—Original—

Comparison of Single-Plate and Double-Plate Osteosynthesis with Locking Plate Fixation for Distal Humeral Fracture in Older Adults

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Background: Management of transcondylar fracture of the humerus in older adults remains a challenging issue in trauma surgery. Both single- and double-plate fixation are used, and the best procedure is yet to be determined. This retrospective study evaluated and compared the clinical and radiological outcomes of single- and double-plate fixation for transcondylar humeral fracture.

Methods: This study included older adults (age >65 years) with transcondylar fractures of the humerus (AO/OTA 13A2-3; transverse, transmetaphyseal fracture) treated at our hospital between 2002 and 2019. The patients were divided into two groups based on the fixation procedures they underwent, namely, single (group S) or double (group D) locking plate osteosynthesis. Postoperative outcomes were investigated.

Results: Group S and group D comprised 11 (11 women) and 17 (2 men; 15 women) patients, respectively. In group S, the elbow was immobilized in a long-arm cast or splints for 2 weeks to prevent early displacement of fracture. Residual numbness of the ulnar digits was observed in two patients in group S and in nine patients in group D. No significant difference was noted between the two groups in the ratio of loss of reduction, loosening of the medial screw, ulnar nerve disturbance, or clinical outcomes. The ratio of elbow contracture significantly differed between 2 groups. The elbow flexion angle was significantly lower in group S.

Conclusions: Open reduction and internal fixation with a double plate appears to be the optimal choice for early postoperative mobilization and maintenance of flexion and arc of the elbow joint.

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Key words: distal humeral fracture, double-plate osteosynthesis, single-plate osteosynthesis, locking plate, elbow fracture

Introduction

Distal humeral fracture is uncommon in the general population. However, owing to an increase in the worldwide population of older adults (age ≥65 years)[1], transcondylar fracture of the humerus—an osteoporotic fracture—is becoming relatively common in this population[2–4]. Double-plate fixation of both medial and lateral columns is commonly used for distal humeral fractures in older adults[5–9]. However, postoperative complications such as deep infection, ulnar nerve disturbance, and complex regional pain syndrome have been reported[9–14]. A biomechanical study reported that single lateral locking plate fixation with a medial cannulated cancellous screw for distal fractures provided rigidity comparable to that of double-plate osteosynthesis with a locking plate[15]. As compared with more-invasive surgical procedures using double plates, single-plate fixation might also reduce postoperative complications, including myositis ossificans, contracture of the elbow joint, and ulnar nerve dysfunction[15]. However, few studies have compared single-plate and double-plate osteosynthesis with locking plate fixation for distal humeral fractures in older adults[9]. Therefore, this study evaluated clinical outcomes of single-plate and double-plate fixation for distal fractures

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of the humerus and compared the 2 procedures[9,15].

Materials and Methods

This retrospective case series was conducted at our institution and affiliated hospitals. This study was approved by the institutional review board of our institution (No. 30-12-1048, No. 450-30-21). The study protocol was consistent with the ethical guidelines of the 1975 Declaration of Helsinki. Written informed consent was obtained from all patients included in this study.

This study included older adults (age >65 years) with a diagnosis of transcondylar fracture of the humerus, (AO/OTA classification 13A2-3; transverse, transmetaphyseal fracture) and more than 3 months of follow-up data. The exclusion criteria included pathologic fracture, history of elbow trauma of the ipsilateral or contralateral side, history of osteoarthritis or rheumatoid arthritis of the elbow joint, a duration of postoperative follow-up greater than 3 months, and open reduction and internal fixation (ORIF) with the posterior approach via ulnar osteotomy. The patients were classified as single (group S) and double (group D) locking plate osteosynthesis groups. Data on demographics, medical history, imaging findings, and follow-up were extracted from the patients' medical records.

Preoperative Evaluation

Preoperative evaluation included anteroposterior and lateral radiographs. If the image quality of plain radiographs did not provide adequate fracture visualization, additional computed tomography scans with multiplanar reconstructions were obtained. The surgical procedure was selected by the attending surgeons.

Device Description

For single-plate fixation, the ONI transcondylar plate system (ONI plate, Teijin Nakashima Medical Co., Ltd., Japan) with a medical cancellous cannulated screw was used. This system comprises an angular stabilization plate with a transcondylar screw, which passes from the lateral epicondyle to the medial wall of the trochlea and finally locks to the ONI plate with the help of an exclusive set screw. For fixation of the medial column, a 4.5-mm cannulated cancellous screw is available.

Four different devices were used for the double-plate fixation, namely, the ONI transcondylar plate system (ONI plate, Teijin Nakashima Medical Co., Ltd. Japan), LCP DHP system (Synthes, Oberdorf, Switzerland), Acumed elbow plating system (Acumed, Hillsboro, OR, USA), and Advanced Locking Plate System elbow plating system (ZimmerBiomet, Chicago, IL, USA). All plating systems comprised 2 anatomically pre-shaped angular stable orthogonal or parallel locking plates.

Surgical Procedures

Surgery was performed with the patient under general anesthesia in the prone or lateral position. The arm was placed on a bar or a pillow, allowing an elbow flexion of up to 120°. A single dose of cefazolin 2 g was administered preoperatively. A pneumatic tourniquet was applied, and a curved posterior incision or bilateral incisions were made in the distal elbow. The ulnar nerve was identified and isolated. Fracture fragments of the distal humerus were reduced and temporarily fixed with Kirschner wires.

In group S, the ONI transcondylar plate system was used. The lateral plate with a transcondylar screw was locked to the plate with an exclusive set screw. For fixation of the medial column, a 4.5-mm cannulated cancellous screw was used in all patients. In group D, double plates were placed dorsolaterally and medially in an orthogonal fashion. In some elbows, the dorsolateral plate needed to be bent slightly to fit the individual anatomy of the distal humerus. The fracture was fixed with locked screws distally and cortical screws proximally. In group D, anterior repositioning of the ulnar nerve was performed when there was concern that the medial plate interfered with ulnar nerve after ORIF. Three hand surgeons individually performed all surgeries.

Postoperative Treatment

In group S, the elbow was immobilized in a long-arm cast or splints for 2 weeks. In group D, the elbow was supported by an upper arm sling for 1 week postoperatively. Active physiotherapeutic mobilization without load was initiated at 2 weeks in group S, and at 1 day after surgery in group D.

Postoperative Evaluation

Standard posteroanterior and lateral radiographs of each patient were obtained during the follow-up period. Any complications, including loss of reduction, screw loosening that affected the stability of plate fixation, ulnar nerve disturbance, contracture of the elbow joint, deep infection, and complex regional pain syndrome, were investigated. Contracture of the elbow joint was defined as more than 15 degrees in flexion and extension Clinical follow-up assessment included range of motion (ROM; measured using a goniometer), flexion and extension of the elbow joint, and Mayo Elbow Performance Score (MEPS) (**Table 1**)[16], which comprises pain, arc of the elbow joint, stability of the elbow joints, and functions related to activities of daily living. Pain in the el-

Table 1 Mayo Elbow Performance Score

Pain (45 points)		
	None	45
	Mild	30
	Moderate	15
	Severe	0
Motion (20 points)		
	Arc more than 100 degrees	20
	Arc 50 to 100 degrees	15
	Arc less than 50 degrees	5
Stability (10 points)		
	Stable	10
	Moderate instability	5
	Gross instability	0
Daily function (25 points)		
	Combing hair	5
	Feeding oneself	5
	Hygiene	5
	Putting on shirt	5
	Putting on shoes	5
Total		100
Excellent	>90	
Good	75-89	
Fair	60-74	
Poor	<60	

bow joint was classified as severe (presence of pain affecting daily activities), moderate (presence of pain not affecting daily activities), mild (presence of pain only when performing heavy physical labor), or absent.

Statistical Analysis

All statistical analyses were performed using the SPSS 25 software (SPSS Inc., Chicago, IL, USA). Patient characteristics were summarized using descriptive statistics. Continuous variables were reported as means and standard deviations, and categorical variables were reported as numbers and percentages. Continuous normally distributed variables were compared using the Welch *t*-test, whereas differences among categorical variables were analyzed using the Fisher exact test. *P*-values of <0.05 were considered significant. In addition, the 95% confidence interval (CI) was used to estimate the precision of statistical significance.

Results

Surgical treatment was performed for 47 patients of 63 consecutive patients with distal humeral fractures at our hospital and affiliated hospitals between April 2002 and March 2019. Among the 47 patients, 39 were older than 65 years, and 32 (2 men and 30 women) of these patients had a transcondylar fracture of the humerus—AO/OTA classification 13A2-3. All fractures resulted from low-energy trauma, and the mechanism of injury was a fall during walking in all cases. The 2 patients with a postoperative follow-up period of less than 3 months or missing data were excluded. Two patients who underwent ORIF through the posterior approach with an olecranon osteotomy were also excluded because of the possible influence of the osteotomy on the olecranon.

Table 2 presents the demographic characteristics of the 2 groups. All patients, except one who was treated with a bilateral approach, underwent ORIF through a posterior approach. Of the patients with fractures, one patient aged 74 years (group D) had open fractures (Gustilo type 1). In group D, 2 female patients (aged 83 and 63 years) had additional fractures of the distal radius on the ipsilateral side. Anterior repositioning of the ulnar nerve was performed to prevent irritation from medial plates in 14 patients in group D. No significant differences were noted between the 2 groups in terms of age, sex, injured side, mean time between injury and surgery, and follow-up duration; however, the ratio of the anterior repositioning of the ulnar nerve varied between the groups (95% CI: 0.444-1.203; P <0.05).

Table 3 shows patient demographics, complications, flexion/extension, arc of the elbow joint, and clinical outcomes according to the MEPS. There was no deep infection or complex regional pain syndrome in either group.

Table 2 Preoperative demographic characteristics of older adults with transcondylar fractures of the humerus

	Single plating (n = 11)	Double plating (n = 17)	95% CI (min–max)	P value
Age (years)	78.5 ± 6.8 (66 ～ 88)	81.1 ± 6.9 (66 ～ 94)	–2.858 ～ 8.058	0.337
Male:Female	0:11	2:15	–0.078 ～ 0.313	0.505
Left:Right	6:5	10:7	–0.333 ～ 0.418	1.000
Time between injury and surgery (days)	21.2 ± 38.1 (6 ～ 11)	17.8 ± 25.3 (1 ～ 111)	–27.944 ～ 21.144	0.778
Follow-up period (months)	21.6 ± 18.6 (3 ～ 64)	12.8 ± 8.8 (3 ～ 27)	–19.493 ～ 1.893	0.103
Anterior repositioning of the ulnar nerve	0	14	0.444 ～ 1.203	0.000*
Description of device	ONI transcondylar plate system, 11	ONI transcondylar plate system, 3 The LCP DHP system, 11 Acumed elbow plating system, 2 ALPS Elbow Plating System, 1		

Data are presented as mean ± SD.
Parentheses represent ranges.
Fisher exact test, Welch t-test.
CI, confidence interval.
*$P < 0.05$.

Table 3 Flexion/extension and arc of elbow joints and clinical outcomes in relation to Mayo elbow performance score

	Single plating (n = 11)	Double plating (n = 17)	95% CI (min–max)	P value
Complications				
Loss of reduction	1	0	–0.232 ～ 0.050	0.393
Loosening of screw (affected stability of plate fixation)	2	0	–0.377 ～ 0.013	0.146
Ulnar nerve disturbance (numbness of 4th/5th fingers)	2	9	–0.023 ～ 0.718	0.115
Contracture of elbow joint	7	2	–0.873 ～ –0.165	0.010*
Range of motion and arc of elbow joint				
Flexion range of injured elbow	111.3 ± 12.1 (80 ～ 120)	127.4 ± 10.2 (110 ～ 145)	7.375 ～ 24.825	0.001*
Extension range of injured elbow	–22.3 ± 11.5 (–40 ～ 0)	–21.8 ± 12.6 (–45 ～ 0)	–9.195 ～ 10.195	0.916
ROM (arc) of injured elbow	88.2 ± 19.8 (50 ～ 110)	105.0 ± 14.0 (75 ～ 130)	3.697 ～ 29.904	0.014*
Mayo Elbow Performance Score (Total Score)	89.1 ± 11.8 (60 ～ 100)	93.5 ± 8.1 (80 ～ 100)	–3.309 ～ 12.109	0.251
Pain	40.0 ± 6.7 (30 ～ 45)	38.2 ± 6.6 (30 ～ 45)		0.458
ROM	16.8 ± 4.6 (5 ～ 20)	20.3 ± 2.8 (15 ～ 25)		0.053
Stability	10.0 ± 0.0 (10)	10.0 ± 0.0 (10)		1.000
ADL	22.3 ± 4.1 (15 ～ 25)	25 ± 0.0 (25)		0.111

Data are presented as mean ± SD
Fisher exact test; Welch t-test; Mann–Whitney U-test; CI, confidence interval.
Parentheses represent ranges.
*$P < 0.05$

All patients exhibited fracture healing with no nonunions or heterotopic ossifications. However, in group S, 2 patients experienced loosening of the medial transcondylar screws, and one patient had a secondary loss of reduction; this patient underwent another double-plate osteosynthesis surgery (**Fig. 1A and B**). In group D, one patient experienced loosening of 2 distal locking screws, but there was no loosening of the screw that affected the stability of plate fixation. No major neurological disturbances were observed; however, residual numbness of ulnar digits was observed in 2 patients (18%) in group S and in 9 patients (53%) in group D. In group S, the cause of the numbness was migration of the medial screw. All patients with residual ulnar neuropathy underwent anterior transposition of the ulnar nerve in group D. There was no significant difference between the 2 groups in the

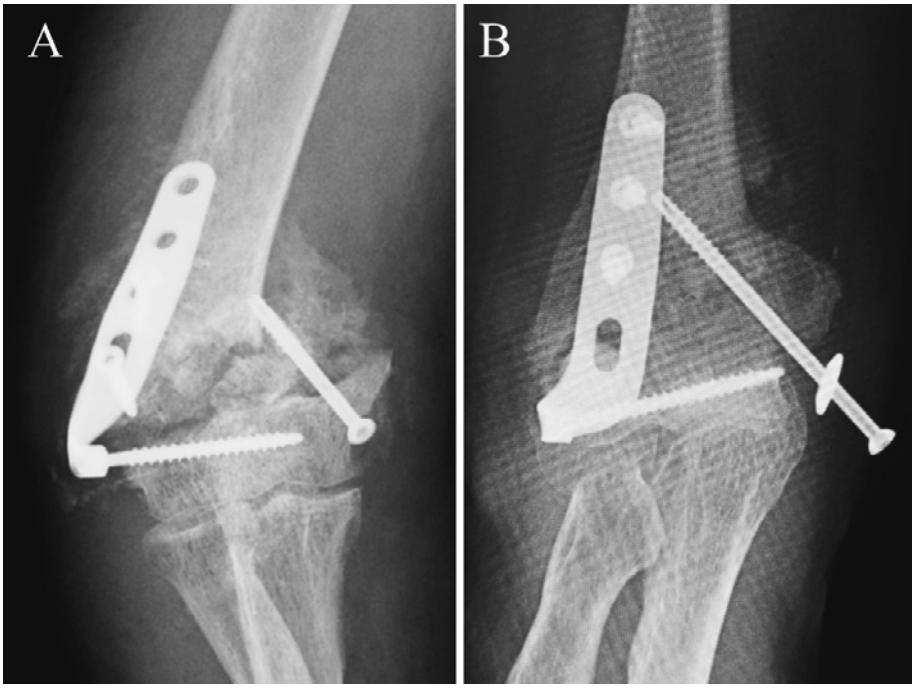

Fig. 1 In group S, two patients showed loosening of the medial transcondylar screw. One patient had a secondary loss of reduction and therefore underwent reoperation via double-plate osteosynthesis (A). The other patient achieved bone union, although loosening of the medial screw was observed (B).

ratio of loss of reduction, loosening of the medial screw, or ulnar nerve disturbance. In contrast, a significant difference was observed in contracture of the elbow joint, which occurred in 7 patients in group S and in 2 patients in group D.

The mean ROM of the elbow in group S was as follows: flexion, 111.3 ± 12.1° (range, 80° to 120°), and extension, −22.3 ± 11.5° (range, −40° to 0°). The mean ROM in group D was as follows: flexion, 127.4 ± 10.2° (range, 110° to 145°), and extension, −21.8 ± 12.6° (range, −45° to 0°). Rotation of the forearm, pronation/supination, was not restricted. The elbow total joint range (arc) in group S and group D was 88.2 ± 19.8° (range, 50° to 110°) and 105.0 ± 14.0° (range, 75° to 130°), respectively. Significant differences were observed in the mean flexion angle (95% CI: 7.375-24.825; P = 0.001) and mean arc of the injured elbow joint (95% CI: 3.697-29.904; P = 0.014). The mean flexion angle and mean arc of the injured elbow joint decreased significantly in group S. However, no significant difference in elbow extension was observed between the 2 groups.

The mean MEPS in group S was 89.1 ± 11.8 (range, 60-100) points, specifically, fair in 1, good in 3, and excellent in 7 patients. Conversely, the mean MEPS in group D was 93.5 ± 8.1 (range, 80-100) points, specifically, good in 6 and excellent in 11 patients. No significant differences were observed in MEPS between the 2 groups.

Discussion

This study investigated the clinical and radiological outcomes in older adults after ORIF for distal humeral fractures via single-plate fixation with an augmented medial screw or double-plate fixation. Adequate fracture fixation and satisfactory functional outcomes were achieved with double-plate fixation in older adults with reduced bone mass. In this study, older patients (age >65 years) with transcondylar fractures of the humerus (AO/OTA 13A2-3 fractures) had outcomes comparable with those of patients evaluated in previous retrospective studies[2,17]. Significant differences were observed in mean flexion range and mean arc of the injured elbow joint, which were restricted in group S. Single-plate osteosynthesis did not provide sufficient stability for early mobilization of the elbow joint; thus, routine immobilization for 2 weeks was required. Therefore, restriction of ROM might be attributable to the duration of immobilization of the elbow joint. Recent research reported that tasks of activities of daily living required a high degree of elbow flexion[18]. Because a greater than 15-degree restriction in the ROM of elbow joint limits many tasks, restriction of ROM has a severe adverse impact on activities of daily living.

Residual numbness of the ulnar digits was observed in

2 patients in group S and in 9 patients in group D. In group S, the cause of the numbness was migration of the medial screw. All patients with residual ulnar neuropathy in group D were among the patients who had undergone anterior repositioning of the ulnar nerve—9 out of 14 (64%) patients. This rate is higher than the 6-27% rate reported in other clinical trials[10–13]. Transposition of the ulnar nerve in elbow trauma is controversial. Some authors recommend routine transposition[19,20]; others do not[9,21,22]. The present patients in group D who underwent neurolysis without anterior transposition of the ulnar had no residual neurological disturbance. Thus, anterior transposition of the ulnar nerve might have resulted in postoperative residual numbness of ulnar digits.

In the present study, double-plate ORIF appeared to be the optimal choice for early postoperative mobilization and restoration of the ROM of the elbow joint. This result is consistent with those of some previous studies[5–9]. Several biomechanical studies reported that double-plate osteosynthesis provides adequate fracture stabilization under most conditions and thus is recommended for comminuted distal humeral fractures due to high-energy trauma[6,7,23]. However, intraoperative and postoperative ulnar nerve dysfunction associated with double-plate osteosynthesis has been frequently reported[9–13].

In contrast, one study proposed that single-plate osteosynthesis augmented with a medial screw may be an alternative for distal humeral fractures due to low-energy trauma[15]. However, the present findings indicate that single-plate osteosynthesis augmented with a medial screw may not provide sufficient stability for early mobilization of the elbow joint and may fail to achieve a satisfactory flexion range in older adults. The present results suggest that double-plate osteosynthesis may be the optimal choice to enable early postoperative mobilization and restoration of elbow ROM.

Limitations

The primary limitation of this study is its retrospective design, which makes the findings susceptible to bias. Other significant limitations include the small sample size and short duration of follow-up. Furthermore, the present patients all had distal humeral fractures due to relatively low-energy trauma, which differs from patients reported in other clinical trials. This may limit the comparability of our data with other studies. The difference between the 2 groups in the duration of postoperative immobilization of the elbow is another limitation of this study. In this study, 4 different plates were used in group D. Bulky plates may cause skin irritation or disturbance of nerves. In addition, fixation procedures (orthogonal vs. parallel fixation) may affect the stability of plate fixation. Moreover, this study investigated surgical outcomes of transcondylar fractures of the humerus (AO/OTA 13A2-3; transverse, transmetaphyseal fracture) in older patients subject to limited inclusion criteria. Finally, the choice of surgical procedure depended on the preference of the 3 hand surgeons, which might have led to selection bias. Prospective studies are warranted in order to obtain detailed information on the differences in clinical outcomes between the 2 procedures.

Conclusions

This comparative study of clinical outcomes of transcondylar fracture of the humerus in older adults revealed a significant lower flexion angle and arc of the injured elbow in patients who underwent ORIF with a single lateral plate with a medial cannulated cancellous screw, as compared with those who underwent double-plate fixation. In older adults, double-plate osteosynthesis appears to be the optimal choice for early postoperative mobilization and restoration of elbow ROM.

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