RESEARCH ARTICLE / *Araştırma Makalesi*

Comparison of Clinical and Radiological Results of Orthogonal and Parallel LC-DCP Plating in AO Type C Distal Humerus Fractures

AO Tip C Distal Humerus Kırıklarında Ortogonal ve Paralel LC-DCP Plaklamanın Klinik ve Radyolojik Sonuçlarının Karşılaştırılması

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Öz

Objective	AO (Arbeitsgemeinschaft für Osteosynthesefragen) type C distal humerus fractures are difficult fractures to reduce and fix due to the difficulty of the elbow anatomy and small size of the broken bone parts. We hypothesize that although parallel plating technique is biomechanically superior for humerus distal fracture, orthogonal plating technique in clinical conditions is as reliable and effective as a method of parallel plating for Type C humerus fractures.
Materials and Methods	Between 2012 and 2018, 36 patients who underwent operations for AO type C distal humerus fractures and met the inclusion criteria were evaluated retrospectively. Parallel plating was performed in 20 patients and orthogonal plating (medial and posterolateral plating) in 16 patients. All patients were fixed with LC-DCP plates. Quick DASH, Mayo elbow, and VAS scores; grip strength; elbow ROM (Range of Motion); extension loss; and evaluations complications at the last visit.
Results	There was no statistically significant difference between the groups in terms of the Quick DASH, Mayo elbow, or VAS scores, grip strength, elbow ROM, extension loss, union time, postoperative heterotrophic ossification, elbow and olecranon nonunion, post-op neuropraxia, or other complications ($P > 0.05$). There was a statistically significant difference between the two groups regarding ulnar nerve transposition ($P < 0.05$).
Conclusion	There are no functional, radiological, or complicated advantages between parallel plating and orthogonal plating, which are frequently used in the literature, for treating type C distal humerus fractures. The surgeon can safely use both techniques, depending on the type of fracture and how both columns are broken.
Keywords	Humerus distal fractures; Parallel plating; Orthogonal plating; intraarticular fractures

Abstract

Amaç	*AO (Arbeitsgemeinschaft für Osteosynthesefragen) tip C distal humerus kırıkları, dirsek anatomisinin zorluğu ve kırık kemik parçalarının küçük olması nedeniyle redükte edilmesi ve düzeltilmesi zor kırıklardır. Humerus distal kırığı için paralel plaklama tekniği biyomekanik olarak daha üstün olmasına rağmen, klinik koşullarda ortogonal plaklama tekniğinin Tip C humerus kırıkları için paralel plaklama yöntemi kadar güvenilir ve etkili olduğunu varsayıyoruz.*
Gereç ve Yöntemle	*2012-2018 yılları arasında AO tip C distal humerus kırığı nedeniyle ameliyat edilen ve çalışmaya alınma kriterlerini karşılayan 36 hasta retrospektif olarak değerlendirildi. 20 hastaya paralel, 16 hastaya ortogonal (medial ve posterolateral) plaklama uygulandı. Tüm hastalar LC-DCP plakları ile tespit edildi. Quick DASH, Mayo dirsek ve VAS skorları; kavrama gücü; dirsek EHA (Eklem Hareket Açıklığı); ekstansiyon kaybı; ve son kontrolde komplikasyonlar değerlendirildi.*
Bulgular	*Gruplar arasında Quick DASH, Mayo dirsek veya VAS skorları, kavrama gücü, dirsek EHA, ekstansiyon kaybı, kaynama süresi, postoperatif heterotrofik ossifikasyon, dirsek ve olekranon kaynamama, ameliyat sonrası nöropraksi veya diğer komplikasyonlar açısından istatistiksel olarak anlamlı fark yoktu ($P > 0.05$). Ulnar sinir transpozisyonu açısından iki grup arasında istatistiksel olarak anlamlı bir fark vardı ($P<0.05$).*
Sonuç	*Literatürde sıklıkla kullanılan paralel plaklama ile ortogonal plaklama arasında tip C distal humerus kırıklarının tedavisinde fonksiyonel, radyolojik veya komplikasyon açısından bir avantaj bulunmamaktadır. Cerrah, kırığın tipine ve her iki kolonun nasıl kırıldığına bağlı olarak her iki tekniği de güvenle kullanabilir.*
Anahtar Kelimeler	*humerus distal kırıkları; paralel plaklama; ortogonal plaklama; eklem içi kırıklar*

INTRODUCTION

Distal humerus fractures comprise 2% of all fractures and one-third of all humerus fractures.[1,2] These fractures are usually comminuted fractures. Due to the complex anatomical structure of the distal humerus and limited amount of subchondral bone, surgical treatment of these fractures is more difficult than for other intra-articular fractures. These fractures occur as a result of slipping down in the elderly, higher-energy falling in young patients, and motorcycle and traffic accidents.

The purpose of treatment of intra-articular fractures of the distal humerus is to provide maximum elbow movement painlessly. Therefore, surgical treatment is the gold standard for treating these fractures. The risk of functional impairment following a distal humeral fracture is high if treated nonoperatively.[3] It is very important to give early joint movement in distal humerus fractures after surgery to prevent elbow stiffness. Prolonged immobility of the elbow joint causes serious contractures; therefore, a strong internal fixation should be applied for the distal humeral fracture. Techniques for restoring the necessary stabilization and anatomical structure in distal humeral fractures are discussed in the literature and it is recommended to use at least two plates.[2, 4-7] The application method of the plates used is still controversial in the literature. Strong internal fixation with absolute anatomical reduction is essential when treating distal humeral fractures. Due to the principles popularized by the AO (Arbeitsgemeinschaft für Osteosynthesefragen) group, orthogonal plating has become a method used by surgeons in recent years.[6,8,9] In the literature, parallel plating is another recommended fixation method, especially for distal humeral bicolumn fractures.[10] There are some studies that show that it provides better stabilization with this method, which is frequently used in osteoporotic fractures.[4,7] The application of two plates to the medial and lateral columns makes it a common technique for multiple-part fractures of the double colon.

The aim of this study is to compare the clinical and radiological results of orthogonal plating and parallel plating in type C distal humerus fractures to compare the advantages of the two techniques.

MATERIALS and METHODS

Patients who underwent operations in our clinic for distal humeral tip fractures between 2012 and 2018 were retrospectively analyzed. We received ethic approval from M.S. Baltalimanı Bone Diseases Teaching and Research Hospital Ethics Committee for this descriptive study (09.03.2020/058-413). The study was conducted in accordance with the principles of the Declaration of Helsinki. Patients with type C fractures (according to the AO classification)10,11 who underwent parallel plate or orthogonal plating operations, were over 18 years of age, had at least 12 months of follow-up, and received LC-DCPs (Limited Contact Dynamic Compression Plates) for fixation were included in the study. Patients with different injuries in the same extremity, pathological fractures, AO type A or type B fractures, Gustillo Type 3 open fractures, patients without olecranon osteotomy, or patients who could not be operated on within 7 days were excluded from the study. Thirty-six patients met the study criteria and were analyzed retrospectively. Orthogonal plating (medial and posterolateral plating) was performed in 16 patients and parallel plating in 20 patients. The mean age of the patients was 37.1 (18-69 years old) and 20 were women and 16 were men. The mechanisms of injury were: 5 patients had traffic accidents, 19 patients had slips down, 7 patients had high falls down, and 5 patients had motorcycle accidents. Nine patients had 14 additional injuries (4 femoral fractures, 4 tibial fractures, 1 other extremity humerus fracture, 1 pelvic fracture, 2 head trauma, and 2 other extremity radius distal fracture). The following data were also collected: age, gender, side, time before surgery, smoking, type of fracture, additional injury, duration of union, follow-up time, and complications. Functionally, the Quick DASH, Mayo elbow, and VAS (Visual Analog Scale) scores were evaluated at the final follow-ups.[12] Elbow ROM (range of motion) and extension loss were measured. The grip forces

were evaluated by comparing the force of the operated arm with that of the intact side.

Surgical technique and postoperative process

Surgery was started for all patients under the tourniquet. The elbow was placed on the arm holder and a 90° flexion position was given. The posterior approach was used. The ulnar nerve was dissected and taken under protection. Chevron olecranon osteotomy was performed for all patients. After the joint surface was fully visible, reduction was started. Small bone parts related to the joint were fixed with temporary K wires. Headless screws (Acumed Hillsboro, Oregon, USA) were used in 11 patients for joint reduction. After joint restoration, the LC-DCP plate application method was left to the surgeon's preference. After fracture reduction was achieved, the distal part was fixed to the distal diaphysis of the humerus. We performed shortening in three patients due to multi-part metaphyseal fragmentation. In orthogonal plating, for fixation, the medial and posterolateral plates were perpendicular to each other (Figure 1 and Figure 2). In parallel plating, the anatomical plates were placed in the medial and lateral columns and fixation was performed. LC-DCP (Acumed Hillsboro, Oregon, USA) plates were used in both groups (Figure 3 and Figure 4). Olecranon osteotomy was fixed with plates or tension bands. Ten patients underwent ulnar nerve transposition.

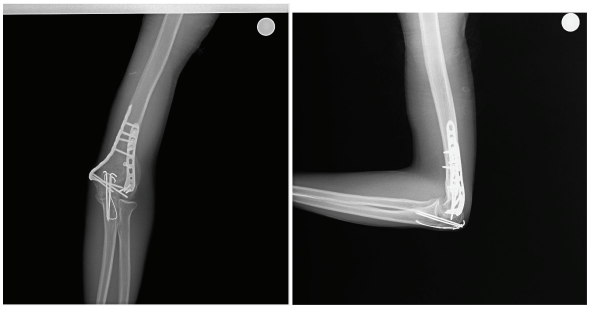

Figure 1 Orthogonal plating postoperative 12. Months

Figure 2 Preoperative views before orthogonal plate application

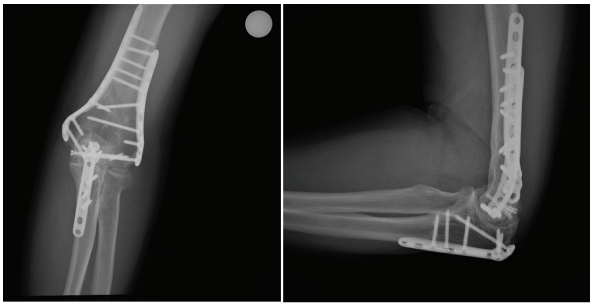

Figure 3 Parallel plating postoperative 12. Months

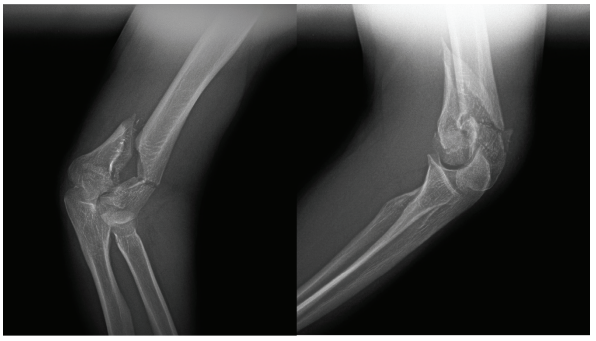

Figure 4 Preoperative views before parallel plate application

The shoulder arm strap was applied to all patients postoperatively, and elbow movements were started within 7 days at the latest in a way that the patient could tolerate. Heterotrophic ossification prophylaxis was not applied to any patient.

In the final follow-ups of the patients, clinical examinations and radiological evaluations were evaluated by different orthopedists.

Statistical analysis

While evaluating the findings of the study, the IBM SPSS Statistics 22 (IBM SPSS, USA, New York) program was used for statistical analysis. The Mann-Whitney U test was used to evaluate the parameters that were not normally distributed. When the parameters were evaluated with the Shapiro-Wilks test, it was seen that the parameters were not homogeneously distributed. Values between the two groups were evaluated using the Mann-Whitney U test. The chi-square test and fischer test was used for categorical variables. Values with p values of <0.05 were considered statistically significant.

RESULTS

In the parallel plate group, eleven patients were female and nine were male. Six patients had type C1, nine C2, and five C3 fractures. The mean values at the last meeting were 19.55 (0-61.4) for the Quick DASH, 87.8 (65-100) for the Mayo elbow, 2.8 (1-5) for the VAS, and 34.5 (14- 64) for the grip strength in the fractured limb (Table 2). Elbow ROM was evaluated as an average of 129.3° (110-135). Extension loss was observed in 5 patients; the mean extension loss was 2.6° (0-10). The mean follow-up was 19.1 (12-33) months. When evaluated radiologically, the union time of the patients in the parallel plate group was 17.1

Table 1. Demographic variables of patients with parallel plates ve orthogonal plates

	Parallel Plates (n: 20) Median (Min-Max)	Orthogonal Plates (n: 16) Median (Min-Max)	p values
Gender			0,94***
Female	11	9	
Male	9	7	
Age	36,7 (18-59)	40,4 (18-69)	0.48*
Fracture side			0,54***
Right	8	8	
Left	12	8	
Type of Trauma			
Traffic Accident	4	1	
Slip Down	11	8	
High Fall Down	3	4	
Motorcyle accident	2	3	
Before the operation time	4,8 (1-7)	4,08 (1-7)	0.37*
Smoking	6 (% 30)	2 (%12,5)	0.25**
Fracture type			0.62***
C1	6 (%30)	4 (%25)	
C2	9 (%45)	7 (%43,7)	
C3	5 (%25)	5 (%31,2)	
Additional Injury	6	3	0.43***

*Mann Whitney U test
**Fisher's Exact test
***Chi Square test

Table 2. Functional scores , examination and complication of patients with parallel plates and orthogonal plates

	Parallel Plates (n: 20) Median (Min-Max)	Orthogonal Plates (n: 16) Median (Min-Max)	p values
Quick DASH Score	19,55 (0-61,4)	22,6 (0-72,7)	0,81*
Mayo Elbow Score	87,8 (65-100)	83,7 (35-100)	0,93*
VAS	2,8 (1-5)	2,7 (1-5)	0,84*
Elbow ROM	129,3 (110-135)	126,6 (100-135)	0.91*
Extension Loss	2,6 (0-10)	5,41 (0-20)	0.17*
Grip Strength			
Healthy Side	41 (18-62)	36 (18-54)	0.25*
Fracture Side	34,5 (14-64)	29,5 (17-52)	0.53*
Union Time (Week)	17,1 (13-25)	18,8 (14-27)	0.57*
Follow Up	19,1 (12-33)	16,2 (12-28)	0,61*
UNT	9 (%45)	1 (%6,2)	0,01 **
Nerve Neuropraxia	3 (%15)	2 (%12,5)	0.82 ***
Olecranon Nonunion	1 (%5)	1 (%6,2)	0.87***
HO	2 (%10)	2 (%12,5)	0,81***
Other Complication	2 (%10)	1 (%6,2)	0.68***
Elbow Nonunion	1(%5)	0	0.36***

*Mann Whitney U test
**Fisher's Exact test
***Chi Square test
(UNT: ulnar nerve transposition, VAS: visual analog scala, ROM: range of motion, HO:Heterotrophic ossification)

(13-25) weeks. Revision was performed in one patient due to elbow nonunion. Olecranon pseudoarthrosis was seen in one patient. In 2 patients, heterotrophic ossification was observed during follow-up. Post-op ulnar nerve neuropraxia was observed in 2 patients, radial nerve neuropraxia in 1 patient, and infection in 2 patients.

Two patients had elbow and olecranon nonunion; one received an autograft alone, and the other underwent grafting with iliac wing and revision surgery. In their last follow-ups, union was observed in these patients. One of the 2 patients with infection was debrided; wound healing was seen after surgery. In the other patient, only antibiotic therapy was given since the infection was superficial and wound healing was achieved. Nine patients underwent ulnar nerve transposition. Recovery was observed in 3 patients with neuropraxia. We released one of two patients with HO (heterotrophic ossification); we did not consider the need for surgery with the other patient.

In the orthogonal plate group, nine patients were female and seven were male. Four patients had type C1, seven had C2, and five had C3 fractures. The mean Quick DASH score of the patients at the last meeting was 22.6 (0-72.7), Mayo elbow score was 83.7 (35-100), VAS score was 2.7 (1-5), and grip strength in the fractured limb was 29.5 (17 -52). The mean elbow ROM was evaluated as 126.6 (100-135). Extension loss was observed in 6 patients. The mean extension loss was 5.41 (0-20). The mean follow-up was 16.2 (12-28) months. When evaluated radiologically, the mean union time of the patients in this group was 18.8 (14-27) weeks. No patient had elbow nonunion and one patient had olecranon nonunion. Two patients had heterotrophic ossification, two patients had ulnar nerve neuropraxia, and one patient had an infection.

We performed grafting and revision with an iliac wing autograft to a patient with olecranon nonunion, and union was observed during follow-up. We achieved wound he-

aling with local debridement and antibiotic therapy in an infected patient. Recovery was observed during follow-up in 2 patients with ulnar nerve neuropraxia. We did not consider the need for surgery in two patients with HO.

For olecranon osteotomy, plates were used in 30 patients and tension bands in 6.

There was no statistically significant difference in terms of age, gender, broken side, time before operation, smoking, type of fracture, or additional injury between the groups (Table 1) ($p> 0.05$).

When evaluated radiologically and functionally, there was no statistically significant difference in terms of the Quick DASH, Mayo, and VAS scores, broken side grip strength, union time, HO, elbow and olecranon nonunion, postop neuropraxia, or other complications (Table 2) ($p> 0.05$).

DISCUSSION

Appropriate fixation methods for intra-articular fragmented distal humerus fractures are widely discussed in the literature.[13-16] Regardless of the fixation method, the main goal is the proper anatomical reduction of this fracture. The strong bicolumn internal fixation afterwards prevents the joint from starting early movement and the development of elbow contracture. Current biomechanics studies always recommend the double-plate application. Compared to single-plate or screw fixation treatment, both clinically and biomechanically, the double-plate treatment provides a stronger fixation.[17] Papaioannou et al. compared the screws applied with minimally invasive methods and the double-plate fixation method applied according to AO principles. The double-plate method showed better results in the series of 75 cases.[17] The best way to apply the double-plate method is still controversial. The cadaver study performed by Caravaggi et al. showed that cadavers with locked parallel plates were more resistant to axial forces than those with orthogonal locked or unlocked plates.[18] Self et al. compared the parallel plate method with methods that fixed plates in many orthogonal positions. A study on sixteen cadavers showed that parallel plating was the strongest fixation method, especially in comminuted fractures;[19] however, Jacobson et al. claimed that orthogonal plating was stronger according to parallel plating in the frontal plane. The plates used in this study were reconstruction and DCP plates.[20] Although, biomechanically, parallel plating is a stronger stabilization method in many studies, it is thought that the superiority of these two methods cannot be demonstrated in the clinic. Eryuva et al., in their 17-case study, observed no significant differences was found between patients with parallel plates and those with 90-angle plates in terms of Mayo scores, elbow ROM, or extension loss.[14] Lee et al., in their prospective randomized study of 72 cases, observed no significant functional, radiological, or complication-related differences between the results of the parallel and orthogonal plating methods.[21] Yu et al., in a meta-analysis, evaluated eight studies that compared the results of orthogonal plating and those of parallel plating and reported that the groups were similar in terms of function, radiology, and complication rates.[22] In our study, there were no significant functional, radiological, or complication-related differences between the two methods, in accordance with the literature. Although parallel plating provides biomechanically superior stabilization, we think that this situation does not show an advantage over orthogonal plating in a clinical evaluation. Schuster et al. compared reconstruction plates, locking compression plates (LCP), and distal humerus plates (DHP) to parallel plate use in type C distal humerus fractures. LCP and DHP have been shown to provide stronger stabilization in osteoporotic fractures.[23] In our study, the LC DCP was used in both methods. In the literature, it is recommended to use LC DCPs, rather than reconstruction plates, in these fractures, especially for stronger stabilization.[24]

In distal humerus intra-articular fractures, olecranon osteotomy is generally preferred for joint reconstruction in the literature.[25-27] In our study, olecranon osteotomy was

performed in several cases, but olecranon nonunion can be seen due to the osteotomy. In the meta-analysis performed by Koziarz et al., 24 studies involving tension band and plate application in olecranon fractures were evaluated. They showed that fixation with plates is less complicated and fewer implant removals than fixation with tension bands.[24] In our study, we mostly preferred using plates for osteotomy fixation. Olecranon nonunion was observed in 2 patients. We used plates in one of these two patients and tension band in the other. In these patients, union was achieved with autograft, graft, and revision surgeries.

Early rehabilitation is required for a successful outcome in distal humeral fractures.[28] Early mobilization opposes the effects of immobilization on the capsular, ligamentous, osteochondral, and muscular tissues. For early rehabilitation, strong stabilization and subsequent edema and pain formation must be prevented. In our study, all the patients were given shoulder arm slings. Afterwards, the pain was taken under control and elbow rehabilitation was started as soon as possible.

There are some literature suggesting routine ulnar nerve anterior transposition after surgery in distal humeral fractures.[29,30] However, Wroden et al. showed that no significant difference was found in terms of ulnar neuropraxia in the late period between patients who underwent anterior transposition and in situ release in the series of 24 cases.[31] Therefore, he suggested applying transposition when tension was observed, instead of routine anterior transposition. In our study, ulnar nerve transposition was performed in 10 patients (27.7%) with tension during post-surgical elbow movements. This decision is left to the surgeon performing the surgery.

There are some limitations of this study. It is a retrospective study, the surgeons who performed the surgery were different, and the plaque application method was left to the preference of the surgeon. Since there was no significant difference between the types of fractures, we think that these limitations will not affect the clinical and radiological results since orthopedic surgeons who have performed this surgery have sufficient experience in elbow surgery. We think that the number of patients examined in both groups is sufficient, compared to similar studies in the literature.

CONCLUSION

In type C distal humerus fractures, strong internal fixation is essential for union and early rehabilitation. We think that there are no functional, radiological, or complicated advantages between parallel plating and orthogonal plating, which are frequently used in the literature. The surgeon can safely use both techniques, depending on the type of fracture and how both columns are broken.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest. No benefits have been or will be received from a commercial party related directed or indirectly to the subject matter of this article.

Ethical approval

This article does not contain any studies with animals performed by any of the authors. This study had an ethical committee approval from the local institution. (Date: 09.03.2020 Number 058/413)

Informed consent

Informed consent was obtained from all individual participants included in the study.

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