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ORIGINAL ARTICLE

A less invasive operative method using a medial cannulated cancellous screw and single plate fixation for the treatment of transcondylar fracture of the humerus in elderly patients in multicenter (TRON group) study

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Abstract

Background Double plate fixation for transcondylar fracture (TCF) tends to be more invasive to the soft tissue, and often carries a higher risk of postoperative complications, including ulnar nerve neuropathy. This study presents the outcomes of TCF of the distal humerus between patients treated with a single plate and cannulated cancellous screw fixation and patients treated with double plate fixation.

Methods Between 2011 and 2021, 371 cases involving treatment of distal humeral fracture were recorded in our multicenter (named TRON group) database. Patients of ≥ 65 years of age with TCF treated with opeb n reduction and internal fixation were included. Clinical outcomes were assessed by the Mayo elbow performance score, range of motion, and total elbow arc joint. Complications included fracture-related infection (FRI) and ulnar neuropathy.

Results There were significant differences in the average operative time (CCS group vs. Plate group: 119.0 min vs. 186.5 min; $p < 0.001$) and average tourniquet time (CCS group vs. Plate group: 91.5 min vs. 121.0 min; $p < 0.001$). FRI occurred as a complication in the Plate group ($n = 6$). The rates of FRI did not differ to a statistically significant extent (CCS group vs. Plate group: 0% vs. 9.2%; $p = 0.477$). No patients underwent reoperation. The rate of sensory symptoms in the Plate group was higher than that in the CCS group (CCS group: none [$n = 25$], numbness [$n = 1$] vs. Plate group: none [$n = 57$], numbness [$n = 15$], sensory depression [$n = 2$]; $p = 0.039$).

Discussion Among patients of ≥ 65 years of age with TCF, the clinical outcomes of patients treated with medial CCS and lateral/posterolateral plate did not differ from those of patients who received double plate fixation, and the former treatment was associated with significantly fewer complications, including ulnar nerve palsy. In addition to double plate fixation, this less invasive method of medial CCS and single plate fixation should be considered as a treatment option for TCF in elderly patients.

Keywords Elbow · Cannulated cancellous screw · Transcondylar fracture

Introduction

As the world population continues to age, fractures in the elderly are increasing. We predict that the number of distal humeral fractures (DHFs) in the elderly will increase [1], and that the number of transcondylar fractures (TCFs), which currently account for approximately 9% of all DHFs, will increase accordingly [2]. TCFs are transverse fractures that occur from the lateral epicondyle just proximal to the articular surface of the distal humerus through the olecranon and coronoid fossa to the medial epicondyle [3]. Most of

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these fractures occur in elderly osteopenic patients due to low-energy injuries, such as falls [4]. Open reduction and internal fixation (ORIF) using a plate is the most common procedure for achieving anatomic reduction in patients with TCF [5–9]. Recently, with the advent of anatomical plates, double plate fixation is often recommended and is often performed for elderly patients [10, 11]. However, double plate fixation tends to be more invasive to the soft tissue, and often carries a higher risk of postoperative complications, including ulnar nerve neuropathy [12]. Furthermore, the elderly are often reluctant to undergo surgical treatment because of poor ADL performance, the presence of various risk factors (e.g., osteoporosis and dementia), and low reserve capacity. Therefore, less invasive surgery is desirable. To treat TCF in elderly individuals, we have sometimes used less invasive operative techniques, which use lateral or posterolateral single plate and medial cannulated cancellous screw (CCS) fixation instead of double plate fixation.

The purpose of this retrospective multicenter study on prospectively collected data was to compare the clinical outcomes, surgical demographic data and complications of single plate and medial CCS versus double plate fixation in the treatment of TCF in elderly patients.

Materials and methods

This multicenter, retrospective study was approved by the ethics committee at each participating hospital. All patients provided their informed consent to participate in the study. Hospitals of the trauma research group of Nagoya (TRON) have registered orthopedic trauma surgery cases in the TRON database annually since 2011–2021. The 13 hospitals participating in the database are all associated with the Department of Orthopedic Surgery of Nagoya University, and orthopedic surgeons perform surgery at these hospitals located in central Japan. From this database, we collected cases involving the surgical treatment of fracture.

Subjects

After receiving approval from the hospital institutional review board, a retrospectively collected database was used to identify 371 patients who underwent treatment for distal humeral fracture (AO classification 13) between 2011 and 2020 A retrospective review of the charts and radiographs was conducted. We included all patients who were ≥ 65 years of age ($n = 225$). From the remaining patients, those with isolated epicondylar fracture (13A1, $n = 6$), wedge or multifragmentary fracture (13A3, $n = 4$), partial articular fracture (13B, $n = 18$) or complete articular fracture (13C, $n = 55$) were excluded. Namely, we only included the patients with AO Type 13A2 fracture. We excluded patients who were followed for < 6 months ($n = 26$), patients with multiple fracture ($n = 9$), patients with incomplete data ($n = 10$), and patients who received CCS fixation alone ($n = 8$). Finally, 91 patients were included in the present study. The patients were divided into two groups: a lateral plate and medial CCS fixation group (CCS group: $n = 26$) and a double plate fixation group (Plate group: $n = 63$) (Fig. 1).

Surgical procedure

The decisions regarding the surgical treatment, ulnar nerve transposition, and postoperative management were based on the surgeon's preference. Procedures were performed under general anesthesia or regional block. Operations were performed in the supine, lateral decubitus and prone positions.

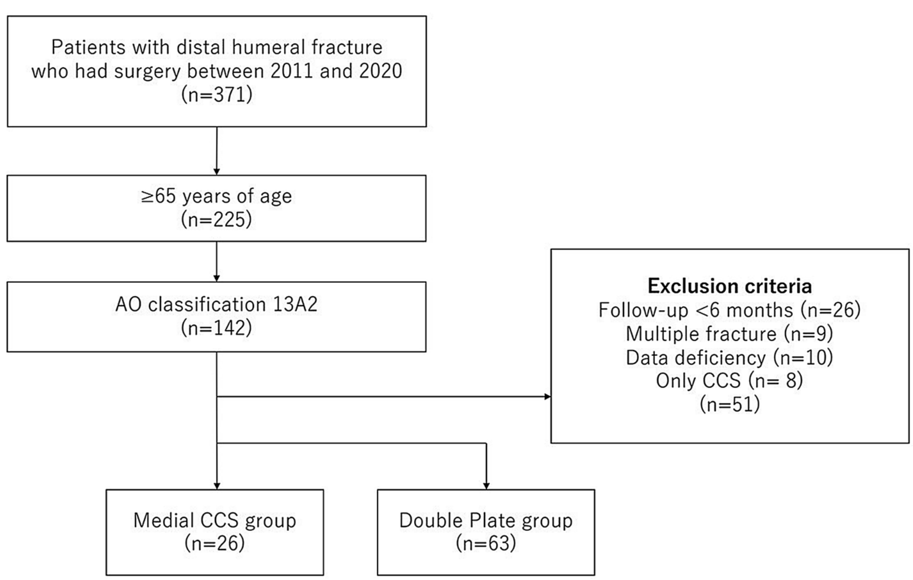

Fig. 1 Flow diagram of the participants included in the study

During the procedures, CCS fixation was performed with a small incision in the medial approach ($n=6$) or with a posterior approach for both CCS and plate fixation ($n=18$). The ulnar nerve was released by simple decompression (CCS group, $n=9$; Plate group, $n=26$) or subcutaneous anterior transposition (CCS group, $n=1$; Plate group, $n=36$). We used eight types of implants: VA-LCP Distal Humerus Plate (Depuy Synthes, Oberdorf Switzerland), A.L.P.S Plate (Zimmer Biomet, Warsaw, IN, USA), VariAx Elbow Locking Plate (Stryker, Mahwah, NJ, USA), PERI-LOC (Smith & nephew, Watford, UK), ONI Transcondylar Plate (Teijin, Okayama, Japan), MEIRA Elbow Locking Plate (MEIRA, Nagoya, Japan), and Mayo Plate (Acumed, Hillsboro, OG, USA). Fracture fixation was achieved by a posterior approach (CCS group, $n=18$; Plate group, $n=54$) and a medial and lateral approach (CS group, $n=8$; Plate group, $n=11$). Internal fixation was performed with a lateral plate (CCS group, $n=4$; Plate group, $n=25$) and posterolateral plate (CCS group, $n=22$; Plate group, $n=40$). Figure 2 shows a representative case of CCS and plate fixation. A medial plate was used for all patients in the Plate group. The postoperative management was tailored to the intraoperative findings. Immobilization consisted of an above elbow cast, cylinder cast, and splint. After removal of immobilization, active movement of the elbow was started with consideration of pain and the patient underwent mild passive mobilization sessions with a physical therapist.

Data collection

The data collected from medical records included age, sex, body mass index, type of injury (fall from a standing height, fall from height, or traffic accident), smoking status (current/former smoking or not), diabetes mellitus (during treatment) status, open fracture. We obtained the time to operation, operative time, operative position, anesthesia method, tourniquet time, type of implant (cannulated screws, plate), and plate position as surgical information.

Clinical evaluation

The clinical outcome was assessed based on the pain level, range of motion, total elbow joint arc and the Mayo Elbow Performance Score (MEPS) [13]. Pain was described as none, mild, moderate, or severe. Range of motion (ROM) was measured in degrees for flexion, extension, pronation, and supination by an occupational therapist. Total elbow joint range (Arc) was measured in degrees of flexion to extension. These values were measured at 3 months after the operation, 6 months after the operation, and at the last follow-up examination.

Complications

Complications, such as ulnar nerve neuropathy and fracture-related infection (FRI) were assessed at the time of the follow-up visits. We diagnosed ulnar nerve neuropathy on motor deficit or the subjective symptoms of paresthesia. FRI was defined by confirmatory criteria and suggestive criteria [14]. Confirmatory criteria included fistula or sinus tract, purulent drainage or pus, microbial growth in two or more deep tissue samples, and histological evidence of pathogens and inflammation in peri-implant tissue. Suggestive criteria included the following clinical signs: erythema; swelling; persistent, increasing, or new onset wound drainage; radiological or nuclear imaging signs; increased serum inflammatory markers; and microbial growth in a single deep tissue sample.

Fig. 2 Radiography **a** Initial plain anteroposterior and lateral radiographs **b** Postoperative anteroposterior and lateral plain radiographs

Radiographic evaluation

Standard anteroposterior and lateral radiographs of each patient were obtained at the 12 months of follow-up. When obtaining anteroposterior and lateral radiographs, the patients' forearms were always held in neutral rotation with the shoulders flexed or abducted and the elbows flexed to 90°. The radiographic evaluation involved measurement of the degree of displacement and deformity of the distal humerus. To evaluate deformity of the distal humerus, the articular surface angle (ASA) and anterior angulation of the articular surface of the distal humerus (ASDH) were measured on anteroposterior and lateral radiographs, respectively [15]. Both angles were measured at 12 months.

In addition, radiographs obtained at 12 months or the latest follow-up visit were assessed for union, delayed union, nonunion, and hardware failure. Fracture healing and alignment were assessed by two orthopedic surgeons. Intraobserver reliability was found to be good. The Kappa value was 0.89 (95% confidence interval: 0.84–0.93), and if the diagnoses differed, the results of the first author were used.

Statistical analysis

Categorical data were compared between the two groups using Fisher's exact test. Continuous variables were analyzed using *t*-tests or Mann–Whitney *U* test, as appropriate. All statistical analyses were performed using the EZR software program (version 1.40, Jichi Medical School, Tochigi, Japan). *P* values of <0.05 were considered to indicate statistical significance [16]. Gala et al. [17] demonstrated a difference in score of approximately 10 points indicates patient improvement in MEPS and set a standard deviation (SD) of MEPS score of 12 points. With a significance level of 5% (2-sided confidence interval of 95%), and a power of 80%, 26 patients were required in each group in our study.

Results

Table 1 shows the demographic data of the patients. There were no significant differences in background characteristics of the patients in the two groups. Table 2 shows the operative data of the patients. A posterolateral plate was used in many cases in both groups. The anesthesia method was mostly regional block in the CCS group, and general anesthesia in the Plate group. There were significant differences in the anesthesia method (CCS group: general (26.9%) vs. regional block (73.1%), Plate group: general (76.2%) vs. regional (23.8%); $p<0.001$). There were significant differences in the average operative time (CCS group vs. Plate group: 119.0 min vs. 186.5 min; $p<0.001$) and average tourniquet time (CCS group vs. Plate group: 91.5 min vs. 121.0 min; $p<0.001$). Table 3 shows the postoperative clinical outcomes of the patients. There were no significant differences in the average Arc, MEPS, or rate of fracture union. The average ASA was 88.0 in the CCS group and 86.6 in the Plate group. The ASDH average was 133.3 in the CCS group and 130.2 in the Plate group. There were no significant differences between the two groups in either the ASA or the ASDH at the last follow-up examination. The complication rate in the Plate group was significantly higher than that in the CCS group. Table 4 shows the postoperative complications. The complications in the Plate group included FRI ($n=6$). The rates of FRI did not differ to a statistically significant extent (CCS group vs. Plate group: 0% vs. 9.2%; $p=0.477$). There were no patients who underwent reoperation. The incidence of sensory symptoms in the Plate group

Table 1 Demographic data

Factor	CCS group	Plate group	*P* value
Number of patients	26	63	
Age, years, mean (SD)	81.00 (6.86)	78.95 (6.74)	0.198
Sex, Male/Female, *n* (%)	7 (26.9)/19 (73.1)	16 (25.4)/47 (74.6)	1
BMI, kg/m^2, mean (SD)	20.93 (2.88)	22.03 (3.42)	0.156
ASA-PS, *n* (%)			
1	17 (65.4)	42 (66.7)	0.239
2	5 (19.2)	18 (28.6)	
3	4 (15.4)	3 (4.8)	
OA none/positive (%)	23 (88.5)/3 (11.5)	60 (95.2)/3 (4.8)	0.352
Mechanism of injury (%)			
Fall from a standing height	25 (96.2)	51 (83.6)	0.248
Fall from height	0 (0.0)	6 (9.8)	
Traffic accident	1 (3.8)	4 (6.6)	

SD standard deviation. *OA* osteoarthritis. *BMI* body mass index. *ASA-PS* American Society of Anesthesiologists physical status

Table 2 Surgical procedures

Factor	CCS group	Plate group	*P* value
Anesthesia method general/regional (%)	7 (26.9)/19 (73.1)	48 (76.2)/15 (23.8)	< 0.001*
Operative position			
Supine	4 (15.4)	5 (7.9)	0.425
Lateral decubitus	9 (34.6)	19 (30.2)	
Prone	13 (50.0)	39 (61.9)	
Operative time, minutes, median [IQR]	119.00 [103.25–148.5]	179.00 [140–248.25]	< 0.001*
Plate position posterolateral/lateral (%)	22 (84.6)/4 (15.4)	39 (61.9)/24 (38.1)	0.045
Time to operation, day, median [IQR]	7.50 [4–10.5]	6.00 [4–8.75]	0.147
Time to union, month, median [IQR]	5.50 [3–6]	5.00 [3–6]	0.444
Tourniquet time, min, median [IQR]	91.50 [82.5–108]	123.00 [110–170]	< 0.001*
Follow-up period, month, median [IQR]	12.00 [6–14.75]	12.00 [9.5–16]	0.144
Postoperative immobilization, *n* (%)			
None	2 (7.7)	8 (13.1)	0.503
Splint	17 (65.4)	44 (72.1)	
Cylinder cast	1 (3.8)	2 (3.3)	
AE cast	6 (23.1)	7 (11.5)	

*$p < 0.05$

Table 3 Postoperative outcome

Factor	CCS group	Plate group	*P* value
MEPS, median [IQR]			
3 months	85.00 [75–90]	75.00 [65–85]	0.063
6 months	90.00 [85–100]	90.00 [80–100]	0.349
Last follow-up	100.00 [95–100]	95.00 [85–100]	0.147
Total elbow joint range, median [IQR]			
3 months	112.50 [97.5–118.75]	105.00 [85–115]	0.182
6 months	115.00 [102.5–125]	110.00 [90–120]	0.487
Last follow-up	120.00 [112.5–125]	110.00 [92.5–125]	0.544
Union of fracture, *n* (%)			
Within 6 months	21 (80.8)	53 (84.1)	0.637
Between 6 and 12 months	4 (15.4)	5 (7.9)	
Nonunion	1 (3.8)	5 (7.9)	

MEPS Mayo elbow performance score

Table 4 Evaluation of postoperative complication

Factor	CCS group	Plate group	*P* value
Motor symptoms at last follow-up, *n* (%)			
None	26 (100.0)	59 (93.7)	0.575
Paresis	0 (0.0)	4 (6.3)	
Sensory symptoms at last follow-up, *n* (%)			
None	25 (96.2)	46 (73.0)	*0.039
Numbness	1 (3.8)	15 (23.8)	
Sensory depression	0 (0.0)	2 (3.2)	
Fracture-related infection, *n* (%)			
None	26 (100.0)	57 (90.5)	0.479
Antibiotic only	0 (0.0)	2 (3.2)	
Debridement	0 (0.0)	4 (6.3)	

was higher than that in the CCS group. (CCS group: none [$n=25$], numbness [$n=1$] vs. Plate group: none [$n=57$], numbness [$n=15$], sensory depression [$n=2$]; $p=0.039$).

Discussion

This study demonstrated that less invasive operative methods with CCS can reduce the rate of complications in patients with TCF. We showed that among patients with TCF there were no significant differences in the clinical or radiographical outcomes of the CCS group and the plate fixation and double plate fixation groups. There were significant differences in the anesthesia method between the CCS group (26.9% general anesthesia) and the Plate group (76.9% general anesthesia). This difference may be related to the shorter operative time in the CCS group. Although double plate fixation is generally recommended for DHF, Shimamura et al. reported that there were no significant biomechanical differences between double plate fixation and CCS and single plate fixation for TCF [18]. Park et al. [2] reported 10 cases of transcondylar fracture in elderly patients that were fixed by two column screws, which is considered to provide weaker fixation than medial CCS and single plate fixation. They reported that there were no complications in patients treated using two column screws, and the mean MEPS of their study population was 93.9.

In a retrospective comparative study between perpendicular plating and parallel plating for DHF in 67 patients, the author reported that the mean operative time was 121 ± 33 min in a perpendicular plating group and 115 ± 27 min in a parallel plating group [19]. On the other hand, a study of double CCS fixation for TCF in 10 patients reported that the mean operative time was 55 min [2]. Our study results also showed that the fixation method with medial CCS and single plate fixation was associated with a shorter operative time in comparison to double plate fixation.

There was no significant difference in the incidence of FRI; however, it is noteworthy that no patients in the CCS group developed FRI, while 6 patients in the Plate group developed FRI. This suggests that FRI is less likely to occur in association with CCS due to the less invasive procedure and short operative time.

The incidence of ulnar nerve neuropathy was lower in the CCS group. We can insert the CCS from the medial epicondyle without interference of the ulnar nerve because the ulnar nerve runs posterior to the medial epicondyle of the humerus. Although, the rates of ulnar nerve subluxation have been reported to be as high as 27.5% [20]. AB Rees et al. [21] reported that a mini-open approach to medial pinning in pediatric supracondylar humeral fractures is safe in cases of the ulnar nerve subluxation because it can be visualized. The medial plate tends to interfere with the ulnar nerve and subcutaneous anterior transposition may be required. Chen et al. reported that the performance of subcutaneous anterior transposition to avoid interference from the plate results in extra nerve damage. Medial CCS fixation, which does not require dissection or transposition, is less invasive with respect to the nerve and has significant advantages [22].

The present study was associated with some limitations. First, this was a retrospective study using a clinical database, and because the subjects were not randomly assigned, the possibility of selection bias must be considered. Since the only data collected were on the fracture type, the degree of displacement was not considered. Second, the follow-up period was relatively short. Third, many orthopedic surgeons performed the operations. We could not investigate the quality of the operators. Fourth, many types of plates were used and the plate properties were not unified. Fifth, subcutaneous anterior transposition was performed in about half of the cases in the plate group. Patients who underwent ulnar nerve transposition at the time of ORIF of a distal humeral fracture had approximately four times the incidence of ulnar neuritis compared to patients who did not undergo the transposition [21]. If the nerve transposition had not performed, it might lead to be fewer complications with the ulnar nerve. Sixth, our cohort had a relatively short follow-up period (the max: 16 month). The follow-up period is insufficiently long to observe improvements in range of motion and clinical outcomes.

Conclusion

Among patients of ≥ 65 years of age with TCF, there was no difference in the clinical outcomes of patients treated with a medial CCS and lateral/posterolateral plate and those treated with double plate fixation, and the former treatment was associated with significantly fewer complications including ulnar nerve palsy. In addition to double plate fixation, this less invasive method of medial CCS and single plate fixation should be considered as a treatment option for TCF in elderly patients.

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Author contribution KT: Data collection and assessment, Study design, Writing the paper. YT: Manuscript preparation, Study and

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Data availability The datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Ethical approval The approval number in our institute is 2020–0564. Consent to participate and publication: All patients provided written informed for their data to be used.

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