RESEARCH ARTICLE / *Araştırma Makalesi*

Is There an Ideal Surgical Treatment for Adult Complex Distal Humerus Fractures?

Erişkin Distal Humerus Kompleks Kırıklarında İdeal Cerrahi Tedavi Seçeneği Var Mı?

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Abstract

Introduction	The purpose of this study is to compare the advantages and disadvantages of various surgical techniques in the treatment of distal humerus complex fractures.
Materials and Methods	Seventy-one patients with distal humerus diaphysis fractures who were treated between 2015 and 2020 were retrospectively investigated. The patients were treated with the posterior approach of open reduction and plate-screw osteosynthesis (Group A), plated with the minimal invasive technique (Group B), operated using the lateral approach (Group C) and treated with an external fixator (Group D). Age, gender, mechanism of fracture, fracture type and AO class, applied surgical method, additional injuries, duration of operation, amount of bleeding, amount of fluoroscopy used, length of hospital stay, radiological angular values, union time, complications, and clinical examination findings of the patients were examined retrospectively and the differences between the mentioned surgical methods were investigated.
Results	Blood loss was significantly less in Groups C and D ($p < 0.001$). The use of fluoroscopy was less in Group A. The length of stay in Group B was significantly shorter than for Group D ($p < 0.001$). Union time was significantly longer for Groups B and D compared to Groups A and C ($p < 0.05$). Shoulder abduction strength loss was higher in Group D ($p < 0.001$).
Conclusion	The fixation with the hybrid external fixator in cases in the distal area that makes plaque placement difficult and especially in multi-part humeral diaphysis fractures is a method that gives good functional results as well as other methods that can be used.
Keywords	Humerus fracture; Diaphysis; minimally invasive; external fixation;

Öz

Amaç	*Çalışmanın amacı distal humerus kompleks kırklarında uygulanmış farklı cerrahi tekniklerin avantaj ve dezavantajlarının karşılaştırılmasıdır.*
Yöntem ve Gereçler	*2015-2020 yılları arasında distal humerus diafiz kırığı tanısı alarak cerrahi tedavi planlanan hastalardan posterior yaklaşım kullanılarak açık redüksiyon ile plak-vida osteosentezi(Grup A), minimal invaziv teknikle plaklama(Grup B), Lateral yaklaşım kullanılarak plak,vida osteosentezi(Grup C) ve eksternal fiksatör ile tespit(Grup D) yapılan 71 humerus kırığı çalışmaya dahil edildi. Hastalar yaş, cinsiyet, kırığın oluş mekanizması, kırığın şekli ve AO sınıfı, uygulanan cerrahi yöntem, ek yaralanmalar, ameliyat süresi, kanama miktarı, kullanılan floroskopi miktarı, hastanede kalış süreleri, radyolojik açısal değerler, kaynama zamanı, komplikasyonlar, muayene bulguları retrospektif olarak incelenerek belirtilen cerrahi yöntemler arası farklılıklar araştırıldı.*
Bulgular	*Kan kaybı miktarı Grup B ve D' de istatistiksel olarak anlamlı derecede az bulundu ($p<0.001$). Floroskopi kullanımı; Grup A'da daha az bulundu. Hastanede kalış süresi Grup B'de Grup D'ye göre kısa bulundu ($p<0.001$). B ve D grubunda kaynama süresi A ve C grubuna göre anlamlı şekilde uzun bulundu ($p<0.05$). Omuz abdüksiyon kuvveti ölçümünde grup D' de grup A ve B'ye göre anlamlı kayıp vardı($p <0.001$).*
Sonuç	*Hibrid eksternal fiksatör ile tespit yönteminin plak yerleşimini zorlaştıracak kadar distal bölgede bulunan, yumuşak doku problemi olan, özellikle çok parçalı humerus diafiz kırıklarında kullanımı diğer yöntemlerle benzer şekilde iyi fonsiyonel sonuçlar vermesi açısından uygun bir cerrahi seçenektir.*
Anahtar Kelimeler	*humerus kırığı; diyafiz; minimal invaziv; eksternal fiksasyon*

INTRODUCTION

Humeral shaft fractures are a common orthopedic injury and constitute 1–3% of all fractures. Approximately 10% of humeral body fractures occur as distal third fractures.[1,2] This fracture is commonly associated with sports injuries and high-energy trauma in younger individuals, however, it may occur in older individuals after falls.[1,2,3] These fractures can result in significant complications with regard to functionality, particularly in patients with fractures close to the elbow joint. Fracture-induced permanent deformities in this area may cause functional loss in the elbow joint and in the hand.[4]

Although humeral shaft fractures can be treated using conservative methods, surgical treatment is required in some patients, including in those with open fractures, in patients with an improper post-reduction fracture alignment, in patients with vascular and/or nerve injuries, and in patients with segmental fractures.[5]

Surgical treatment includes plate-screw osteosynthesis, intramedullary nailing, and external fixation.[6]

Surgical treatment enables early return to work for patients and minimizes the loss of the work force. It is also a cost-effective option for treatment. Surgical treatment has therefore been preferred in recent years.

Although many studies in the current literature have described humerus distal diaphyseal fractures, the exact indications for surgical treatment of these fractures remain unclear.6 The purpose of this study is to compare the advantages and disadvantages of various surgical techniques in the treatment of distal humerus fractures.

MATERIALS and METHODS

Between 2015 and 2020, 71 patients with complex distal humerus fractures treated surgically over the five years with a minimum six-month follow-up were included in the study. Patients were categorized into the following groups: those operated on using a posterior approach comprising open reduction and plate-screw osteosynthesis (Group A), those who underwent minimally invasive plating (Group B), those who underwent an operation using a lateral approach (Group C), and those who underwent external fixator placement (Group D).

Exclusion criteria were as follows: (a) fractures that extended to the shoulder and elbow joint, (b) fractures of the proximal humeral diaphysis, (c) fractures treated using conservative management, and (d) unavailability of complete medical records.

The following patient data were documented from hospital records to compare the surgical methods used: age, sex, fracture mechanism, type and AO classification of the fracture, surgical method, surgical time, intraoperative blood loss, amount of fluoroscopy used, length of hospitalization, postoperative radiologically documented angulation, fracture healing time, complications, and postoperative clinical evaluation findings.

Clinical and radiological evaluation

Angulation on anteroposterior and lateral radiographs and healing time were evaluated postoperatively. Varus angulation was considered negative (-) and valgus angulation was considered positive (+) on the anteroposterior radiographs. Flexion angulation was considered positive (+) and extension angulation was considered negative (-) on the lateral radiographs.

Fracture healing was defined as the absence of pain along the fracture line on clinical examination with a strong and continuous callus bridge in at least three cortices on the anteroposterior and lateral radiographs.[7]

Clinical evaluation included measurements of the range of motion at the elbow joint using a goniometer and of the strength of elbow flexion and extension, as well as of the strength of shoulder abduction (expressed in N) using a

digital hand dynamometer (Figure 1). These values were compared with those of the unaffected side, and the rate of loss relative to the unaffected side was calculated. The strength:loss ratio of the other side based on the measured maximum strength was calculated for the patients who underwent surgery for bilateral fractures.

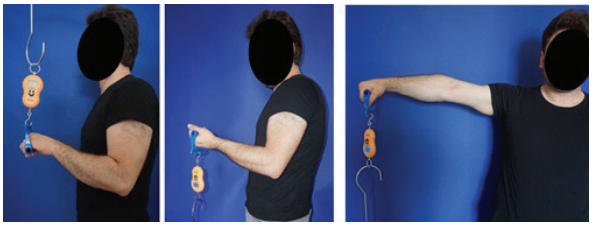

Figure 1: Incision and retraction made to protect the ulnar nerve

The Quick Disabilities of the Arm, Shoulder and Hand Questionnaire (QuickDASH) scale and the Mayo elbow performance index (MEPI) score were used for functional evaluation.

Statistical analysis

Descriptive analyses were performed to obtain information on the general characteristics of the study population. The Kolmogorov-Smirnov test was used to test the normality of the variables. One-way analysis of variance (One-way ANOVA) and the Kruskal-Wallis analysis of variance were used to compare the total scores of the continuous variables among the four groups. The Mann-Whitney U test with the Bonferroni adjustment was used for multiple comparisons. Normally distributed continuous data were expressed as mean±standard deviation and non-normally distributed continuous variables were represented by the median and interquartile range (Q1–Q3). Categorical variables were compared using the chi-square test and were presented as counts and percentages. A p value <0.05 was considered statistically significant. All analyses were performed using the SPSS Statistics version 23.0 software program (IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp.)

Ethics committee approval

This study was approved by the Ethics Committee of the Sakarya University Medical Faculty (14/11/2017 - 71522473/050.01.04/218)

RESULTS

Of the 71 patients included in the study, 29 (41%) were females and 42 (59%) were males. The patients' mean age was 35.3 (16–89) years. The right humerus was involved in 38 (54%) patients and the left humerus was involved in 33 (46%) patients, while the dominant side was involved in 42 (59%) patients.

The fracture mechanisms were as follows: traffic accidents in 32 (45%) patients, simple falls in 32 (45%) patients, falling from a height in five (7%) patients, and gunshot injuries in two (3%) patients.

The distribution of the fractures based on the AO classification was as follows: 1-2-A1 in two patients, 1-2-A2 in three patients, 1-2-B1 in 29 patients, 1-2-B2 in 19 patients, 1-2-B3 in 10 patients, 1-2-C1 in three patients, and 1-2-C3 in five patients.

The posterior approach was used in 20 patients (Group A), the anterior minimally invasive approach (MIPO) was used in 15 patients (Group B), the lateral approach was used in 17 patients (Group C), and hybrid external fixator placement was used in 19 patients.

The mean time between the commencement and completion of surgery was 77.4 minutes. The mean surgical time was 65 (60–70) minutes in the minimally invasive approach (MIPO), 75 (70–85) minutes in the lateral approach, 77.5 (70–87.5) minutes in the posterior approach, and 70 (70–90) minutes in the hybrid external fixator group. The shortest and longest surgical times were 30 minutes and 180 minutes in the MIPO and the posterior approach groups, respectively. No statistically significant intergroup difference was observed in surgical time (p

Table 1. Results of the comparisons among the four groups for patient characteristics

	Group A (n=20)	Group B (n=15)	Group C (n=17)	Group D (n=19)	P *
Age	32.15±8.2	42.87±22.1	33.47±13.48	34.68±10.18	0.131
Gender, male	12 (60)	9 (60)	11 (64.7)	10 (52.6)	0.905
Side, right	12 (60)	7 (46.7)	9 (52.9)	10 (52.6)	0.890
Surgery length (min)	77.5 [70-87.5]	65 [60-70]	75 [70-85]	70 [70-90]	0.079
Loss of blood (ml)	200 [150-200]	50 [50-80]	180 [150-200]	50 [35-50]	**<0.001** [a]
Flouroscopy usage (Sec)	9.5 [7-17]	36 [25-60]	24 [24-36]	70 [60-78]	**<0.001** [b]
Fracture healing time (day)	52 [42-60]	72 [65-80]	56 [48-60]	100 [90-120]	**<0.001** [a]
Elbow range of motion	135 [130-135]	135 [130-135]	135 [130-135]	130 [130-135]	0.296
Loss of flexion strength %	0 [0-0]	12.5 [0-16.6]	0 [0-10]	10 [0-15]	**0.002** [c]
Loss of extension strength %	0 [0-14]	0 [0-12.5]	10 [0-12.5]	12.5 [0-25]	0.054
Loss of shoulder abduction strength %	0 [0-0]	0 [0-0]	0 [0-20]	15 [0-20]	**<0.001** [d]
Angulation, anteroposterior	0 [0-0]	-4 [-6-0]	-2 [-5-0]	-4 [-6-0]	**<0.001** [e]
Angulation, lateral	0 [-4.5-0]	-2 [-5-0]	0 [-3-2]	8 [4-12]	**<0.001** [f]
MEPI	100 [90-100]	85 [85-100]	90 [85-100]	90 [90-100]	0.164
QuickDASH	2.3 [0-5.65]	2.3 [0-9.1]	4.5 [0-11.4]	4.5 [2.3-6.8]	0.284
Hospitalization	7 [4.5-8]	5 [3-6]	7 [6-8]	9 [7-10]	**0.001** [g]
Postoperative Complications	0 (0)	1 (6.7)	2 (14.3)	0 (0)	0.598

Data were shown as mean±standard deviation, median [IQR] and n (%).
*: Pairwise comparison results were shown in Table 2.

=0.079) (Table 1).

The mean intraoperative blood loss was 121.6 (30–300) mL. The mean intraoperative blood loss was 50 (50–80) mL in the MIPO, 180 (150–200) mL in the lateral approach, 200 (150–200) mL in the posterior approach, and 50 (35–50) mL in the hybrid external fixator group. A statistically significant intergroup difference was observed in the volume of intraoperative blood loss and a significant difference was observed between the MIPO and the lateral and posterior approaches (p <0.001). A significant difference was also observed between the hybrid external fixator and the lateral and posterior approaches (p <0.001) (Tables 1 and 2).

The mean duration of fluoroscopy was 39 seconds. Fluoroscopy was not performed in all patients, however, the longest duration of fluoroscopy was 84 seconds. The fluoroscopy time across the study groups was as follows: 36 (25–60) seconds in the MIPO group, 24 (24–36) seconds

Table 2. Pairwise comparison results

Pairs	a	b	c	d	e	f	g
Group B – Group C	**p<0.05**	NS	NS	NS	NS	NS	NS
Group B – Group A	**p<0.05**	**p<0.05**	**p<0.05**	NS	**p<0.05**	NS	NS
Group B – Group D	NS	NS	NS	**p<0.05**	NS	**p<0.05**	**p<0.05**
Group C – Group A	NS	NS	NS	NS	**p<0.05**	NS	NS
Group C – Group D	**p<0.05**	**p<0.05**	NS	NS	NS	**p<0.05**	NS
Group A – Group D	**p<0.05**	**p<0.05**	**p<0.05**	**p<0.05**	**p<0.05**	**p<0.05**	NS

in the lateral approach group, 9.5 (7–17) seconds in the posterior approach group, and 70 (60–78) seconds in the hybrid external fixator group. A significant difference was observed between the posterior approach and the MIPO and external fixator groups (p <0.001) and between the lateral approach and external fixator groups (p <0.001). (Tables 1 2).

The mean length of hospitalization was 6.7 (3-10) days. The length of hospitalization was significantly shorter in the MIPO group than in the hybrid external fixator group (p <0.001) (Tables 1 and 2).

The mean time until fracture healing was 72.7 (36–120) days during postoperative follow-ups. The healing time was 72 (65–80) days in the MIPO group, 56 (48–60) days in the lateral approach group, 52 (42–60) days in the posterior approach group, and 100 (90–120) days in the hybrid external fixator group. The healing time was significantly longer in the hybrid external fixator and MIPO groups than in the posterior and lateral approach groups (p <0.05) (Tables 1 and 2).

The mean elbow joint range of motion measured during the follow-ups after fracture healing was 132.5º (125–135º). No statistically significant intergroup difference was observed (p =0.296) (Table 1). Angulations observed on the anteroposterior radiographs were higher in the MIPO, lateral approach, and hybrid external fixator groups than in the posterior approach group (p <0.001). Lateral angulation was significantly higher in the external fixator group than in the other groups (p <0.001) (Tables 1 and 2).

Elbow flexion strength loss was 12.5% (0–16.6) in the MIPO group, 0% (0–10) in the lateral approach group, 0% (0–0) in the posterior approach group, and 10% (0–15) in the hybrid external fixator group. Loss of flexion strength was greater in the MIPO and external fixation groups (p =0.002). No significant intergroup difference was observed in extension strength loss (p =0.054). Significant loss of shoulder abduction strength was observed in the external fixator group compared with the posterior approach and MIPO groups (p <0.001) (Tables 1 and 2). The mean MEPI was 92.9 (80–100), and the mean QuickDASH score was 4.5 (0–13.6). No intergroup difference was observed in the functional scores.

Five patients with preoperative radial symptoms showed symptom resolution within six months postoperatively. None of the patients developed iatrogenic injury. Nonunion and implant failure occurred in one and two patients, respectively. No significant intergroup differences were observed in complications.

DISCUSSION

Although many studies have described humerus distal diaphyseal fractures, the exact indications for surgical treatment of these fractures remain unclear.[6] The purpose of this study is to compare the advantages and disadvantages of various surgical techniques in the treatment of distal humerus fractures.

This study showed that the surgical time was longer in both groups that underwent open reduction and plate-screw osteosynthesis. In a study performed by Esmailiejah et al., the authors compared 33 patients with humeral fractures treated with plate-screw osteosynthesis together with open reduction and 32 patients who underwent MIPO and observed that the surgical time was shorter in the MIPO group, although this difference was statistically insignificant.[8,9] Catagni et al. reported a mean surgical time of 30 minutes in a study that investigated 84 patients who underwent external fixation for humeral diaphyseal fractures.[10] Surgical time is an important variable that is known to affect the outcomes of all operations.[8] Longer surgical time is associated with a higher complication rate.8 In the present study, the surgical time was longer in both groups that underwent open reduction and plate-screw osteosynthesis, which is consistent with findings of previously reported studies. Although the surgical time

was shorter in patients who underwent the minimally invasive and hybrid external fixator procedures, intergroup comparison showed no statistically significant differences . In the present study, blood loss was lesser in the groups in which minimally invasive and hybrid external fixator techniques were used than in the other groups. This difference was statistically significant . Blood loss accompanying long bone fractures may weaken an individual's immunity and predispose patients to infection and sepsis. Reportedly, the average total blood loss in patients with humeral shaft fractures was approximately 500 mL.[11] Current studies in the literature have reported that minimally invasive methods are associated with a low volume of blood loss.[12,13,14,15] Fluoroscopic guidance, particularly for minimally invasive procedures, is widely being used in orthopedic surgery. Reportedly, radiation exposure is significantly higher during minimally invasive surgical procedures than during open surgery.[16,17,18] In the present study, the duration of fluoroscopy was significantly longer in the external fixator group than in the open surgery group. A statistically significant increase was observed in the MIPO group compared with the lateral approach group.

In the present study, the healing time was longer in the hybrid external fixator and MIPO groups than in the other groups, in contrast to the findings reported in the current literature, and this difference was statistically significant. In this study, no statistically significant difference was observed in the healing time between the posterior and lateral approach groups, which concurs with the results of previous reports in the literature.[9,19,20] A retrospective study that compared conventional open reduction and plate-screw osteosynthesis with the MIPO technique for middle and distal humeral shaft fractures reported that the MIPO technique was associated with more rapid healing.[18] In another study by Esmailiejah et al., the healing time was shorter in patients who were treated using the MIPO technique compared with those who underwent open reduction and plating, however, the difference was statistically nonsignificant.[9] Yin et al. reported no significant difference in healing time in a study that compared the lateral and posterior approaches for the management of distal humeral diaphyseal fractures.[19] Scaglione et al. reported a mean healing time of 12 weeks (83.2 days) among 85 patients who underwent external fixator placement as the definitive treatment for humeral diaphyseal fractures.[20] Healing time is an important factor associated with functional restoration in patients, with treatment costs, and with the loss of work power. The longer healing time observed in the hybrid external fixator group is attributable to the fact that patients who underwent external fixation were exposed to significant high-energy trauma, and external fixation was performed for comminuted fractures with a short distal fracture fragment. The delay in the MIPO group is attributable to the application of the relative fixation.

Shoulder and elbow range of motion may be adversely affected by the surgical technique used for treatment of humeral fractures. Studies in the literature have not reported a significant difference between the minimally invasive and open reduction plating techniques.[18,21] In the present study, upon treatment completion, no statistically significant difference was observed, which is consistent with the findings of previous studies.

The acceptable parameters to avoid functional and cosmetic issues in cases of humeral diaphyseal fractures include the following: 3 cm shortness, 20° anterior-posterior angulation, and 30° varus angulation.[22] Esmailiejah et al. compared patients who underwent MIPO and those who underwent open surgery and observed that the MIPO group included a greater number of patients with >5° of varus deformity, however, the difference was statistically nonsignificant.[9] Studies have reported that among the various techniques used for the management of complex humeral diaphyseal fractures, the plate-screw osteosynthesis method is associated with superior results radiologically.[23] A limited number of reports have discussed the use of external fixators for humeral diaphyseal fractures. In a study by Aynacı et al., in which an external fixator was

used to treat humeral diaphyseal fractures, the authors did not observe malunion in any patient.[30] However, a statistically significant intergroup difference was observed in the angulation measured on the anteroposterior radiographs. Statistical analysis showed lesser angulation in the posterior approach than in the other groups . Varus and valgus angulation measured in all groups were within acceptable limits and were not associated with cosmetic issues in any patient.[22] Lateral angulation was significantly higher in the hybrid external fixator group than in all other groups in the present study. The greater sagittal plan angulation in the hybrid external fixator group is attributable to the closed surgical method used and to the inability to perform open anatomical reduction.

Postoperative evaluation of extremity function is based on measurements of functional scores and range of motion to perform intergroup comparisons.[9,18] Muscle strength is measured using special devices and dynamometers to assess isokinetic muscle strength.[23,24] Broadbent et al. measured elbow flexion and extension strength in 110 patients with humeral fractures and observed that flexion strength loss was lesser in the non-surgical group than in the surgical group and it was greater in those with delayed union. Notably, patients with delayed union also showed greater extension strength loss.[23] In the present study, using a simple hand dynamometer, elbow flexion, extension strength, and shoulder abduction strength were measured in both extremities after complete fracture healing. Loss of strength, if any, was calculated as a percentage relative to the unaffected side. Flexion strength loss was greater in the MIPO and hybrid external fixator groups than in the posterior approach group.

No statistically significant intergroup difference was observed in the percentage of extension strength loss . Following paired comparison, significant shoulder abduction strength loss was observed in the external fixator group compared with the posterior approach and MIPO groups . In the view of the authors, the greater loss of abduction strength in the hybrid external fixator group than in the other groups is attributable to the fact that the Schanz screws driven proximal to the fracture line were located close to the deltoid muscle, these patients presented with complex types of fractures, and this method was selected owing to difficult reduction in these patients. Additionally, the hybrid external fixator system placement results in pain and restricted shoulder movements during fixation; therefore, patients may avoid shoulder movements, which may contribute to the significant loss of shoulder abduction strength.

The MEPI used to evaluate elbow joint function is frequently described in current literature. No intergroup difference was observed in the MEPI scores across several previously reported studies.[9,18,27] In a study performed by Yin et al., no intergroup difference was observed in the MEPI scores between the posterior and lateral approaches.28 In the present study, no significant intergroup difference was observed in the MEPI scores.

The DASH score is commonly used for the intergroup comparison of shoulder, elbow, and hand functions. Some studies reported no significant difference in the DASH scores of different methods used for humeral diaphyseal fractures with regard to functionality.[19] In the present study, no significant intergroup difference was observed in the DASH scores.

A retrospective study that compared the MIPO technique with conventional open reduction and plate-screw osteosynthesis for middle and distal humeral shaft fractures reported a lower rate of iatrogenic radial nerve injury (0–31.3%) in the MIPO group.[18] A study that compared the lateral and posterior approaches showed a statistically significant lower rate of complications associated with the lateral approach.[19]

Scaglione et al. reported delayed healing and refracture in one patient each in a study that investigated 85 patients

with humeral diaphyseal fractures treated with an external fixator.[20] In the present study, no significant intergroup difference was observed in the complication rates.

CONCLUSION

The functional results of different surgical techniques applied in similar fracture types were similar. The selection and application of a suitable treatment for an existing fracture can lead to better functional results regardless of the surgical method used. Fixation with the hybrid external fixator in cases where the distal area makes plate placement difficult, particularly in multipart humeral diaphyseal fractures, provides good functional results as along with the other methods that can be used. All known methods yielded similar functional results. Thus, the surgical method selected will primarily be based on the surgeon's preference.

Conflict of Interest

None of the authors received any outside funding or grants in support of their research or for the preparation of this work. Neither they nor any member of their immediate families received payments, other benefits, a commitment or an agreement to provide such benefits from a commercial entity.

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Declaration of Contribution

AÇ Uyar, Writer of the manuscript. Corresponding author.
A Kochai, Co-writer of the manuscript.
M Uysal, Reviewer of the manuscript.
A Akar, Data collection.
U Özdemir, Manuscript editing.

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