

SUPRAKONDİLLER HUMERUS KIRIKLARININ TEDAVİSİNDE MEDİAL VE LATERAL ÇAPRAZ PİNLEME VE SADECE LATERAL PİNLEME RETROSPEKTİF KARŞILAŞTIRMALI KLİNİK BİR ÇALIŞMA

MEDIAL AND LATERAL CROSSED-PINNING VERSUS ONLY LATERAL PINNING IN THE TREATMENT OF SUPRACONDYLAR FRACTURES OF HUMERUS A RETROSPECTIVE COMPARATIVE CLINICAL STUDY

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ÖZ

AMAÇ: Bu çalışmadaki amacımız suprakondiler humerus kırığı (SHK) sebebiyle opere edilen pediatrik hastalarda çapraz pinleme tekniği (ÇP) ile lateral pinleme tekniğinin (LP) klinik ve radyolojik sonuçlarını karşılaştırmaktır.

GEREÇ VE YÖNTEM: 2017 - 2019 yılları arasında hastanemizde ÇP yada LP ile SHK ameliyatı geçiren hastalar retrospektif olarak incelendi. Yaş, cinsiyet, redüksiyon şekli, Gartland sınıfı, ameliyat süresi, pin sayısı, postop nöro-vasküler durum, postop ilk Baumann açısı ve son takip Baumann açısı, lateral kapitel-lo-humeral açı, pin çıkarma süresi, takip süresi, Flynn kriterleri ve komplikasyonlar (fiksasyon yetmezliği, infeksiyon, sinir yaralanması, kaynamama, avasküler nekroz, revizyon cerrahisi) değerlendirildi.

BULGULAR: 77 hasta çalışmaya dahil edildi. 51 hastaya ÇP, 26 hastaya LP gerçekleştirildi. Çapraz pinlenen hastaların 24'üne medial açık redüksiyon uygulandı. Her iki grup arasında; kullanılan pin sayısı, postoperatif erken ve son kontrol baumann açısı, lateral capitulo humeral açı, pin çıkarma süresi, takip süresi, Flynn kriterleri ve komplikasyonlar açısından anlamlı bir fark görülmedi ($p>0,005$). Hiçbir hastada kaynamama, gecikmiş kaynama veya avasküler nekroz saptanmadı. Ameliyat süresi LP grubunda daha kısa idi ($p = 0,038$). ÇP grubunda 4 hastada iyatrojenik ulnar sinir felci, LP grubunda 1 hastada fiksasyon hatası saptandı.

SONUÇ: Çalışmamız her iki grubun fonksiyonel sonuçlarının benzer olduğunu ortaya koymuştur. Bununla birlikte, ulnar sinir hasarı kapalı redüksiyon ve perkütançapraz-pinleme yapılan hastalarda daha yaygındı. İstatistiksel olarak komplikasyonlar açısından iki grup arasında anlamlı fark olmamakla birlikte, sınırlı medial açık prosedür ile çapraz pinleme veya sadece lateral pinleme suprakondiler humerus kırıklarının tedavisi için daha güvenli olabilir.

ANAHTAR KELİMELE: Pediatrik, Humerus, Suprakondiler kırık, Çapraz pinleme, Lateral pinleme

ABSTRACT

OBJECTIVE: In this study, we aimed to compare the clinical and radiological results of cross-pinning technique (CP) and lateral pinning technique (LP) in pediatric patients operated for supracondylar humerus fracture (SHF).

MATERIAL AND METHODS: The medical records of patients undergoing operations for an SFH either with crossed-pinning technique or only lateral pinning technique between the years 2017 and 2019 at the same institution were retrospectively reviewed. Age, gender, reduction type, Gartland class, duration of surgery, number of pins, postop neuro-vascular status, postoperative initial Baumann's angle and Baumann's angle at last follow-up visit, Lateral capitulo humeral angle, pin removal time, follow-up time, Flynn's criteria and complications (revision for fixation failure, infection, nerve palsy, nonunion, avascular necrosis) were evaluated for all patients.

RESULTS: 77 patients were included in the study. Of these, crossed-pinning (CP) technique was performed on 51 patients while only lateral pinning technique (LP) was performed on 26 patients. Among the CP group, 24 of the cross-pinned patients had undergone a medial open reduction. There was no significant difference between the groups; in terms of the number of pins used, postoperative initial Baumann's angle and Baumann's angle at last follow-up visit, Lateral capitulo humeral angle, pin removal time, follow-up time, Flynn's criteria and complications ($p>0,005$). Nonunion, delayed union or avascular necrosis was not detected in any of the patients. However, the duration of the surgery was shorter in the LP group ($p= 0,038$). Iatrogenic ulnar nerve palsy was detected in four patients in the CP group and 1 fixation failure was detected in the LP group.

CONCLUSIONS: Our study revealed that the results of both groups were comparable in terms of functional results. However, ulnar nerve injury was more common in patients undergoing closed reduction and percutaneous crossed-pinning. Although there was no statistically difference in terms of complications among the groups, only lateral pinning or crossed-pinning with a limited medial open procedure may be safer for treatment of supracondylar humerus fractures.

KEYWORDS: Pediatric, Humerus, Supracondylar fracture, Crossed-pinning, Lateral pinning

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INTRODUCTION

Supracondylar fractures of the humerus (SFH) are the most common type of fracture around the elbow and the second most common fracture of the upper extremity in the pediatric age.

The reason for this is that the supracondylar region has a thin architecture and ligamentous laxity is much more efficient than in the adults in the pediatric age (1). It is more common in boys and more likely to occur especially in children aged 5 - 7. (2). These fractures are generally classified by using the Gartland classification.

Historically, Gartland had classified fractures in three subgroups (3). However, this classification has been evolved and currently classifies fractures in four subgroups. Besides, it defines the medial column comminution as a different entity and surgical fixation of type 2, 3, 4, and medial column fractures are advocated (4). 95% of these fractures are extension-type SFHs and the fracture mechanism is the falling on the open hand while the elbow is stretched. The remaining 5% consists of flexion-type fractures and these fractures occur directly by falling on the elbow (olecranon) (5).

These fractures tend to develop more deformity, especially in the coronal plane compared to other pediatric fractures, as the supracondylar area has a quite low remodeling potential.

In addition, the complex vascular and neural structures surrounding the elbow make these structures prone to injury during trauma and surgery. Cubitus varus has been reported to be between 5 and 15% after surgical treatment (6, 7), and it has been reported that ulnar nerve injury can be seen in 15% of the patients after medial pinning (8). The surgery recommended to be performed is the fixation of the fracture with the pins after an open or a closed reduction. However, while the percutaneous pinning technique to be used is widely controversial, there is no consensus on the open techniques that will be applied as well. Commonly used pinning techniques are medial and lateral crossed-pinning techniques and only lateral pinning technique, but the number of pins used in each technique is also a matter of discussion (9, 10).

Advocates of these two different pinning techniques generally have discussed the results of their clinical experience in terms of preserving neuro-vascular structures and the stability of fracture stabilization. The purpose of our study is to compare the functional and radiological results of patients who underwent crossed-pinning and lateral pinning due to the SFH in our clinic and to investigate the pros and cons of both techniques.

MATERIAL AND METHODS

Patients operated for SFH between the years 2017 and 2019 in the same institution were included in the study. After obtaining institutional ethics committee approval, the medical records of the patients were reviewed retrospectively. The study was conducted in accordance with principles for human experimentation as defined in the Declaration of Helsinki.

Inclusion criteria were as follows: age below 12 years, presenting prior to the 3rd day of the injury, having no previous or concomitant injury of the same elbow. Patients with metabolic and neurological diseases, open fractures from any grade, and patients with neurovascular injury due to trauma were excluded from the study.

Also, patients having a flexion type fracture were excluded from the study as we had only two patients from these subgroups and including these patients may disrupt the homogeneity of the groups.

After the first evaluation of the medical records, 256 cases of operated for SFH were detected. Of the 256 cases operated, 77 patients who met the study criteria were included in the study.

Treatment, Follow-Up And Evaluation

All surgeries were performed either by 8 experienced orthopedic trauma surgeons or under the supervision of these surgeons by 11 senior residents. The surgical technique to be performed was at the discretion of the operating surgeon. After the first admission to the emergency service all patients diagnosed with Gartland type 2 or 3 fractures were examined for neuro-vascular status. Independent from neuro-vascular status all patients were prepa-

red for surgery as soon as possible. The closed temporary reduction was performed only for too many displaced fractures and the upper extremity was placed in a long arm cast positioned in a 80 degrees of flexion until surgery.

All surgeries had performed in a supine position. Elbow was positioned on the C-arm during surgery. Tourniquet was placed prior to wrapping but was not inflated if reduction could be obtained with a closed manner. However, if closed reduction could not be obtained, the tourniquet had inflated. Medial or lateral incisions were performed for open reductions and the choice of incision method was at the discretion of the staff surgeon. After open or closed reduction, fixation from the lateral side or medial + lateral side was performed, the reduction was verified under image intensifier and if was appropriate surgery was ended. The number of the pins that will be introduced had chanced for every patient and was at the discretion of the operating surgeon. After surgery, the extremity was placed in a long arm a cast in 80 - 90° of flexion and was followed-up with cast for 3 weeks.

The first visit was on the 10th postoperative day and the second was the 3rd week. The cast was removed at the 3rd week and elbow ROM exercises were started. Patients were called for a visit at the postoperative 5th week. If callus was evident in X-rays pins were removed and ROM exercises were continued. If appropriate ROM had not been achieved, patient was consulted with a physical therapy clinic and rehabilitation had continued under the supervision of a physical therapy specialist. Thereafter patients were called for follow-ups once a for three months during the first year.

Age, gender, reduction type, Gartland class, duration of surgery, number of pins, postop neuro-vascular status, postoperative initial Baumann's angle and Baumann's angle at last follow-up visit, Lateral capitellohumeral angle, pin removal time, follow-up time, Flynn's criteria (6) and complications (revision for fixation failure, infection, nerve palsy, nonunion, avascular necrosis) were recorded for all patients. Flynn's criteria evaluate the degree of loss in carrying angle, degree of loss in flexion and extensi-

on and then classifies the results as excellent, good, fair and bad. Post-operative initial and final x-rays of the patients were evaluated by the first two authors for Baumann's angles and lateral capitellohumeral angles. Correlation between two authors was evaluated using the interclass correlation coefficients (ICC) test. ICC was found to be > 0.80 (excellent correlation) for 55 of the patients and > 0.70-0.80 (very good correlation) for 22 of the patients. The mean values of the both measurements were taken into account for the controversial results. Clinical assessments of the loss in carrying angle of the forearm, degree of loss of flexion and extension of the elbow were carried out by the third author who was blind to the surgical technique used and results were classified using Flynn's criteria by the same author.

All statistical analyses were performed using SPSS 25.0 (IBM Corporation, Armonk, NY, USA) For quantitative data, independent samples t-tests were used together with bootstrap results while the Mann-Whitney U test was used with Monte Carlo simulation technique for the comparison of two independent groups. Quantitative variables are expressed as means and categorical variables are given as numbers; 95% confidence intervals (CIs) were calculated p values < 0.05 were considered statistically significant.

ETHICS COMMITTEE

This study was approved by Umraniye Training and Research Hospital ethics committee (Reference Number:00117103830).

RESULTS

Of the 77 patients, fixation of the fracture was carried out using the CP technique for 51 patients and only LP for 26 patients. All surgeries had performed in 36 hours after trauma. Among the CP group, 18 had undergone a medial open reduction and 6 had undergone a lateral open reduction and the remaining 27 had undergone a closed reduction and CP operation. The mean age at the time of the operation for the CP group was 50.3 months (24 - 126).

Among the LP group, 11 had undergone a lateral open reduction and LP and the remaining

15 had undergone a closed reduction and LP operation. The mean age at the time of the operation for the LP group was 54.5 months (28-98). Preoperative demographic data for both groups were similar (**Table 1**).

Table 1: Preoperative patient characteristics

Groups	Crossed-Pinning group n=51	Lateral-Pinning group n=26	P ^a
Gender	26	15	
Male(n)			
Female(n)	25	11	0.579
Age (Months)	50,3(24-126)	54,5 (28-98)	0,667
Follow Up (Months)	18,8 (12-35)	17,3 (12-24)	0,483
Gartland Class			
Type 2	10	7	0,467
Type 3	41	19	

n:number
^aMann Whitney u test(Monte Carlo)

There was no significant difference between the groups by the means of; the number of pins that used to fix the fractures, postoperative initial Baumann's angle and Baumann's angle at last follow-up visit, Lateral capitellohumeral angle, pin removal time, follow-up time, Flynn's criteria and complications (revision for fixation failure, infection, nerve palsy, nonunion, avascular necrosis) Table 2. However, the duration of surgery was shorter in the LP group (**Table 2**).

Table 2: Postoperative follow-up data of both groups

Groups	Crossed-Pinning group n=51	Lateral-Pinning group n=26	P ^a
Number of pins (mean-range)	2,92 (2-4)	2,47 (2-4)	0.544
Surgery duration (min)(mean-range)	71,4 (45-110)	62,3 (40-105)	0.038
Reduction technique (n)			
Open	24	11	
Closed	27	15	0.541
Initial Baumann's Angle (mean-range)	75,6° (68-81)	74,01° (68,8-77,5)	0.776
Final Baumann's Angle(mean-range)	75,2° (70-84)	74,7° (71-77,7)	0.614
Lateral capitellohumeral angle (mean-range)	44,5° (38-60)	41,8° (39,5 - 46)	0.495
Time of pin removal (day) (mean-range)	32,07 (28-48)	30,8 (26-42)	0.422
Flynn's criteria (n)			
Excellent	46	23	
Good	3	2	
Fair	2	1	
Bad	0	0	0,823
Complications (n)			
Ulnar nerve palsy after surgery	4	0	
Pin tract infection	6	2	
Revision surgery	0	1	0.374

n:number
min:minutes
^aMann Whitney u test(Monte Carlo)

Although in general complications were comparable, the post-operative iatrogenic ulnar nerve damage was more common in the CP group. 4 patients had sustained an ulnar nerve injury in the CP group and none in the LP group.

Among 4 patients who sustained ulnar nerve palsy at the postoperative early stage, 3 had obtained the recovery of their nerve functions until the postoperative 6 months. In all patients, one medial and two lateral pins were used. All had undergone a closed reduction and a per-

cutaneous pinning. Postoperatively medial pin was not removed in any of the patients. Despite early removal of the whole pins at postoperative 3rd week and aggressive physical therapy and rehabilitation sensory function were functions obtained, but ulnar nerve motor functions were not recovered (**Figure 1**).

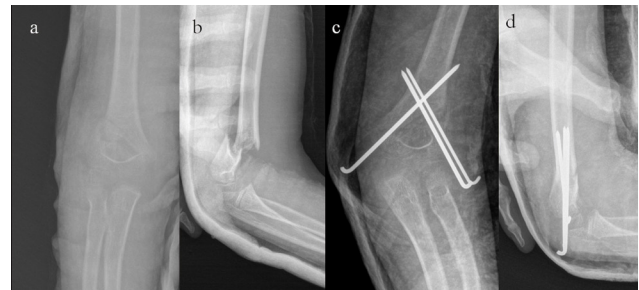


Figure 1: a,b) Anterior-posterior (AP) and lateral x-rays of a 9 year old male sustained a Gartland type 3 SFH after a fall from a tree. c,d) Early postoperative AP and lateral x-rays after closed reduction and CP showing anatomic reduction and stable fixation of the fracture. Patient had an ulnar nerve palsy at postoperative first examination. Medial pin was not removed not to disrupt the stability of the fixation. Note also the over-introduced lateral pins

There was no need for revision surgery in the CP group either for the failure of the fixation or for a malunion. However, a failure of the fixation was detected in the LP group. This was a 2 years old boy who sustained a Gartland type 3 fracture. A closed reduction and percutaneous pinning (CRPP) with 2 pins from the only lateral side was performed for the patient. Failure of the fixation was detected at the 10th postoperative day and a revision operation via a medial open reduction and crossed-pinning was performed. This patient achieved the union and full ROM of his elbow at postoperative 3rd month (**Figure 2**).



Figure 2: a,b) Anterior-posterior(AP) and lateral x-rays of a 2 year old male sustained a Gartland type 3 SFH after a fall from the couch. c,d) Early postoperative AP and lateral x-rays after closed reduction and LP showing anatomic reduction. e,f) Postoperative x-rays at postoperative 10.th day showing displacement of the fracture

No statistically significant difference was detected between groups by the means of clinical

results. In the CP group; 46 (90.1%) patients were graded as excellent, 3 (5.8%) patients were good and 2 (3.9%) patients were fair according to Flynn's criteria. In the LP group; 23 (88.4%) patients were graded as excellent, 2 (8%) patients were good and 1 (3.8%) patient was fair. Also, a statistically significant difference was not evident for Flynn's criteria between patients going under a closed or open reduction in both groups ($p>0.05$). An analysis between subgroups of medial open and lateral open techniques revealed no significant difference between groups by the means of any data evaluated ($p>0.05$).

In both groups, patients having a pin-tract infection (6 in CP and 2 in LP group) were treated using oral antibiotics and no further interventions had needed. Nonunion, delayed union or avascular necrosis, compartment syndrome, or myositis ossificans were not detected in any of the patients.

DISCUSSION

Of all complications associated with fractures of the supracondylar humerus, nerve injury ranks highest. All nerve and arterial structures surrounding the elbow including; Median nerve, Ulnar nerve, Radial nerve, Anterior interosseous nerve, Posterior interosseous nerve, Brachial artery and vein are at risk after the initial trauma. Particularly extension-type fractures are associated with nerve injuries and the Anterior interosseous nerve is under the greatest risk for this kind of fractures. Although flexion type fractures have rarely been reported to be associated with nerve injuries, ulnar nerve injuries have been reported to be the dominant nerve that is injured in flexion type fractures (11). Currently, the widely advocated operative treatment for Gartland extension-type supracondylar humeral fractures is reduction followed by percutaneous pin fixation. Although there is an ongoing debate on optimal pin replacement technique; placement of a medial pin along with lateral pins may risk ulnar nerve, however the use of lateral pins alone may not be stiff enough to ensure the stability of the fixation(12). In this study, we compare the functional and radiological results of patients who underwent crossed-pinning and lateral pinning due to the

SFH in our clinic. Our results revealed that functional results including ROM and carrying angle of the forearm was similar between groups.

Neither pinning technique, nor reduction technique (medial open, lateral open, closed) did not an effect on these results. Both pinning techniques were comparable by the means of obtaining and maintaining anatomic reduction until union as there was no significant between groups in Baumann's angles and lateral capitellohumeral angles. Operation time had decreased in the LP group as medial pinning had not performed in this group. However, there was no difference between groups by the means of pin numbers. Probably surgeons had preferred to use as possible as K wires to obtain the best stability. However, the ulnar nerve damage was more common after closed reduction and crossed-pinning.

Recent studies examining the stability of the different pinning techniques have reported the crossed-pinning technique being the most stable pinning technique (13). However, different biomechanical studies have reported the appropriately positioned lateral pins being enough stable to prevent the failure of the fixation until the union. Feng et al. (14) had shown two lateral pins placed divergent in lateral epicondyle to be as effective as crossed-pinning in preventing displacement except for valgus displacement. However, the authors had not reported introducing a third pin from lateral epicondyle as this will not enhance the stability of the fixation. Also, it has been shown that a third pin did not strengthen crossed two pin construct but better-stabilized fractures with medial comminution (15). In line with the aforementioned biomechanical studies in a meta-analysis by Brauer et al (16), loss of reduction has been reported to be associated mostly with only lateral pinning. However, authors had not mentioned the clinical results of these displacements in long-term follow-ups. In contrast with the literature reporting biomechanical studies, our results revealed no statistically significant difference between groups by the means of the quality of reduction and loss of reduction. Baumann's angles and lateral capitellohumeral angles were similar and this had not changed

during follow-ups. Also, several previous studies had reported reduction quality in the sagittal and coronal plane after surgery and during follow-ups to be similar for patients treated either with closed reduction and CP or closed reduction and LP (17,18). In addition, although divergent placed pin configuration had been reported to be as stable as crossed-pin technique, as seen in our second case failure of the fixation still remains to be a constant problem even after only lateral divergent pinning. Probably there is a discrepancy in the findings between biomechanical studies and clinical trials, as unique structural features of the pediatric supracondylar region could not be reflected in the laboratory.

Despite the whole efforts to prevent nerve injury and obtain a stable fixation, only lateral pinning may not be efficient particularly in cases with medial comminution (15). Because of immature bone and to the excessive swelling of the tissue, anatomic landmarks can be missing and palpation of the medial epicondyle and ulnar nerve may not be possible. In this kind of a situation, it is advocated not to hesitate to make a limited incision on the medial epicondyle to protect the ulnar nerve (19). To our experience, a 1,5 cm incision gives the surgeon enough space to palpate the medial epicondyle and the nerve clearly and ensure safe placement of the medial pin. As seen in our cases all nerve palsies had occurred after percutaneous medical applications of the pins and there was not any functional difference between the patients undergoing an open or a closed reduction. There were no nerve injuries among the patients undergoing a medial open reduction and crossed-pinning group. In a study by Dost et al. (20) examining the efficiency of the limited medial open technique with CP, authors had reported 89% excellent results according to Flynn's criteria, none ulnar nerve palsy and 5 cubitus varus deformities.

Decision-making on treatment SFH in pediatric age may have several challenges as every treatment choice may have serious advantages and disadvantages. A failure of fixation needing a revision surgery, accepting a minimum varus or valgus alignment and permanent or tempo-

rary ulnar nerve palsy are the worst scenarios for these fractures and the choice of the treatment depends on the surgeons' experience. Lee et al. (21) in their study examining the best treatment method (CP and LP) for displaced SFH in children had reviewed the previous data and suggested a decision analysis tool in terms of function. The author's decision tool had used ulnar nerve injury and loss of reduction needing revision as the worst scenario and created a decision tree model. Their a decision tree model had favored the LP over the CP in terms of the function. In line with this finding, as seen in our series patients in the LP group needing revision surgery had achieved the union and full ROM just in three months. However, one of the patients among 4 patients with ulnar nerve palsy in the CP group had sustained a permanent ulnar nerve palsy and this will negatively affect the whole life of the patient. Sure, we can't drive exact conclusions on the correlation between the amount of Bauman's angel and clinical results from our study. Excluding the patient that had lost his reduction, our patients Bauman's angels were within normal ranges in both groups. But current literature suggests that a moderate valgus or a varus can be tolerated and will not create a functional impairment other than cosmesis. Even if a tardy ulnar palsy tends to develop due to a cubitus valgus, an osteotomy or a nerve transposition procedure can improve the patients' functions (22, 23).

The treatment of iatrogenic ulnar nerve injury is another point of controversy among orthopedic surgeons. There are three main ways to follow at the postoperative initial period; exploring the ulnar nerve (24), removing the medial pin and waiting for the recovery of the nerve (25) and just waiting for the recovery of the nerve without intervening. Kalenderer et al. (26) in their series including 25 patients with ulnar nerve injury occurred after closed reduction and crossed-pinning had not intervened the medial pin before union in any of the patients.

Authors had reported total recovery of the nerve in all patients in 7 months. We also did not intervene to the medial pin in any of the patients. But in contrast with previous authors, ulnar nerve did not recover in one of the cases. Another

possible factor that may cause an ulnar nerve injury is the un-controlled introduction of the lateral pins (27). As seen in our case (figure 1) tips of the lateral pins have passed the medial cortex about a centimeter. Although the medial pin is the usual suspect for the nerve injury particularly in this case, the development of the permanent nerve dysfunction pushes us to think about also injury of the nerve by lateral pins.

As a conclusion, our study revealed that both pinning techniques were comparable by the means of preserving the stability of the fixation until union and functional results were similar as well. However, ulnar nerve palsy was common in the crossed-pinning group and we recommend using medial pinning with a limited medial incision or with a medial open technique as malreduction or failure of fixation can be addressed but permanent ulnar nerve palsy will create irreparable functional limitations for patients.

There were some limitations of our study. The major limitations were that it was not a prospective randomised study, the number of individuals included was relatively small and surgeries had been performed by different surgeons.

Also, intraoperative fluoroscopy times were not recorded, but we believe that the data presented was enough to drive conclusions about early postoperative ulnar nerve palsy and loss of reduction. To drive exact conclusions also about correlations between incision techniques, radiological results, and clinical outcomes we recommend future multicentric randomised clinical studies.

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