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Closed reduction and percutaneous lateral pin fixation in the treatment of displaced supracondylar fractures of the humerus in children

Çocuklarda ayrılmış suprakondiler humerus kırıklarının tedavisinde kapalı redüksiyon ve lateralden perkütan çivileme

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Amaç: Çocuklarda ayrılmış suprakondiler humerus kırıklarının tedavisinde kapalı redüksiyon ve lateralden perkütan çivileme ile tedavi sonuçları değerlendirildi.

Çalışma planı: Otuz dört çocuk (25 erkek, 9 kız; ort. yaş 7.2; dağılım 3-13) ayrılmış suprakondiler humerus kırığı nedeniyle tedavi edildi. Beş hastada Gartland tip 2, 29 hastada tip 3 kırık vardı. Tüm olgularda kapalı redüksiyondan sonra, lateralden iki K-teli 11 olguda paralel, 23 olguda çapraz olarak gönderildi. Beş olguda üç adet K-teli kullanıldı. Tespit süresi ortalama 3.8 hafta (dağılım 3-6 hafta) idi. Son kontrollerde dirsek ön-arka grafilerinde Baumann ve taşıma açıları; yan grafilerde humerokapitellar açı ölçüldü ve sağlam taraf ile karşılaştırıldı. Klinik olarak fleksiyon-ekstansiyon aralığı muayene edildi. Sonuçlar Flynn ve ark.nın ölçütlerine göre değerlendirildi. Ortalama izlem süresi 22.6 ay (dağılım 10-48 ay) idi.

Sonuçlar: Tüm kırıklar kaynadı. Olguların hiçbirinde çivi yolu enfeksiyonu, miyozitis ossifikans, kompartman sendromu ve iyatrojenik sinir yaralanması oluşmadı. Flynn ve ark.nın ölçütlerine göre, fonksiyonel olarak tüm olgularda (%100), radyografik olarak 33 olguda (%97.1) tatminkar sonuç elde edildi. Bir olguda 14 derece kubitus varus saptandı. Son kontrollerde ortalama Baumann açısı, humerokapitellar açı ve taşıma açısı sağlam taraf ile anlamlı farklılık göstermedi (p>0.05).

Çıkarımlar: Çocuklarda ayrılmış suprakondiler humerus kırıklarının tedavisinde kapalı redüksiyon ve lateralden perkütan çivileme etkili, güvenilir ve sağlam bir yöntemdir.

Anahtar sözcükler: Kemik teli; çocuk; dirsek eklemi/yaralanma; kırık tespiti, internal/yöntem; humerus kırıkları/cerrahi/radyografi.

Objectives: We evaluated the results of closed reduction and percutaneous lateral-pin fixation in the treatment of displaced supracondylar fractures of the humerus in children.

Methods: Thirty-four children (25 boys, 9 girls; mean age 7.2 years; range 3 to 13 years) were treated for displaced supracondylar fractures of the humerus. Five patients had Gartland type 2, and 29 patients had type 3 fractures. After closed reduction, lateral-pin fixation was performed with two parallel (n=11) or crossed (n=23) K-wires. Three K-wires were used in five patients. The mean duration of fixation was 3.8 weeks (range 3 to 6 weeks). For comparison with the normal side, the Baumann and carrying angles were measured on anteroposterior, and the humerocapitellar angle on lateral radiographs. The range of motion of the elbow was assessed clinically. The results were evaluated according to the criteria of Flynn et al. after a mean follow-up of 22.6 months (range 10 to 48 months).

Results: Union was achieved in all the patients. Complications such as pin-tract infections, myositis ossificans, compartment syndrome, or nerve injuries did not occur. According to the criteria of Flynn et al., functional and radiographic results were satisfactory in all the patients (%100) and in 33 patients (%97.1), respectively. One patient developed cubitus varus of 14 degrees. No significant differences were found between the mean Baumann, humerocapitellar, and carrying angles of the normal and affected sides (p>0.05).

Conclusion: Closed reduction and percutaneous lateral pinning proved an efficient, reliable, and safe method in the treatment of displaced supracondylar fractures of the humerus in children.

Key words: Bone wires; child; elbow joint/injuries; fracture fixation, internal/methods; humeral fractures/surgery/radiography.

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Supracondylar fractures of the humerus represent 60% of all fractures around elbow joint with a peak incidence between 4 to 7 years of age in children.[1-10] Many different methods are described for the treatment of extension type suppracondylar humeral fractures; however closed reduction with percutaneous pin stabilization is the current preferred method of treatment.[4-22] Two major complications associated with percutaneous pinning are iatrogenic ulnar nerve palsy and loss of reduction with development of cubitus varus/valgus or a hyperextension deformity. The optimal pin configuration that provides an adequate stability of the fracture to maintain reduction and promote proper union while minimizing the risk of neurovascular injury is still a subject for many investigations.[14-25]

In this study, we evaluated the results of closed reduction and percutaneous lateral-pin fixation in the treatment of displaced supracondylar fractures of the humerus in children.

Patients and methods

Thiry-four children (25 boys, 9 girls; mean age 7.2 years ; range 3 to 13 years) who had Gartland type 2 or Gartland type 3 fractures were included in the study. Five patients had type 2 and 39 patients had type 3 fractures. Closed reduction and percutaneous pinning with the use of fluoroscopy was performed for all patients under general anesthesia. Patients with open fractures, or other traumas and those who were treated with open reduction were excluded from the study. The direction of the displacement was posteromedial in 22 patients, posterolateral in eight patients and posterior in four patients. One patient with a median nerve palsy and weakness of radial pulses at the first examination was also noted to have coldness in his hand.

Figure 1. The views of a patient with a displaced supracondylar humerus fracture **(a,h)** preoperative;**(c,d)** after closed reduction and percutaneous crossed lateral pinnig in a posterior splint;**(e,f)** before the removal of the pins;**(g, h)** Anteroposterior and lateral views of the patient at the 12 month, postoperatively.

Following the satisfying reduction under fluoroscopy, K-wires were inserted from the lateral condyle with the use of a hand perforator (Fig 1 a-h, 2 a-e). The entry holes of the laterally inserted 2mm K-wires were opened at the distal fragment of the fracture. The wires were inserted vertically to the long axis of the humerus. Then, the wires were directed to the medial cortex of the proximal fragment. Taking into consideration of the anatomical location of the radial nevre, transecting the intermuscular septum posteroanteriorly, we inserted the wires from the posterior of the lateral supracondylar ridge to prevent the radial nevre injury. After the fluoroscopic control, the pin directing medially was positioned at the medial cortex without penetrating it. So the ulnar nerve was located at this level and not very mobile, was protected. Provided these pins are not very long, the pins were released after penetrating the medial cortex. All the pins were bended and left out of the skin to prevent their migration. The motion of the elbow was examined under general anestesia and the carryigng angle was evaluated subjectively at the extension of the elbow.The quality of the reduction was accepted as good when the flexion was 110 degrees or more.

After the last fluoroscopic control, the elbow was placed in a splint at approximately 90° flexion. The pins were paralel in 11 children and crossed in 23 children. Three K-wires were used in five patients to augment the stabiltiy and two K-wires in twenty-nine patients. The operating surgeon's own decision was effective in choosing either parallel or closed wires. All the patients were observed 24 hours for edema and neurovascular complications postoperatively and the next day they were discharged after the radiographic control. Radiological and clinical controls were made with a one week periodic time. The pins were removed after radiological healing and then active exercises were started. The mean duration of fixation was 3.8 weeks (range 3 to 6 weeks). At the last follow up, anteroposterior and lateral graphies were taken. Baumann's angle was measured on anteroposterior radiographs and humerocapitellar angle were measured on lateral radiographs. The results were compared with the normal side. The range of motion of the elbow was assessed clinically. The results were evaluated according to the criteria of Flynn et al.[26] after a mean follow up of 22.6 months (range 10 to 48 months).

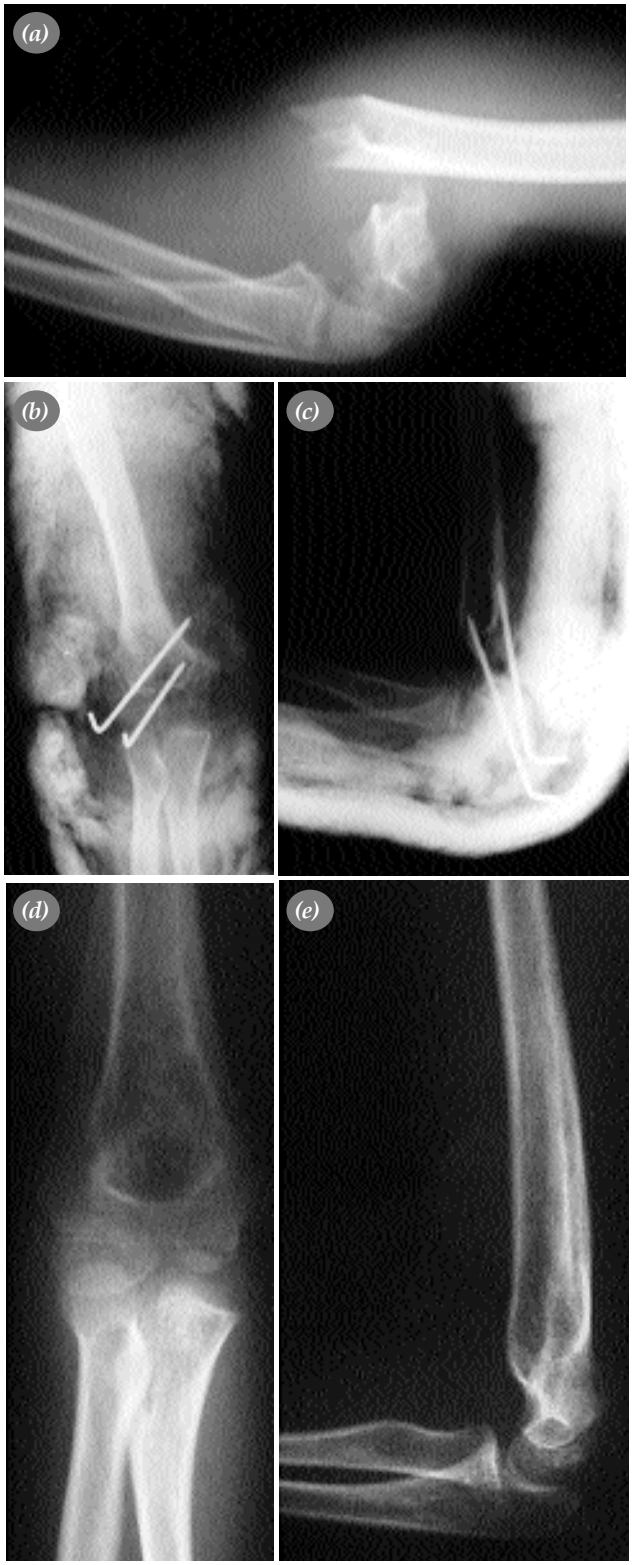

Figure 2. A view of a 8 year old child with a displaced supracondylar humerus fracture, **(a)** preoperative; **(b,c)** early postoperative in a posterior splint after closed reduction and percutaneous lateral pinning;**(d,e)** anteroposterior and lateral views at the 14th postoperative month.

Table 1. Criteria of Flynn et al.[26] for evaluation of the results

	Functional			Cosmetic		
Results	Motion loss (°)	Number	%	Carrying angle (°)	number	%
Satisfactory						
Excellent	0-5	29	85.3	0-5	26	76.5
Good	6-10	3	8.8	6-10	5	14.7
Fair	11-15	2	5.9	11-15	2	5.9
Unsatisfactory						
Poor	>15	–	–	>15	1	2.9

Statistical analysis were made with the use of the SPSS version -7.5 for Windows programme for t-test comparisons.

Results

Union problems, pin-tract infections and myositis ossificans did not occur. No patient had pain or iatrogenic ulnar nerve palsy and compartment syndrome did not occur in any patient. Vascular impairment of a patient who had median nevre palsy and weakness of distal pulses at presentation improved after closed reduction. Also the neural deficency disappeared later. No neural deficencies were noted at the final follow up.

After the examination of both elbow with a goniometer, in 29 patients (85%) the flexion-etension gap was found within 5° according the criteria of Flynn et al.[26] Functional and radiographic results were satisfactory in all the patients (100%) and in 33 patients (97%) respectively. The results was poor in one patient who developed 10° varus deformity.

At the final follow-up the mean Baumann's angle, humeocapitellar angle and carrying angle was 74.6°, 38.8° and 63° respectively on the injured side. There were significant differences for these three values between the operated and the normal elbows ($p>0.005$)

Discussion

The incidence of supracondylar humerus fracture in chidren is 3%; Many surgeons deal with this type of injury in their orthopaedic practice and faces with many problems. Closed reduction of the displaced fracture and maintanance of their position with a cast immobilization is difficult due to their anatomical features. The fractures may be displaced even after an anatomically reduction when the elbow edema dissappears. The position of fracture stability is approximately 100° flexion of the elbow, however this position is not generally accepted because of its negative effect on the extremity circulation. Open reduction has many disadvantages. It prolongs the hospitalization time, has risk of infection and also yields to restriction of the elbow motion due to the soft tissue scars of the surgical intervention. Closed reduction and percutaneous pinning is preferred as a current treatment modality which avoids these problems.[14-24] However, iatrogenic ulnar nerve injury and loss of reductions are the two major complications associated with this method. Cubitus varus/valgus or a hyperextension deformity develops after a loss of reduction. To prevent these deformities, an anatomic reduction should be performed and stable osteosynthesis should be achieved in this position.

The best configuration for the stabilization of the osteosynthesis is controversial in the orthopaedic literature. Zionts et al.[15] investigated the torsional strength forming minimal 10° internal rotation at flexion in human cadavera, and compared the results. In this study, they noted that two medially and laterally crossed pins were the most strongest.Two crossed lateral pins followed this model and than the two lateral pins. A biomechanical comparison of all pin configurations were performed by Lee et al.[16] in extension, varus,valgus, internal rotation and external rotation using a pediatric synthetic bone model. Divergent configuration laterally to prevent ulnar nerve palsy had enough stability but in axial rotation testing, this type of configuration had less stability than other configurations. In this study divergent pins provided more sta-

bility than crossed pin in extension, and varus testing. Herzenberg et al.[17] using a canine fracture model, demonsrated the best results with crossed medial and lateral pins. These are all in-vitro studies. Different results are achieved with comperative in-vivo studies. Topping et al.[18] found no significant differences in early and late posoperative Baumann's angle between crossed-pin group and lateral-pin group. Enough stability was achieved with laterally placed parallel pins for fracture reduction. Authors have recommended crossed pin fixation for open fractures or for fractures which needed vascular repairment. Skaggs et al.[19] found no ulnar nevre palsy and no reduction was lost in 124 children managed with only lateral-entry pins. In an other study of Skaggs et al.[20] of 141 children who had Gartland type-2 fracture, seventy-four were treated with lateral pins only and sixty-seven were treated with crossed pins. Of 204 children who had a Gartland type-3 fracture, fifty-one were treated with lateral pins only and 153 were treated with crossed pins. The configuration of the pins did not effect the Baumann's angle in both Gartland type-2 and Gartland type 3 fractures. Reynolds and Jackson[27] found no differences in results between the two different methods. They suggested that stabilty depends on three factors that are under the control of the surgeon: the size of the pin, the distance between the pins along the line of the fracture, the pins being in the bone on both sides of the fracture. Solak and Aydın[28] believed that for any orthapedic surgeon who treats type III supracondylar fractures, there is no difference in the results between crossed-pinned and lateral pinned fixation but that the experience of the treating surgeons is the most important factor in obtaining a good final outcome. France and Strong[22] also noted no difference between 32 laterally pins and 14 crossed pins of 46 patients' results. However they observed ulnar nerve palsy in the crossed-pin group.

Although the results showed no difference, some authors who believed the biomechanical superiority of crossed pins preferred specific crossed-pin technique to decrease the ulnar injury. Green at al.[29] performed cross-pinning with a medially mini-open incison. Shannon et al.[30] preferred Dorgan's pinning-configuration method after closed reduction to avoid the iatrogenic ulnar nevre injury. Following reduction, the two wires were introduced through the lateral condyle accross the fracture and were crossed above the fracture line. The wires which were driven into the medial condyle did not penetrate the medial condyle.

Cubitus valgus and varus deformities of supracondylar humerus fracture did not develope as a late complication of these fractures. An initial displacement which is not corrected by surgery contributed to these deformities.[9,23] In vitro studies were unable to assess the resistance of the thickened periosteum of children to displacement after reduction and pinning; also the addition of a long-arm splint provides additional resistance to rotational and angular displacement. The interdigitation at the fracture site in a well-reduced in vivo fracture can not be simulated by an in vitro model.

Crossed-wire pinning which is the most resistant pin configuration in many biomechanical studies, is commonly accepted fixation method. However, there are some authors who advocated the use of the third wire to prevent the displacement of the distal fragment.[24,25] According to Skaggs et al.[19] the crossing of the wires or the number of wires are not very important, but the engagement of the sufficient bone in the proximal and distal fragment is more important. Maximum separation of the pins at the fracture site is very important for the biomechanical stability. Kallio et al.[31] advocated that the pins should be aimed toward the posterior cortex at an angle of 10° with the diaphyseal axis. Special attention should be directed for optimum pin placement with the lateral techniques. The use of a third pin requires the more medial pin to enter the joint and thus increases the risk of joint penetration and infection. It is suggested that the most appropriate way was to position the divergent pins on the lateral cortex. In our study, the pins were directed to the posterior cortex of the humerus in the patient who developed cubitus varus deformity. We preferred the use of two pins laterally to decrease the risk of infection. We used the third pin for the old children or large bones, when a good stability was not achieved. Lee at al.[16] suggested that the medial epicondyle is in a relatively posterior position anatomically, so the medial pin of the crossed-wires is typically inserted in a slight posterior to anterior direction. This also may allow

increased anterior opening at the fracture line and results in loss of reduction.

The commonly known complication in the treatment of closed reduction and percutaneous pinning of displaced supracondylar fractures of the humerus is iatrogenic ulnar nerve palsy with the use of medial pin.[32-36] The rate of ulnar nerve injuries varies in different studies. Lyons et al.[33] have reported this number as 6 %, Royce et al.[34] as 3%, Ağuş et al.[35] as 58 %. According to Ippolito et al.[36] the difference in the incidences was a result of neurological examinations which were not well detailed. Also the examinations of the children in the emergency room were hard to detect the neurogical injuries. So the incidences may be higher.[34] And also the hypothesis of hyperflexion of elbow during placement of the medial pin increases the risk of nerve injury was also suggested.[20] It is found that postoperative nerve palsies after percutaneous pinning was with direct injury to the nerve, not after manipulation of closed reduction.[29,30,32,34] Skaggs et al.[20] noted the incidence of ulnar nerve injury as 4% in patients whom the pins were applied without hyperflexion of the elbow and as 15% in whom the medial pin was applied with the elbow hyperflexed. Different techniques are performed to decrease the rate of ulnar nerve injury. Wind et al.[37] advocated the use of ulnar nerve stimulation with a stimulator or K-wire for identification of nerve location. Royce et al.[34] performed a short medial percutaneous incision for the swollen elbows. Also it is suggested that the mechanism of the nerve injury is not only due to direct penetration of the nerve but also due to the iatrogenic construction of the nerve by the cubital tunnel retinaculum. In cases of swelling, there is a risk for medial pinning and also the retraction of skin around the pin is also a potential risk for injury.[37,38] It is also showed that lateral-pins decrease the rate of ulnar nerve injury when compared with medial-pins, however this method has not accomplished the risk. Foed et al.[39] noted 2 ulnar nerve injuries of laterally pinned 32 patients and 5 ulnar nerve injury in 34 medial-lateral pinned group. Subsequent follow up was done weekly. All of them recovered at the end of the 6th month.

Radial and interosseous nerve palsies are also noted in the laterally pinned supracondylar humerus fractures. Shannon et al.[30] noted 3 interosseous nerve injuries of 20 patients, and Foed et al.[39] noted 2 radial nerve injuries of patients of 32 patients. We did not note any injuries of these nerves. This may be coincidental, however the entry holes of the both pins were in the distal fragment in our technique, also the pins were directed from the lateral supracondylar ridge of the humerus. These applications may be effective in the results.

Although most of the ulnar nerve injuries recover spontaneously between 4 and 6 months, permanent damage have been reported in the literature.[34,38] Lyons et al.[33] observed spontenous functional recovery after the removal of medial pin. However, Rasool[38] advocated the early exploration of the nerve. Clawing of the fingers may occur rarely after ulnar nerve injuries. Pathological electromyographic measurements can be detected in most of ulnar nevre injuries during the early postoperative period.

This condition is miserable fort the child's family and the surgeon. Iatrogenic nerve injuries are gaining importance currently in our country while new rules are put in order to judge these malpractises.

As a result we concluded that our results are successful with the application of our surgical method. The main goal of the treatment of displaced pediatric supracondylar humerus fractures is to achieve an anatomic reduction. This reduction should be supported by a fixation with a good stability and less morbidity. When all these are taken into consideration, we believe that closed reduction and percutaneous lateral pinning is an efficient, reliable and safe method.

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