrected with forearm movements. Medial and lateral translations were corrected with thumb maneuvers. After these maneuvers, the elbow was slowly flexed and force was applied anteriorly to the olecranon using a thumb. The limb was flexed in pronation or supination, depending on the condition of the distal fracture fragment. Following reductive maneuvers, the reduction in the anteroposterior and lateral planes was evaluated with the help of C-arm X-Ray. After the reduction was approved, one 1.6 mm thick K-wire was placed in the lateral condyle and its position was examined using a C-arm X-Ray. The K-wire was moved forward until it crossed the fracture line and reached the opposite cortex. Following the placement of the K wire, one 1.6 mm thick K-wire was placed on each of the medial and lateral planes using similar instructions. After placement of all wires, fracture stability was examined both in varus/valgus stress and in full flexion/extension. Following these controls, imaging was performed again using a C-arm X-Ray. The wires were left protruding from the skin so that they could be easily removed under outpatient clinic conditions.

The procedure was terminated after applying dressing and a long arm splint.

Patients' extremities were immobilized through the application of a long arm splint for 3 weeks postoperatively. After the third week, patients were asked to exercise using full range of motion of their elbows. Patients were called for follow-up at 10-day intervals. After union was validated through these follow-ups, the K-wires were removed in an outpatient clinic setting. Final follow-up of patients was conducted at the third postoperative month.

Demographic data, operation dates and follow-up dates of all patients were recorded. The time of removal of the K-wires, complications during hospitalization and follow-ups were also recorded. Measurements were made on the radiographs taken on post-operative day 1. The angle of each K-wire among themselves in the coronal plane, the angle of each K-wire with the fracture line and the angle of each K-wire with the humeral shaft were measured.

Of the 2 different K-wires placed laterally, the one with a more proximal entry point into the bone was considered as pin number 1, and the K-wire with a more distal entry point into the bone was considered as pin number 2. The medial K-wire was considered as pin number 3. All measurements were performed by two different orthopedic surgeons who were not part of the surgical team and were not authorized to access the demographic data of the patients (Figure-1). The mean of two different measurements was used for statistical analysis.

Pre-operative, post-operative, and follow-up radiologic images of one of the patients are presented in Figure-2.

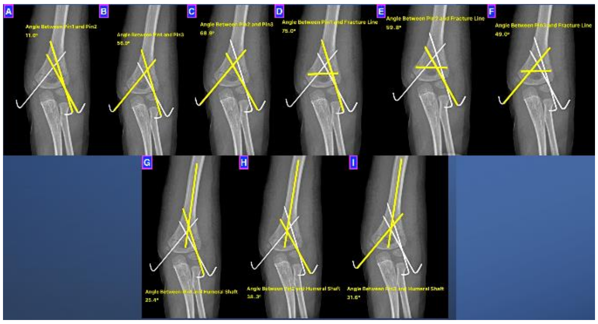

Figure-1. Angle between Pin 1 and Pin 2(A), Angle between Pin 1 and Pin 3(B), Angle between Pin 2 and Pin 3(C), Angle between Pin 1 and fracture line(D), Angle between Pin 2 and fracture line(E), Angle between Pin 3 and fracture line(F), Angle between Pin 1 and humeral shaft(G), Angle between Pin 2 and humeral shaft(H), Angle between Pin 3 and humeral shaft(I).

Figure-2. Preoperative, postoperative, and follow-up radiologic images of one of the patients.

Statistical analysis

SPSS 25. 0 package program was used for statistical analysis of the data. Categorical data was presented as numbers and percentages, and continuous data as means and standard deviation (medians and minimums-maximums where necessary). Comparisons of continuous data between groups were made according to the distribution of data. Student's T test was used for variables that met the assumption of parametric distribution, and Mann Whitney U test was used for variables that did not meet this assumption.

The correlation between variables was determined by Pearson's Correlation Coefficient. $r \geq 0.91$ indicates very high correlation between variables; $0.90 \leq r \geq 0.71$ indicates high correlation between variables; $0.70 \leq r \geq 0.51$ indicates moderate correlation between variables; $0.50 \leq r \geq 0.31$ indicates low correlation between variables; $r \leq 0.3$ indicates no correlation between variables. A statistical significance of $p<0.05$ was considered as significant for all analyses.

RESULTS

A total of 167 patients who met the inclusion criteria were included in the study. The left upper extremities of 109 (61.9%) and the right upper extremities of 67 (38.1%) patients were operated on. The mean age of the patients was 5.5 ± 1.9 years. Complications were encountered in 14 (8%) of 167 patients. The distribution of these complications is summarized in Figure-3.

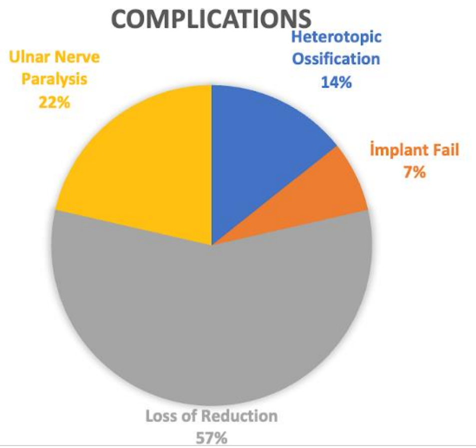

Figure-3. The distribution of the complications.

Patients with complications were analyzed separately and it was examined whether there was a relationship or correlation between complications and angular parameters of these patients. Accordingly, the angle between the lateral pins, the angle between the medial pin and the lateral pin 2, and the angle between lateral pin 2 and the humeral shaft were found to be larger in patients with complications than in patients without complications. All data related to these comparisons is provided in Table-1.

The correlation and relationship between the angular parameters and pin removal time, which was considered as the time of union, are shown in Table-2.

Table-1. Data showing the relationship between angular parameters in patients with and without complications.

Angle	No Complication Group	Complication Group	p
P1-P2	7,1±5,5	14,7±10,4	**0,0001***
P1-P3	69,6±11,1	72,1±12,9	0,434
P2-P3	73,3±11,6	81,1±12,9	**0,017***
P1-FL	61,9±14,9	61,6±17,2	0,934
P2-FL	57,7±14,6	50,1±16,5	0,065
P3-FL	46,7±14,2	43,7±17,9	0,466
P1-HS	34,4±9,9	32,8±11,6	0,572
P2-HS	38,0±9,3	46,6±9,4	**0,001***
P3-HS	35,7±8,9	39,2±11,7	0,170

Pin 1 (P1): From the lateral pins, the entry point to the bone is more proximal, Pin 2 (P2): From the lateral pins, the entry point to the bone is more distal, Pin 3 (P3): Medial pin, FL: Fracture Line, HS: Humeral Shaft, *: Statistically significant

Table-2. Data showing the relationship between boiling time and angular parameters.

Angle		P1-P2	P1-P3	P2-P3	P1-FL	P2-FL	P3-FL	P1-HS	P2-HS	P3-HS
Pin Output Time. (week)	r	0,33	-0,10	-0,01	0,08	-0,02	-0,03	-0,18	0,03	-0,01
	p	0,0001	0,180	0,899	0,269	0,738	0,970	0,018	0,694	0,889

P1: Pin1, P2: Pin2, P3: Pin3, FL: Fracture Line, HS: Humeral Shaft,

DISCUSSION

Closed reduction with percutaneous pinning is considered the gold standard treatment method for SHF (10, 11). Closed reduction using two lateral and one medial percutaneous pins for treatment of these fractures provide a high chance of success with a low chance of complications. No clear correlation between the coronal plane pin configuration used in this technique and union time has been found.

Despite numerous prior biomechanical and clinical studies, there is no consensus on the ideal K-wire configuration in pediatric SHF (12). However, the generally accepted opinion is that better stability can be achieved by using two lateral pins and one medial pin crossing the fracture line (13). All patients in our study underwent operations using two lateral and one medial percutaneous pins. In their study, Durusoy et al. examined the effect of the angle between the fracture line and K-wires on stability in SHF with a computer-aided 3D model in order to determine the optimal K-wire configuration (14). In their study, nine different angle combinations using 30-, 45- and 60-degree angles between K-wires and fracture lines were used. According to the results of their study, as the angle between the medial pin and the fracture line increases, the load on the lateral pin and fracture displacement decreases, and as the angle between the lateral pins and the fracture line increases, the stress on the medial pin and fracture displacement increases (14). In our study, it was concluded that the angle between the lateral and medial pin and the fracture line was not associated with either fracture union time or complication rates. This result indicates that the angular configuration between the fracture line and the pins does not have a direct effect on time of union despite resulting biomechanical differences.

Lee et al. published a series of 61 patients with Gartland Type 2 and Type 3 fractures treated with only lateral pinning, some of the patients receiving diverging lateral pins and in parallel lateral pins (15). The results showed that success was obtained with K-wires in both configurations (15). In another series of 30 patients, patients were treated with either diverging or parallel lateral pins and the groups were compared in terms of time of union and clinical outcomes (16). Comparable to the results from the study of Lee et al., Gopinathan et al. concluded that there was no significant relationship or correlation between lateral pin configuration and clinical outcomes and time of union (16). Hannonen et al. also examined the pin configurations of patients who underwent divergent percutaneous pinning and concluded that the angular proximity of the lateral pins may be associated with fracture displacement. They also stated that the minimum satisfactory angle between the divergent lateral pins is 25° (17). The mean angle between the lateral pins of the patients in our study was 7.7 ± 6.3, and despite this, fracture union rates were quite satisfactory. On the other hand, there are biomechanical studies showing that divergent pin configuration may provide better stability (18). In the present study, no relationship or correlation was found between the coronal angular configurations of the two lateral pins and the medial pin and time of union. Similar to the present study, Skags et al. found that pin configuration did not affect the permanence of reduction in Gartland Type 2 and Type 3 fractures (19).

The incidence of ulnar nerve injury due to medial pinning ranges from 0% to 9.4% (20, 21). In our study, this rate was 1.76%. Loss of reduction rate is 4% for patients treated with only lateral pins, and 2% for patients treated with both medial and lateral pins (22, 23). In our study, the loss of reduction rate was 4.56%. However, no patient required revision surgery. Some pin configuration parameters were found to significantly affect complication rates. Since there were very few patients in the complication subgroups, no solid inferences or comments on this issue could be made. Studies with a greater number of patients are needed in order to produce more conclusive data.

In this study, the relationship between coronal angular configuration of the two lateral and one medial percutaneous pins used in closed reduction technique and time of union and complications were examined. However, Bitzer et al. showed in their biomechanical analysis study that the configuration of the pins in the sagittal plane is as important as their configuration in the coronal plane in treating SHF (24). Therefore, further studies evaluating pin configuration in 3D are needed.

This study had some limitations. The retrospective design of the study was one of these limitations. The small sample size and the small number of patients in complication subgroups also limited the generalizability and interpretability of the data. Another limitation was that the measurements were taken manually, rather than by a computer.

The quality of fracture reduction is the basis of postoperative functional recovery (25). In their study on SHF patients with loss of reduction, Sankar et al. clearly concluded that intraoperative reduction is the most important factor for fracture stability regardless of the pin fixation technique (26).

CONCLUSION

The results of the present study support that the main parameter affecting union in SHF is not the configuration of the pins in the coronal plane, but the fracture reduction and stability obtained, a conclusion which is supported by data found in the literature.

Conflict of interest statement: The authors have no conflicts of interest to declare.

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