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Surgical Outcomes of Coronal Shear Fracture of the Distal Humerus in Elderly Adults

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Background: This study evaluated clinical outcomes of elderly adults with coronal shear fractures (CSFs) of the distal humerus treated by open reduction and internal fixation (ORIF).

Methods: Between April 2002 and March 2019, data from eight elderly patients (76.3 ± 5.1 years) with CSFs of the distal humerus were analyzed retrospectively. Postoperative complications, range of motion of the elbow joint, and functional elbow scoring (Mayo Elbow Performance Score; MEPS) were assessed.

Results: The mean follow-up duration was 23.6 ± 13.9 months. CSFs were treated by a buried implantable headless screw or Kirshner wires or bioresorbable screw with/without lateral locking plates. There were no superficial or deep infections or elbow joint instability. Seven patients obtained fracture healing, but one patient exhibited nonunion. Osteochondritis dissecans was present in one patient. Three patients had a step-off deformity (>2 mm) of the articular surface. Two patients exhibited collapse of the fractured articular surface. A patient with severe comminution of both the capitellum and trochlea exhibited collapse of the entire articular surface, with osteonecrosis of the capitellum and trochlea. Mean range of motion of the elbow was 116.3±12.7° of flexion and -28.8±14.1° of extension. The mean MEPS was 78.8±10.2 points, representing patients scored as excellent (n=1), good (n=3), and fair (n=4).

Conclusions: ORIF yielded satisfactory outcomes for elderly adults with noncomminuted CSFs of the distal humerus. However, treatment of comminuted articular fracture fragment and complex posterior fracture remains challenging. (J Nippon Med Sch 2022; 89: 81–87)

Key words: coronal shear fracture, distal humeral fractures, capitellum, trochlea, elbow injury

Introduction

As the global population of adults aged 65 years or older increases dramatically worldwide[1], distal humeral fractures in old age are increasingly common osteoporotic fractures[2–4]. Coronal shear fractures (CSFs) of the humerus have also been reported in older adults, although such fractures are uncommon[5–8]. In older adults with osteoporosis, CSFs of the distal humerus are usually caused by low-energy trauma, typically from falls. Direct compression force to an articular aspect from the radial head in a semi-flexed or hyperextended elbow, or from spontaneous reduction of an elbow subluxation or dislocation, is considered the cause of such fractures[9]. About half of CSFs are associated with the proximal radius or ulna areas; the remaining CSFs occur as isolated fractures not involving the proximal radius or ulna[8,10–12].

Because CSF of the humerus is uncommon, there have been few case reports describing clinical outcomes after treatment for CSFs of the humerus, which includes closed reduction[13], excision[14], open reduction with or without internal fixation[5,10,12], and prosthetic replacement[11]. The few case series that exist advocate nonsurgical management of these fractures[13,15,16]. However, since CSFs of the distal humerus are intraarticular fractures, the lack of soft tissue attachments of these fracture fragments results in nonunion and aseptic necrosis of the articular surface[11,17]. Thus, to avoid complications such as chronic pain, mechanical symptoms, instability, and contracture of the elbow joint, nonsurgical management is inadvisable[14,18].

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Management of these fractures has been improved by the use of internal fixation techniques with locking plate systems, implantable variable pitch, and headless compression screws, and by the development of a wide range of surgical approaches[5–7]. Open reduction and internal fixation (ORIF) and the use of devices provide good to excellent outcomes for CSFs in most patients[5].

To date, only a limited number of CSFs of the humerus have been reported in elderly patients with osteoporosis, and no study has reported surgical outcomes for older adults with CSFs of the humerus treated with ORIF. CSFs of the humerus in older adults occasionally have comminuted fracture fragments, making management extremely difficult[6,7,11]. This retrospective study investigated radiographic and clinical outcomes for a series of elderly patients who presented to our hospitals with isolated CSFs of the capitellum and trochlea.

Materials and Methods

1. Patients and Medical Records

Between April 2002 and March 2019, consecutive patients aged 65 years or older with CSFs of the distal humerus were investigated, and those treated by ORIF were enrolled. Surgical treatments were performed for eight elbows of eight patients with CSFs of the humerus at our hospital and related hospitals. All patients were female (mean age, 76.3 ± 5.1 years; range: 66-83 years). All CSFs were classified as low-energy injuries, eg, a direct fall onto the elbow or outstretched hand. This retrospective human non-interventional study was approved by our Institutional Review Board (No. 30-12-1048, No. 450-30-21). The study protocol conformed with the ethical guidelines of the 2013 Declaration of Helsinki. Written informed consent was obtained from each patient preoperatively, to enable surgical procedures and publication of the case information presented in this study. Moreover, this investigation was carried out with an opt-out method at our hospital and on the websites of our related hospitals. Patient demographic data, medical history, imaging findings, and follow-up data were extracted from medical records.

2. Preoperative Evaluation

Preoperative evaluation included anteroposterior and lateral radiographs. In addition, preoperative computed tomography scans with multiplanar reconstructions were obtained from all patients. Using Dubberley's criteria[11], we classified fractures as type 1 (fracture involving the capitellum with or without the lateral trochlear ridge), type 2 (fracture involving the capitellum and the trochlea as one piece), and type 3 (fracture consisting of both the capitellum and trochlea as separate fragments) fractures. The fractures were then subclassified with respect to the absence (A) or presence (B) of posterior condylar comminution. According to Dubberley's criteria[11], the radiologic classification was type 1A, n = 1; type 1B, n = 2; type 2B, n = 2; and type 3B, n = 3. No patient had an isolated trochlear fracture or a fracture of the proximal radius or ulna regions. One patient had an associated contralateral humeral neck fracture and received extended treatment by ORIF using a locking plate system.

3. Surgical Procedures

All patients received general anesthesia, followed by a varus and valgus stress test to evaluate instability due to concomitant ligamentous injury. Surgery was then performed with a sterilized tourniquet on the patient's upper arm. Three different approaches were used for surgical treatment: A lateral approach[19] was used for five, an anterolateral approach[20] for one, and a posterior approach with ulnar osteotomy for two patients. After the articular surface of the distal humerus was exposed, the fracture site was debrided to remove blood clots and any interposing tissue. After performing anatomical reduction and confirmation by fluoroscopy, internal fixation was performed with implantable screws, bioresorbable screws, Kirschner wires, and a locking plate system. As for the implantable headless bone screws, Acutrak or Acutrak mini screws (Acumed, Hillsboro, OR, USA), headless bone screws (KLS Martin; Tuttlingen, Germany), a double threshold screw (Meira, Nagoya, Japan), and TwinFix (Stryker Leibinger, Kalamazoo, MI, USA) were used. In a patient with a Dubberley type 2B fracture, headless screws with a bioabsorbable pin made from hydroxyapatite poly-L-lactide pin (FIXSORB; Takiron Co, Ltd, Osaka, Japan) were used. In a patient with a Dubberley type 3B fracture, multiple Kirschner wires were used. No patient had a collateral ligament tear or lateral ligament disruption of the elbow joint or a radial head fracture postoperatively. In two patients with a Dubberley type 3B fracture, a lateral plate was applied to prevent shortening of the distal humerus. The LCP DHP elbow plating system (Synthes, Oberdorf, Switzerland) was used for lateral plate fixation. The final anatomical reduction and implant position were confirmed by fluoroscopy. Wound closure was done in layers over a drain to prevent infection. One of three hand surgeons performed all surgical procedures.

4. Postoperative Treatment

The elbow was immobilized in a long-arm cast or

Table 1 Mayo Elbow Performance Score (MEPS) for elbow function (pain, stability, range of motion and daily functional tasks) across four domains, and the grading

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	100-90	
Good	75-89	
Fair	60-74	
Poor	<60	

splints for 2 weeks, with the elbow at approximately 90 degrees of flexion. Active range of motion (ROM) exercises, without loading, were started at 2 weeks postoperatively.

5. Postoperative Evaluation

Standard posteroanterior and lateral radiographs were obtained from each patient every 2 weeks until bone union, and once or twice every 3 months during follow-up. Radiographs were obtained at each follow-up appointment, to evaluate the status of bone union. Radiographs of the operative and contralateral sides were compared to identify possible postoperative complications such as hardware loosening, heterotopic ossification, step-off or collapse of the articular surface, aseptic necrosis, and posttraumatic arthritis.

Using the system of Broberg and Morrey[21], we classified radiographs of the posttraumatic arthritis as Grade 0 (normal), Grade 1 (slight joint-space narrowing and minimal osteophyte formation), Grade 2 (moderate joint-space narrowing and osteophyte formation), or Grade 3 (severe joint-space narrowing with gross destruction).

Clinical follow-up included assessment of ROM, as determined by a goniometer, and Mayo Elbow Performance Score (MEPS)[22], to assess possible limitations in elbow activities (**Table 1**). As for contracture of the elbow joint, we defined extension contracture of the elbow joint as an extension lag greater than 30 degrees, as compared with the contralateral side, and flexion contracture of the elbow joint as a decrease in ROM to less than 120 degrees of flexion, as compared with the contralateral side.

Results

Detailed patient demographic and clinical data, along with follow-up period, complications, flexion/extension, total ROM in flexion-extension of the injured elbow joint, and postoperative clinical outcomes, as assessed by MEPS, are shown in **Table 2, 3**. Mean duration of follow-up was 23.6 ± 13.9 months (range, 9-49 months).

Postoperative monitoring from 1-12 weeks after ORIF revealed no complications in wound healing or infections. The fractures of seven patients healed in 6-8 weeks and had no noticeable elbow joint instability, but one patient exhibited nonunion. Osteochondritis dissecans was present in one patient. Three patients had a step-off deformity (>2 mm) of the articular surface (**Fig. 1A**), and two patients exhibited collapse of the fractured articular surface (**Fig. 1B**). A patient with severe comminution of the capitellum and trochlea exhibited collapse of the en-

Table 2 Preoperative demographic and clinical data for older adults with transcondylar fractures of the humerus

Case	Age (years)/ Sex	Injured Side	Mechanism	Preoperative complications	Dubberley classification	Associated Injury	Posterior Column Involvement	Approach	Device of fixation
1	82/F	Lt	Fall	DM, osteoporosis	1A	none	none	Anterolateral	headless screws
2	73/F	Lt	Fall	Osteoporosis	1B	Rt. distal radius fx	+	Lateral	headless screws
3	75/F	Lt	Fall	DM, osteoporosis	1B	none	+	Lateral	headless screws
4	78/F	Lt	Fall	Osteoporosis	2B	Lt. humeral neck fx	+	Lateral	headless screws
5	83/F	Lt	Fall	Osteoporosis	2B	No	+	Lateral	headless screws & bioresorbable pin
6	66/F	Lt	Fall	Osteoporosis	3B	none	+	Posterior	headless screws & lateral locking plate
7	74/F	Rt	Fall	Osteoporosis	3B	none	+	Posterior	headless screws & Kirshner wires
8	79/F	Rt	Fall	HT, DM, Osteoporosis	3B	none	+	Lateral	headless screw & lateral locking plate

DM, diabetes mellitus; HT, hypertension; KW, Kirschner wire; Lt, left; Rt, right

Table 3 Flexion/extension and total range of motion during flexion–extension of elbow joints and clinical outcomes, according to Mayo Elbow Performance Score

Case	Follow-up period (months)	Complications	Osteoarthritis grade	ROM in flexion/ extension	Arc of injured elbow joint	MEPS (100)	Pain (45)	ROM (20)	Stability (10)	ADL (25)
1	22	-	0	0/135	135	100	45	20	10	25
2	9	step-off deformity	1	–25/95	70	70	30	15	10	15
3	49	step-off deformity	2	–40/110	70	70	30	15	10	15
4	43	collapse	2	–30/120	90	80	30	15	10	25
5	10	osteochondritis dissecans	1	–25/110	85	85	45	15	10	15
6	14	step-off deformity	1	–25/135	110	85	30	20	10	25
7	18	collapse, aseptic necrosis	3	–45/110	65	70	30	15	10	15
8	24	collapse	2	–50/115	65	70	30	15	10	15

ADL, activities of daily living; MEPS, Mayo Elbow Performance Score; ROM: range of motion

tire articular surface with osteonecrosis of the capitellum and trochlea (**Fig. 1C**). Secondary surgery for the removal of implants was performed in three patients with Dubberley type 3B fractures, because of irritation caused by the plates, screws, or Kirschner wires. At the final follow-up, using the system of Broberg and Morrey[23] we classified one elbow as normal, three as Grade 1, three as Grade 2, and one as Grade 3.

At the final follow-up, two patients had no pain, and six patients reported mild pain during vigorous activity. Mean range of elbow motion was 116.3±12.7° (range, 95° to 135°) of flexion and -28.8±14.1° (range, -50° to 0°) of extension. The average total ROM in flexion-extension of the elbow joint of injured elbow joints was 87.5±22.8° (range, 65° to 135°). The average loss of ROM of the affected elbows was 10° of flexion-extension, as compared

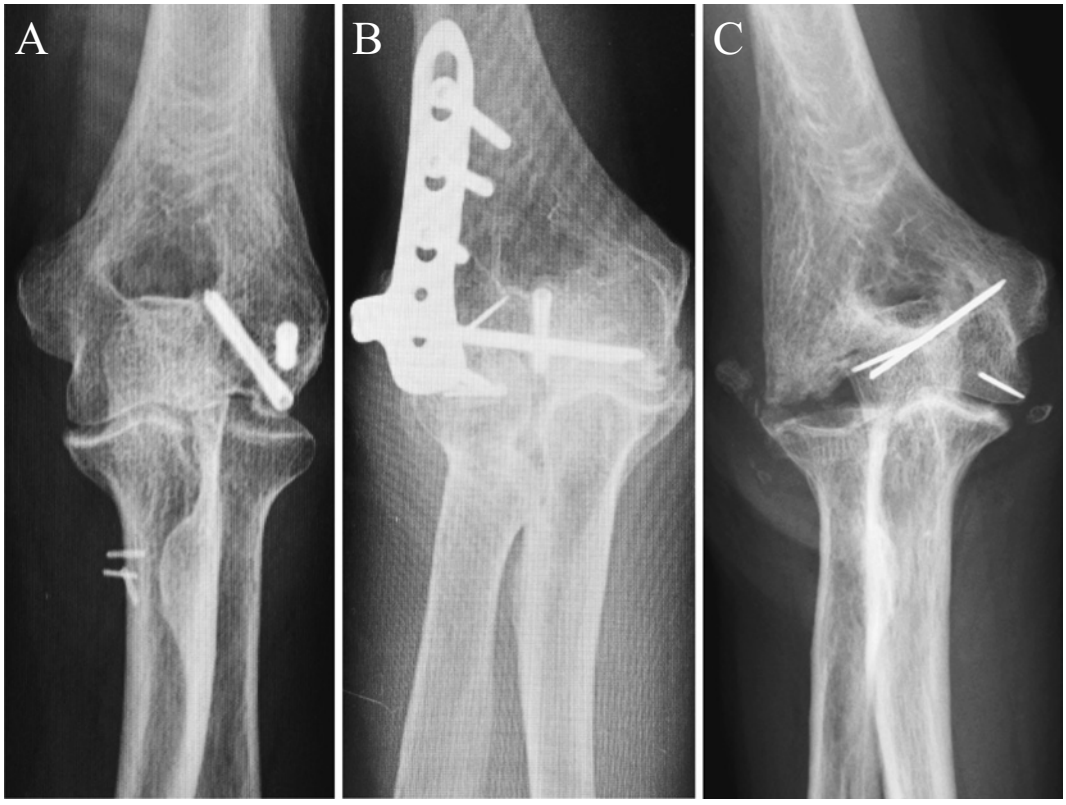

Fig. 1 Representative anteroposterior radiographs of three patients at the final follow-up examination. A: anteroposterior radiograph of a 75-year-old woman (Case 3, 49 months postoperatively) showing a step-off deformity (>2 mm) of the articular surface, slight joint-space narrowing, and minimal osteophyte formation (Broberg and Morrey, Grade 1). B: anteroposterior radiograph of a 79-year-old woman (Case 8, 24 months postoperatively) showing collapse of the entire articular surface of the trochlea and capitellum, and moderate joint-space narrowing with osteophyte formation (Broberg and Morrey, Grade 2). C: anteroposterior radiograph of a 74-year-old woman (Case 7, 18 months postoperatively) showing an articular fragment of the trochlea and capitellum that had failed to heal and were to be resorbed, indicating avascular osteonecrosis, and severe joint space narrowing with gross destruction (Broberg and Morrey, Grade 3).

with the unaffected elbow. Extension contracture of the elbow joint (more than 30 degrees of extension, as compared with the contralateral side) and flexion contracture of the elbow joint (<120 degrees of flexion, as compared with the contralateral side) were observed in four and five patients, respectively. Rotation of the forearm and pronation/supination was not restricted, as compared with the contralateral elbow. The mean MEPS was 78.8± 10.2 points (range, 70-100 points), corresponding to patient scores of excellent (n = 1), good (n = 3), and fair (n = 4).

Discussion

In this study, we investigated the clinical and radiologic outcomes for isolated CSFs of the humerus, without fracture of the proximal radius or ulna, in elderly patients with ORIF. All patients had accompanying osteoporosis, as defined by bone mineral density values on dual-energy X-ray absorptiometry or history of compression fracture of the vertebrae. All patients had injured their elbows by low-energy trauma, such as falls. Comminution of the fracture fragments or the cortex of the distal humerus was present in all but one patient, who had a Dubberley type 1A fracture.

In our case series, some patients exhibited collapse of the articular surface, resulting in articular incongruity. Although patients with articular congruity had satisfactory functional outcomes, some with articular collapse had severe restriction of ROM and deficits in elbow function. These findings are consistent with those of previous studies, which reported that maintaining articular congruity is more important than preventing flexion contracture[8,11]. Thus, adequate fracture fixation and support of articular congruity are essential in ensuring satisfactory functional outcomes.

Isolated CSFs of the distal humerus include fracture of

the capitellum and/or trochlea. Outcomes for isolated CSFs of the capitellum were satisfactory in >90% of patients who underwent ORIF[5,24]. Isolated CSF of the trochlea is uncommon, and clinical outcomes are thus unclear[25,26]. Moreover, it remains challenging to achieve favorable outcomes with ORIF for CSFs of both the capitellum and trochlea in patients with severely fragmented fractures and comminution of the posterior cortex of the distal humerus, which are associated with poor surgical outcomes[6,7,11]. Thus, to restore articular surface conformity of the distal humerus and prevent collapse along with malalignment of the articular surface of the distal humerus, bone grafting and, occasionally, an angular stabilizing device such as a locking plate system are required[7,11,18]. When a patient has severe osteochondral fragmentation of the articular surface and comminution of the posterior cortex of the distal humerus, as are present in type 3B fractures, it is difficult to maintain fracture stability. At the final follow-up, the outcome was classified as fair for one patient who presented with comminution of the capitellum and trochlea. In a recent series, Brouwer and colleagues reported that nonunion of the coronal shear fractures was more frequent for Dubberley type 3B fractures than for other types of CSFs[6]. They reported that 44% (8/18) of Dubberley type 3B fractures had the radiographic signs of developed nonunion; however, no fracture in patients with Dubberley type 2A or 2 B fractures was later classified as nonunion. Two patients with Dubberley type 3B CSFs but without severe osteochondral fragmentation of the articular surface progressed to bone union and congruity of the articular surface in our study. The patient who presented with severe osteochondral comminution of the articular surface exhibited nonunion and aseptic necrosis of the articular surface, who should have been required a total elbow arthroplasty[11,17]. Thus, total elbow arthroplasty might be appropriate for patients with comminution of the articular surface.

To our knowledge, no previous study focused on surgical outcomes for CSFs of the humerus treated with ORIF in older adults. In elderly patients with osteoporosis, CSFs of the distal humerus, which result from low-energy trauma, frequently exhibit comminution of the osteochondral fragment and posterior cortex of the distal humerus. In our series, the clinical outcomes for CSFs of the humerus were less favorable than those in the few known published reports, most likely because our patients were older.

1. Limitations

The major limitation of this study is its retrospective design, which makes it more susceptible than a prospective design to variable bias. Other important limitations are its small sample size and short follow-up duration, which likely complicate clarification of optimal procedures and the time required for fixation for these fractures. In addition, the surgical approach chosen could have affected radiographic and clinical outcomes. Thus, a larger-scale prospective study is needed.

2. Conclusion

In elderly patients with osteoporosis, CSFs of the distal humerus caused by low-energy trauma frequently exhibited comminution of the osteochondral fragment and posterior cortex of the distal humerus. Treatment of CSFs of the distal humerus in the elderly with reduced bone mass was challenging to achieve stable fixation and full restoration of functional range of motion.

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