



Functional results of the parallel-plate technique for complex distal humerus fractures

Paralel plak tekniği ile tedavi edilen kompleks humerus distal uç kırıklarında fonksiyonel sonuçlar

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Amaç: Kompleks humerus distal uç kırığı nedeniyle açık redüksiyon ve paralel plak tekniğiyle internal tespit uygulanan hastaların fonksiyonel sonuçları değerlendirildi.

Çalışma planı: Kompleks distal uç humerus kırığı nedeniyle 21 hasta (14 erkek, 7 kadın; ort. yaş 47; dağılım 16-85) olecranon osteotomisi ile açık redüksiyon ve paralel plak tekniğiyle tedavi edildi. Kırıklara ileri derecede eklemiçi veya metafizer parçalanma (n=10), eklemiçi parçalanma ve osteoporotik özellikler (n=7), eklemiçi ve metafizer parçalanma ile birlikte kemik kaybı (n=4) eşlik etmekteydi. AO sınıflamasına göre, kırıkların 12'si C3, altısı C2, üçü C1 kırık idi. Sekiz hastada açık kırık vardı. Kırık ile ameliyat zamanı arasındaki süre ortalama altı gün (dağılım 1-17 gün) idi. Fonksiyonel sonuçlar Mayo dirsek performans skoru, Jupiter dirsek skoru ve Kol, Omuz ve El Engellilik (DASH) skoru ile değerlendirildi. Ortalama takip süresi 28 ay (dağılım 12-48 ay) idi.

Sonuçlar: Toplam hareket açıklığı ortalama 90.2±31.1°, fleksiyon 118.1±17.4°, ekstansiyon 27.8±17.4° bulundu. Mayo dirsek performans skoru ortalama 86.1±12.6, DASH skoru 7.6±9.5 idi. Jupiter dirsek skoruna göre sonuçlar yedi hastada mükemmel, 11 hastada iyi, iki hastada orta, bir hastada kötü olarak değerlendirildi. Radyografik olarak, hiçbir hastada kaynama sorunuyla karşılaşılmadı. Yedi hastada (%33.3) değişik derecelerde heterotopik ossifikasyon görüldü; iki hastaya ciddi hareket kısıtlılığı nedeniyle heterotopik ossifikasyon rezeksiyonu yapıldı. Bir hastada derin enfeksiyon nedeniyle debridman yapıldı. Bir hastada ise dirsek eklemine kondroliz gelişti. Açık kırıklı hastaların hareket açıklığı anlamlı derecede daha düşük bulunurken (p<0.05), Mayo dirsek performans ve DASH skorları kapalı kırıklı hastalardan farklılık göstermedi (p>0.05).

Çıkarımlar: Erken harekete izin verecek stabilitede osteosentez tekniği ve paralel plaklama tekniği ile tedavi edilen distal humerus kırıklarında fonksiyonel sonuçlar tatmin edicidir.

Anahtar sözcükler: Kemik plağı; dirsek eklemi/cerrahi; kırık tespiti, internal/yöntem; kırık, parçalı; humerus kırığı/cerrahi.

Objectives: We evaluated functional results of patients treated with open reduction and internal fixation with the parallel-plate technique for complex distal humerus fractures.

Methods: Twenty-one patients (14 males, 7 females; mean age 47 years; range 16 to 85) underwent open reduction with olecranon osteotomy and internal fixation with the parallel-plate technique for distal humerus fractures accompanied by highly intra-articular or metaphyseal comminution (n=10), intra-articular comminution and osteoporosis (n=7), and intra-articular and metaphyseal comminution with bone loss (n=4). According to the AO classification, there were 12 C3, six C2, and three C1 type fractures. Eight patients had open fractures. The mean time to surgery was six days (range 1 to 17 days). Functional results were evaluated using the Mayo elbow performance score, Jupiter elbow score, and DASH (Disabilities of the Arm, Shoulder and Hand) score. The mean follow-up was 28 months (range 12 to 48 months).

Results: The mean total range of motion was 90.2±31.1°, flexion was 118.1±17.4°, and extension was 27.8±17.4°. The mean Mayo elbow performance score and DASH score were 86.1±12.6 and 7.6±9.5, respectively. According to the Jupiter elbow scores, the results were excellent in seven patients, good in 11 patients, moderate in two patients, and poor in one patient. Radiographically, solid union was achieved in all the patients. Heterotopic ossification of varying degrees was seen in seven patients, two of whom underwent resection of heterotopic ossification due to severe limitation of movement. Debridement was performed in one patient due to the development of deep infection. Chondrolysis of the elbow occurred in one patient. Patients with open fractures had significantly lower range of motion than those with closed fractures (p<0.05), but the Mayo elbow performance score and DASH score did not differ significantly in this respect (p>0.05).

Conclusion: Functional results are satisfactory in distal humerus fractures treated with stable osteosynthesis and parallel-plate technique that allow early active motion.

Key words: Bone plates; elbow joint/surgery; fracture fixation, internal/methods; fractures, comminuted; humeral fractures/surgery.

Intra-articular fractures of the distal humerus are very rare. They comprise only 0.5% of all fractures.^[1] The treatment of these fractures is still debated, and an ongoing quest for the ideal solution still remains. In the elbow the principles of absolute stabilization and early mobilization is of more importance than in any other joint.^[2-4] According to the AO classification, nonunion and implant loosening is more common in type C fractures of the distal humerus involving the joint surface.^[6] This type of fracture is more frequent in elderly women with osteoporosis.^[1] In these patients there is an increased incidence of problems with osteosynthesis.

In complex fractures of the distal humerus the treatment is generally more difficult and the failure rate higher with old internal fixation techniques.^[7] In order to classify a fracture as complex, the following criteria are required:^[4,7] (i) advanced intra-articular or metaphyseal fragmentation ; (ii) poor bone quality (osteoporotic); (iii) bone loss; (iv) history of failed internal fixation.

Biomechanical and clinical studies have shown that the double plate technique where the plates are placed at right angles to each other (medial and posterolateral) can not sometimes provide adequate stability for some types of fractures.^[6,8-10] To overcome this problem, a parallel plating technique has already been developed by moulding the plates into the anatomical curve of the distal humerus.^[7] The only report on this technique was published by the team who first invented it.^[4] Further retrospective data is required to determine the superiority of the parallel plating technique over other methods.

In this study, the results of the parallel plating technique in patients with complex distal humerus fractures were analyzed.

Patients and methods

Çalışmaya, 2004-2007 yılları arasında, kompleks distTwentyone adult patients (14 men, 7 women; mean age 47; distribution 16-85) operated on between 2004-2007, were included in the study. All of the patients were treated with a parallel plating technique for complex fractures of the distal humerus.

Twelve of the fractures were caused by road traffic accidents, 7 patients fell at home and the remaining two fell from a height.

The pattern of the complex fractures was as follows: In 10 patients there was intra-articular or metaphyseal fragmentation. In 7 patients intra-articular fragmentation and osteoporotic features were present and the remaining 4 patients had intra-articular and metaphyseal open fractures with bone loss.

Multiple concomitant traumatic injuries were also present in the patients included in this study. These injuries were more frequent in patients who sustained high-energy trauma. Twenty additional injuries were present in 10 patients. These included closed head trauma in 3 patients (1 patient was operated on due to a subdural hematoma), femoral shaft fractures in 3 patients, tibial fractures in 2 patients, pelvic fractures in 4 patients, the distal radius fractures in 2 patients, double forearm fractures in 2 patients and lumbar (L4) burst fracture, olecranon fracture, the patella fracture, the medial malleol fracture all occurring in four separate patients.

According to the AO classification^[5] 12 patients had C3, 6 patients had C2 and 3 patients had C1 cervical neck fractures. According to Gustilo-Anderson classification^[11] there were grade 2 open fractures in six patients, and grade 3B open fractures in 2 patients.

There was an average delay of six days (distribution 1-17 days) between the admission of the patients and the surgery. Two patients had delayed surgery due to multiple fractures requiring a series of operations. Three other patients needed intensive care unit management before the surgery which caused a delay.

Surgical techniques

All patients were operated on in the supine position under a pneumatic tourniquet. The elbow was exposed with a posterior approach and the ulnar nerve was dissected and retracted. The fracture and joint surface were then exposed by a "V" shaped olecranon osteotomy in 19 patients. In one patient the joint surface was exposed between the fragments of the existing olecranon fracture. The last patient did not require osteotomy as the fracture was exposed from the medial and lateral sides of the triceps.

Fragments of the joint surface were reduced and temporarily fixed with Kirschner (K) wires. Once the joint surface had been restored, the diaphysis and distal fragments were reduced and again temporarily fixed using 2.0 mm K-wires. Acutrak (Acumed, Hillsboro,



Figure 1. (a,b) Anteroposterior and lateral radiographs of a comminuted Gulltillo-Anderson type II open intercondylar fracture, in a 47-year-old male patient (c) Open reduction with metaphyseal shortening and internal fixation with anatomical plates (d) Complete healing of the fracture was seen 3 years after the operation. Note the heterotopic ossification which recurred after its surgical removal.

Oregon, USA) screws were used in two patients for fixation of the intra-articular fragments. The metaphyseal butterfly wedge fragments were also reduced to maintain the column length. In three patients, there was a severely comminuted metaphyseal fragmentation involving both medial and lateral columns along with soft tissue damage. In these patients the humeral diaphysis was embedded in the metaphysis resulting in a 2 cm shortening of the humeral length^[7] (figure 1).

Mayo anatomic plates (Mayo Clinic Congruent Elbow Plates, Acumed, Hillsboro, Oregon, ABD) were used for permanent fixation. Osteosynthesis was achieved step by step according to the principles described by the team that developed the system.^[7,12] The anatomical plates were placed to the medial and lateral columns parallel to each other. Plate length was chosen according to the proximal extension of the fracture line and each plate was fixed at least with three bicortical screws at the diaphysis. The plates were fixed to the distal fragment with 3.5 mm cortical screws, extending to the opposite condyle and the proximal fixation was initially done with a cortical screw. Then the fracture was compressed at the supracondylar level with the insertion of an eccentric screw through one of the proximal holes in both plates. An attempt was made to hold the distal fragments together by at least 2 screws extending to the opposite column. Proximal fragments were fixed according to the configuration of the fracture by at least three bicortical screws. In patients with advanced

osteoporotic fractures and metaphyseal fragmentation, locking screws have been used since the end of 2005. Once stability was achieved, the olecranon osteotomy was reduced and fixed by a long cancellous or a 6.5 mm cannulated screw using the tension band technique. In 15 patients in whom the medial plate extended to the ulnar groove, anterior transposition of the ulnar nerve was also performed. Skin grafting was required in two patients with grade 3B open fractures. In one of these patients the skin graft was applied during the surgery; whereas in the other patient the skin graft could only be performed following a 10 day application of a vacuum dressing.

Postoperative care

Following the operation, the elbow was bandaged and immobilized in a splint at 120° of flexion. The arm was kept elevated for 3–4 days in order to reduce the oedema and inflammation. The splint was subsequently removed and active assisted ROM exercises were initiated. Ice was applied following the exercises. On average the patients were discharged at the end of the first week. At this point the splint was removed and a hinged elbow brace was used to protect the internal fixation. Indomethacin prophylaxis for heterotopic ossification was performed for the first postoperative month (75 mgr/day) (13).

Patients were followed-up on a weekly basis for the first six weeks. Then the patients were seen every



Figure 2. Preoperative (a,b) X-Rays and (c,d) CT scans of a 57-year-old female patient who sustained a comminuted intraarticular intercondylar humerus fracture. (e,f) Control X-Rays and (g,h) elbow range-of-motions, 4 years after the open reduction and internal fixation with parallel plating.

month for follow-up until the 6th postoperative month. After this, they were seen six-monthly. Functional ability, the elbow range of movement, Mayo elbow performance scores, ^[14] Jupiter elbow scores ^[15] and the arm, shoulder and hand disability (Disabilities of the Arm, Shoulder and Hand-DASH) scores ^[16] as well as radiological findings were evaluated at the final follow-up. The mean follow-up period was 28 months (range 12 to 48 months). T test was used to evaluate the effect of various factors including age, heterotopic ossification and fracture type on functional ability. The spearman coefficients were used in the correlation analysis.

Results

At the last follow-up the mean range of elbow movement was $90.2 \pm 31.1^\circ$, flexion was $118.1 \pm 17.4^\circ$, and extension was $27.8 \pm 17.4^\circ$. In eighth patients (38.1%)

the extension lag was less than 30 degrees and there was more than 130° of flexion. No limitation in the pronation-supination was detected with the exception of those who had an accompanying proximal radial-ulnar fracture (Figure 2). The mean Mayo elbow performance score was 86.1 ± 12.6 in the last follow-up. Jupiter elbow score results were excellent in 7 patients, good in 11, moderate in 2, and poor in one. The mean DASH score, which considered the effect of upper limb problems on daily activity, was 7.6 ± 9.5 .

Radiographically, union was achieved in all patients both at the fracture and the olecranon osteotomy sites. Heterotopic ossification of varying degrees (Brooker type 4 in 2 patients, type 3 in 3 patients and type 2 in 2 patients) was seen in seven patients, two of whom underwent resection of the heterotopic ossification due to severe elbow stiffness.

Two patients developed complications that resulted in permanent problems. In one patient a deep infection developed requiring surgical debridement and the removal of all osteosynthetic material, at 8 months, following the healing of the fracture. This patient scored poorly on the Jupiter score, however he was still able to return to work and function at full capacity. Chondrolysis of the elbow occurred in the other patient. This patient has been followed conservatively as he had no pain nor functional inability.

In seven patients (33.3%) complications requiring surgery occurred, but did not result in permanent damage. In two patients resection of heterotopic ossification was performed for limitation of movement due to brooker type 4 heterotopic ossification. In five patients due to irritation, the implants used for fixation of the olecranon osteotomy were removed. In two of these patients the column procedure with resection of anterior and posterior capsule was performed to increase elbow range of movement.

As a prognostic factor only open fractures had a significant negative effect on the range of movement ($p < 0.05$). There was no significant difference between patients with open fractures or closed fractures in terms of Mayo elbow performance scores and DASH scores ($p > 0.05$). Factors such as the formation of heterotopic ossification, fracture type and surgery delayed for more than one week did not affect functional ability ($p > 0.05$).

There was a significant correlation between the DASH, Mayo elbow scores and the range of movement values ($p < 0.05$).

Discussion

Management of fractures of the distal humerus, especially those which are intra-articular, is always difficult for both surgeons and patients. Many clinical and experimental studies have been performed in order to find an effective method for a stable, painless and functional result in these patients. It has been shown that the treatment attempts with minimal osteosynthesis and long term immobilization resulted in severe elbow stiffness.^[15,19,20] For many years more rigid fixation techniques to allow early mobilization, have been researched to avoid this complication. Early range of movement is of greater importance after the elbow fractures than any other intra-articular fracture.^[15,21] However there are two significant obstacles to

be surmounted in order to achieve this objective. The first challenge is to find an appropriate implant congruent with the anatomy of the distal humerus, that allows sufficient stability.^[2,22] The second problem is that these fractures often occurs in elderly osteoporotic patients or in young adults who have been exposed to high-energy trauma. The search for an appropriate implant to provide stable osteosynthesis has been ongoing for several years.^[23] In this study anatomically pre-shaped plates developed by the Mayo Clinic have been applied properly according to the principles described by the developing team.^[7] In biomechanical studies, the parallel plating technique was shown to be superior to the perpendicular (medial and posterolateral) plating technique.^[9,10] This system allows greater perioperative stability than previous reconstruction or 1/3 tubular plates, as confirmed by the absence of non-union in our series.

According to the AO classification, in type A and B distal humerus fractures, more satisfactory results were obtained.^[6] However in large series, problems such as nonunion and heterotopic ossification have been reported in low transcondylar and comminuted intra-articular fractures.^[6] In our patients there were complex comminuted fractures due to osteoporosis and high energy trauma. None of our patient had a previously failed surgery.

The post-operative complications of distal humerus fractures are classified under five main headings: union problems (at the fracture and olecranon osteotomy sites), elbow stiffness, infection, nerve injury and late arthritis related to trauma. The reported prevalence of union problems was between 0-9%.^[2-5,11,14,16,19] Non-union of distal humerus fractures has been attributed to the fracture configuration and to the instability of the fixation materials.^[4,6] In this study union problems have not been seen in any patients. Problems of union at the olecranon osteotomy site are more frequent after transverse osteotomies.^[3] We have not encountered any non-union after fixation with a 6,5 mm long cannulated screw and tension band wiring technique. However, in five patients (23.8%) fixation material was removed because of discomfort. Stiffness is a common problem after elbow fractures. Although the frequency of capsular contracture and heterotopic ossification has not been analyzed, a rate of 4 to 16 % of resurgery for elbow stiffness has been reported in several studies.^[4,21] In two patients, heterotopic

ossification leading to limitations of movement, was resected. Infection is more frequent after open and comminuted elbow fractures. In our series the only patient who required debridement due to infection was a patient with a grade 3B open fracture. In the literature infection has been reported at a rate of 3 to 7 %.^[2,4,6] Complications such as nerve damage and avascular necrosis^[2,4,6,15,21] have not been encountered in our series. Although joint surface degeneration rate is reported up to 80% in the long-term studies, this complication did not affect the clinical results at the same rate.^[2,15] In our series only one patients developed high grade postraumatic arthritis due to chondrolysis, however this patient had a satisfactory functional outcome and therefore was managed conservatively. In most studies about the distal humerus fractures the results were evaluated according to the range of motion and different scoring systems.^[2-4,14,15,19,22] The DASH score that evaluate upper extremity as a whole has been used in few studies.^[2,24] In our study range of motion was in agreement with other studies.^[2,4,24] In our study where most problematic complex fractures were addressed, four patients eventually had some limitation despite resurgery to increase the range of motion. However, the functional score of these patients was not bad. Despite the mild to moderate limitation of motion, patients could continue with their daily life. In another longer term (19 years) study, a similar result has been reported.^[2]

The only prognostic factor with a negative effect on range of motion and functional scores was open fractures. In open fractures, the final range of movement and functions are worse than closed fractures, probably due to soft tissue damage.^[4]

In conclusion, the parallel plating technique is a succesfull treatment option in the management of complex fractures of the distal humerus, when one complies with the principles. Our results also support this. The absolute stability of the system allowing early range of motion is probably the most important advantage of this technique. Introduction of an early rehabilitation program along with the emphasis on early use of the elbow will improve the functional success of this technique.

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