Original Article
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Are Outcomes Comparable for Repair of AO/OTA Type 13C1 and Type 13C2 Distal Humeral Fractures Using the Paratricipital Approach?

Soonchul Lee, MD, Eugene Baek, MD, Minwook Kim, MD, Junhan Kim, MD, Hyunil Lee, MD*, Do Kyung Kim, MS†, Yoon Jang, MD†, Soo-Hong Han, MD

Department of Orthopaedic Surgery, CHA Bundang Medical Center, CHA University School of Medicine, Seongnam,
**Department of Orthopedic Surgery, Inje University Ilsan Paik Hospital, Goyang,*
†CHA Graduate School of Medicine, Pocheon, Korea

Background: Studies have reported favorable outcomes using the paratricipital approach for fixation of distal humeral intra-articular fractures. However, literature evaluating the clinical results of the approach remains limited. The objective of this study was to compare clinical outcomes between type 13C2 and type 13C1 distal humeral fractures after open reduction and internal fixation performed using the same approach and same type of plate.

Methods: A total of 52 adults with type 13C1 or 13C2 distal humeral fractures were treated surgically at our institution during 2006 to 2018. We retrospectively analyzed data from 29 of these patients (19 with type 13C1 fractures and 10 with 13C2 fractures) who met the inclusion criteria. All subjects were followed for a minimum of 2 years postoperatively. Clinical and radiologic results were analyzed to determine differences in outcomes between the two types of fractures. Clinical results were evaluated using elbow range of motion (ROM), Mayo Elbow Performance Score (MEPS), and Quick Disabilities of the Arm, Shoulder and Hand (Q-DASH) score. Alignment, fracture union, and presence of posttraumatic arthritis were evaluated radiologically.

Results: The patients' mean age was 51 years, and the mean duration of follow-up was 29 months. Mean ROM was 129.5° ± 21.5° in the type 13C1 group and 123.0° ± 20.6° in the 13C2 group (p = 0.20). Mean Q-DASH score was 12.6 ± 11.7 in the 13C1 group and 16.2 ± 19.8 in the 13C2 group (p = 0.60). Mean MEPS was 92.9 ± 8.5 in the 13C1 group and 85.0 ± 14.1 in the 13C2 group (p = 0.09). Carrying angle did not differ significantly between the 13C1 and 13C2 groups. No patient in either group exhibited nonunion or posttraumatic arthritis.

Conclusions: Although the paratricipital approach has the disadvantage of limited visualization of articular surfaces, there were no differences in surgical outcomes between type 13C1 and type 13C2 distal humeral fractures after fixation using this approach. Thus, surgeons may need to consider using the paratricipital approach for open reduction and internal fixation of 13C2 distal humeral fractures.

Keywords: *Intra-articular distal humerus fractures, Paratricipital approach, Surgical outcome*

Surgical treatment of intra-articular distal humeral fractures is challenging for even the most experienced surgeons.[1] It is technically demanding, and achieving adequate exposure of the articular surface is important. Additionally, distal humeral fractures have a high risk of postoperative dysfunction and complications, such as nonunion and elbow stiffness.[2,3] To reduce the likelihood of dysfunction and

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Correspondence to: Soo-Hong Han, MD
Department of Orthopaedic Surgery, CHA University School of Medicine, 335 Pangyo-ro, Bundang-gu, Seongnam 13488, Korea
Tel: +82-31-780-5289, Fax: +82-31-881-7114
E-mail: hsoohong@cha.ac.kr

complications, anatomic reduction of the articular surface, rigid fixation, and early joint motion are important.[2,4-6)]

Traditionally, olecranon osteotomy has been used because it provides sufficient exposure of the articular surface for accurate reduction of AO/Orthopaedic Trauma Association (AO/OTA) type 13C fractures.[7)] Favorable outcomes have been reported with the olecranon osteotomy approach, especially for complex intra-articular fractures of the distal humerus, including types 13C2 and 13C3.[8)] Although olecranon osteotomy provides maximum visualization of the articular surface, it is accompanied by potential complications, such as delayed union, nonunion, and implant-related problems.[9)] Furthermore, elbow dysfunction or heterotopic ossification may occur because of difficulty with early joint movement.[10-12)]

Various surgical approaches, including triceps reflecting (Bryan and Morrey's approach), triceps-reflecting anconeus pedicle, triceps splitting (Campbell's approach), and triceps sparing (paratricipital approach), have been proposed to avoid olecranon osteotomy and accompanying implant complications. Each approach has its own set of advantages and disadvantages.[13,14)] The paratricipital approach suggested by Schildhauer et al.[15)] has become popular for distal humeral intra-articular fractures because it permits early active range of motion (ROM) of the elbow, maintenance of the blood supply, and innervation of the anconeus muscle, which contributes to dynamic posterolateral stability of the joint.[1)] Favorable outcomes have been reported for fixation of type 13C2 fractures using this approach, but limited exposure of the articular surface remains a potential disadvantage of the approach.[9,16)]

Currently, there is a paucity of evidence regarding the clinical outcomes of open reduction and plate fixation for type 13C1 and 13C2 distal humeral fractures using the paratricipital approach. The objective of this study was to compare outcomes of internal fixation using the same paratricipital approach and plate configuration between type 13C2 fractures and type 13C1 fractures, with the goal of determining whether this approach can be applied safely and effectively for type 13C2 fractures.

METHODS

The study protocol was approved by Institutional Review Board of CHA Bundang Medical Center (IRB No. 2020-04-069-003); the requirement for informed consent was waived because of the study's retrospective design.

Study Population

Fifty-two patients (aged ≥ 18 years) with an AO/OTA type 13C1 or 13C2 distal humeral fracture were treated surgically at our institution during 2006 to 2018. We excluded patients with a concomitant fracture of the ipsilateral extremity (n = 4), refracture because of nonunion (n = 2), open fracture (n = 1), olecranon osteotomy (n = 2), parallel plating (n = 3), less than 2 years of follow-up (n = 5), or incomplete data (n = 6). We retrospectively reviewed the medical records of the remaining 29 patients, all of whom were followed up for at least 2 years after surgery. All patients underwent surgical treatment using the paratricipital approach and perpendicular plate fixation. The fractures were type 13C1 in 19 patients and type 13C2 in 10 patients (Fig. 1). The type of fracture was determined by preoperative computed tomography. All operations were performed by a single orthopedic trauma surgeon (SHH). The subjects were divided into two groups according to the type of fracture, and their data were analyzed retro-

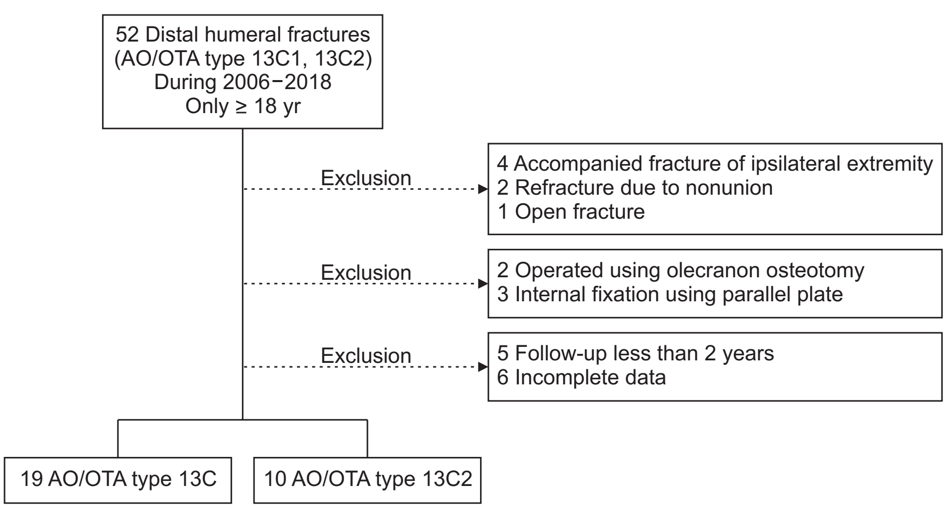

Fig. 1. Flowchart of study subjects. OTA: Orthopaedic Trauma Association.

spectively.

Surgical Technique

Under general anesthesia, each patient was positioned prone on the operating table, and a tourniquet was applied on the fractured arm. The shoulder was abducted 90°, and a sterile cloth was placed under the arm. This positioning allowed unrestricted elbow ROM. The incision was generally located in the posterior midline, but it was curved depending on the condition of the skin and the presence of neurological symptoms. While keeping the triceps attached to the olecranon, the lateral condyle was exposed through the lateral intermuscular septum. Dissection was extended proximally as required, but for no more than 10 cm from the lateral condyle (remaining within the approximately distal 1/3 of the humerus) to avoid radial nerve injury.[17] The ulnar nerve was identified proximal to the medial epicondyle, as it passed from anteriorly to posteriorly through the intermuscular septum at the arcade of Struthers.[17] The long head of the triceps was dissected from the medial intermuscular septum. By connecting the medial and lateral windows, the posterior humerus and fracture fragments were exposed, providing adequate visualization of the articular surface and both columns (Fig. 2). The articular fragments were reduced anatomically under direct vision, and temporary fixation was achieved with Kirschner wires. By reducing the medial and lateral columns, the distal fragments were approximated, reduced anatomically, and also fixed temporarily with Kirschner wires, with the alignment and reduction status assessed by fluoroscopy. Fixation of all fractures followed AO principles, using bicolumn perpendicular plating (Fig. 3). DePuy Synthes (Seoul, Korea) 3.5-mm locking compression plate distal humerus plates were used for fixation. We assessed whether the plate contacted the ulnar nerve in the flexed position during elbow movement, and anterior transposition of the ulnar nerve was performed if necessary.

Postoperative Care

A long-arm splint was applied posteriorly for pain management and maintenance of the reduction postoperatively. As soon as pain allowed, patients began intermittent elbow motion with a thermoplastic splint. After suture removal, the splint was removed, and active flexion/extension and rotation were permitted.

Outcome Measurements

Clinical and radiologic outcomes were analyzed at last follow-up. Function was assessed using the Quick-Disabilities of the Arm, Shoulder and Hand (Q-DASH) score and Mayo Elbow Performance Score (MEPS) questionnaires, as well as elbow ROM (flexion and extension) measured with a goniometer. Carrying angle for alignment and the presence of fracture malunion, nonunion, or posttraumatic arthritis were evaluated on standard radiographs (Fig. 4).[18] Articular step-off more than 2 mm or angulation more than 5° in any plane was considered indicative of malunion.[9] Nonunion was defined as lack of bone healing

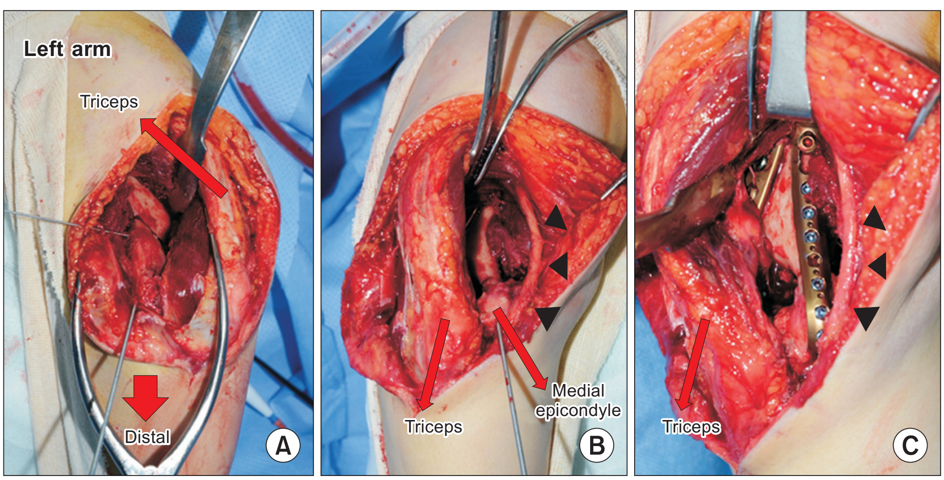

Fig. 2. (A) After a posterior midline incision was made at the elbow, a lateral window was created by dissecting the lateral side of the triceps muscle proximally from the lateral condyle, while keeping the triceps attached to the olecranon (short arrow: distal, long arrow: triceps). (B) To create the medial window, first the ulnar nerve was identified proximal to the medial epicondyle, and then the long head of the triceps was dissected from the medial intermuscular septum. By connecting the two windows, adequate visualization of the articular surface and both columns was achieved (left arrow: triceps muscle, right arrow: medial epicondyle of humerus, black arrowhead: ulnar nerve). (C) After temporary fixation with Kirschner wires, the fracture was fixed using bicolumn perpendicular plating (red arrow: triceps muscle, black arrowhead: ulnar nerve).

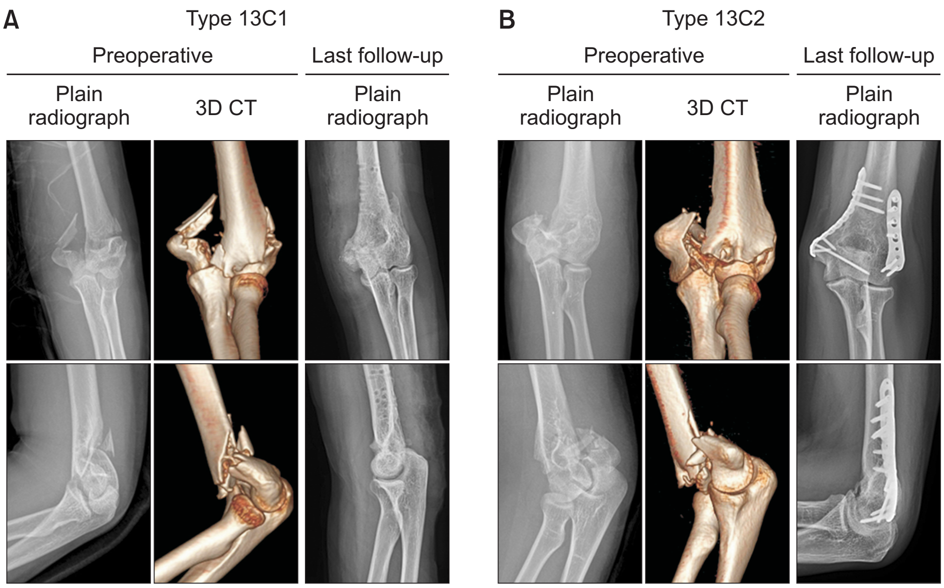

Fig. 3. Preoperative and postoperative plain radiographs and three-dimensional reconstructed computed tomography images of each type of distal humeral fracture. (A) Type 13C1 fracture of a 49-year-old woman with a slip and fall injury. (B) Type 13C2 fracture of a 28-year-old man who was injured while playing soccer. 3D: three-dimensional, CT: computed tomography.

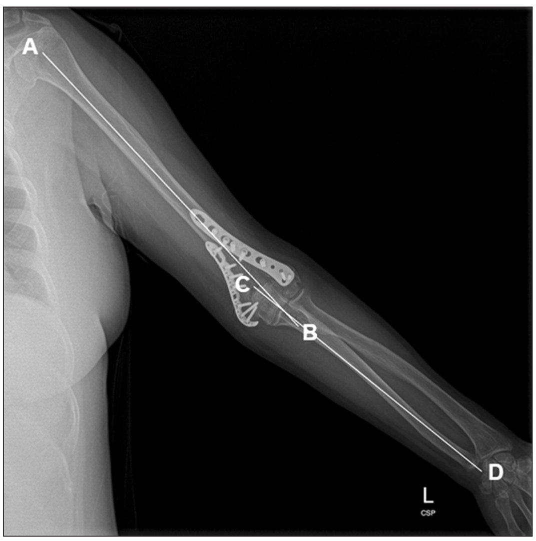

Fig. 4. Measurement of carrying angle. The carrying angle was determined by measuring the angle between the longitudinal axes of the humerus (A, B) and the ulna (C, D) on a plain radiograph (anteroposterior view) of the elbow that included the humerus head and the wrist.

progression in radiographic and clinical evaluations during the first 3 months postoperatively.[19] Implant removal and return to occupation were also assessed.

Statistical Analysis

Data are presented as mean ± standard deviation. Outcomes of the two groups (13C1 and 13C2) were compared using the Mann Whitney *U*-test, and categorical variables were analyzed with Fisher's exact test. These tests were performed with IBM SPSS ver. 26 (IBM Corp., Armonk, NY, USA). Less than 0.05 was designated as the *p*-value level of significance.

RESULTS

Of the 29 patients included in this study, 6 were men and 23 were women. The fractures were caused by a traffic accident (n = 1), slip and fall injuries (n = 23), sports injuries (n = 4), and an unknown injury (n = 1). The mean patient age was 51 years, and the mean follow-up duration was 29 months. The mean time from injury to surgery was 2 days. Baseline characteristics did not differ significantly between the 13C1 and 13C2 groups (Tables 1 and 2).

Functional outcomes were not significantly different between groups (Table 3). Mean ROM of the elbow flexion and extension was 129.5° ± 21.5° in the type 13C1 group and 123.0° ± 20.6° in the type 13C2 group ($p = 0.20$). Mean MEPS was 92.9 ± 8.5 in the type 13C1 group and 85.0 ± 14.1 in the type 13C2 group ($p = 0.09$). MEPS was graded as excellent in 17 patients (59%), good in 11 patients (38%), and poor in 1 patient (3%). Mean Q-DASH score was 12.6 ± 11.7 in the type 13C1 group and 16.2 ± 19.8 in the type 13C2 group ($p = 0.60$).

There were no postoperative complications, such as infection, heterotopic ossification, or ulnar nerve injury in either group. No patient exhibited malunion or nonunion on their final follow-up radiographs. Mean carrying angle was 11.9° ± 3.7° in the type 13C1 group and 11.1° ± 4.1° in the type 13C2 group ($p = 0.55$). During follow-up, 9 of the 29 patients underwent removal of their plates. Five patients simply wanted the implant removed, whereas the plates were removed from the other patients to improve ROM (n = 1) or because of tingling sensations (n = 2) or

Table 1. Baseline Characteristics of the Study Population

Characteristic	AO/OTA type		*p*-value
	13C1 (n = 19)	13C2 (n = 10)	
Age (yr)	52.9 ± 15.9	48.3 ± 15.4	0.45*
Sex			0.63†
Male	3	3	
Female	16	7	
Mean follow-up (mo)	28.7 ± 2.7	29.5 ± 4.5	0.66*
Time to surgery (day)	2.3 ± 1.4	1.6 ± 1.2	0.22*

Values are presented as mean ± standard deviation or number.
OTA: Orthopaedic Trauma Association.
*Mann Whitney *U*-test. †Fisher's exact test.

a foreign body sensation (n = 1). Eleven patients were retired or had no occupation before surgery. Eighteen patients returned to work after surgery: 16 were engaged in light activities (e.g., cashier or office work), and 2 had jobs requiring strength (e.g., machine operation).

DISCUSSION

In this retrospective study, we compared surgical outcomes of open reduction and plate fixation repair of type 13C1 versus type 13C2 distal humeral fractures using the paratricipital approach. We found no differences in surgical outcomes between the two types of fractures. The paratricipital approach has several advantages for surgical repair of distal humeral fractures. With this approach, insertion of the triceps tendon is not disrupted, and olecranon osteotomy can be avoided. Risks of nonunion or implant complications associated with olecranon osteotomy are thereby eliminated.[9] Because the incision is made in a less vascular plane with the paratricipital approach, the risk of direct damage to the triceps and scar formation is reduced and triceps function is preserved.[20] Consequently, early elbow movement is possible, and fibrosis or adhesions of the joint can be reduced. Aitken and Rorabeck[21] claimed that early exercise is the most important factor affecting recovery of elbow function, and all of our patients began early ROM exercises as soon as tolerated (within 2 weeks postoperatively). Additionally, the paratricipital approach preserves innervation and blood supply of the anconeus muscle, which contributes to dynamic posterolateral stability of the elbow joint.[1]

Compared with the olecranon osteotomy approach, the paratricipital approach allows limited access to the surgical field.[22] This may be disadvantageous for type 13C1 and 13C2 fractures, which require thorough visualization of bony fragments involving the intra-articular surface. Nevertheless, we conjectured that sufficient indirect reduction of the fracture site would be possible through the paratricipital approach because the fracture at the joint surface was not severe with type 13C2 fractures. Even with severe metaphyseal comminution in type 13C2 fractures, anatomical reduction of the articular surface is possible by first performing fixation of both columns. Alternatively, fixation of the intra-articular fracture can be performed first, followed by conversion of the intercondylar fracture to a supracondylar fracture when a simple intra-articular fracture is present. Moreover, when the field of view is limited and reduction is difficult using the paratricipital approach, it is possible to switch to an olecranon osteotomy approach, although this was not necessary in the current study.[1]

Various methods have been used for fixation of fracture fragments, including pin fixation, screw fixation, wire fixation, and metal plate fixation.[5] In a previous biomechanical and clinical study, double plate osteosynthesis was found to be the most accepted method for internal fixation of distal humeral fractures.[23] However, it is controversial whether perpendicular or parallel plating provides optimal stability. Our preference is perpendicular plating fixation, which provides sufficient stability. We placed one plate on the medial supracondylar ridge and the other plate posterolaterally.[24] Bicolumn anatomic restoration and sufficient stability promote early mobilization of distal humeral fractures.[25]

Previous studies reported surgical outcomes of the paratricipital approach. In their analysis of 22 patients,

Table 2. Last Clinical Outcomes for Each Patient

Age (yr)/ sex	AO/ OTA type	Mode of injury	Q-DASH score	MEPS	Carrying angle (°)	Range of motion (°)	Implant removal	Return to occupation
63/F	C1	Slip and fall	2	100	15.3	95	Y	No occupation
75/F	C1	Slip and fall	0	100	15.8	135	N	No occupation
77/M	C1	Slip and fall	23	95	10.5	90	N	No occupation
39/F	C1	Slip and fall	2	100	7.7	90	N	Y
43/F	C1	Slip and fall	27	100	7.1	150	Y	Y
29/F	C1	Sports	0	100	11.7	130	N	Y
75/F	C1	Slip and fall	0	100	16.4	110	N	No occupation
31/F	C1	Slip and fall	20	80	5.6	140	Y	Y
68/F	C1	Slip and fall	16	85	4.5	150	N	No occupation
46/F	C1	Slip and fall	11	100	11.5	150	Y	Y
55/F	C1	Slip and fall	9	85	10.5	150	Y	Y
70/F	C1	Slip and fall	25	85	9.8	120	N	No occupation
64/F	C1	Slip and fall	43	75	14.8	135	Y	No occupation
62/F	C1	Slip and fall	20	90	13.5	105	N	No occupation
34/F	C1	Slip and fall	0	100	12.1	150	N	Y
39/F	C1	Slip and fall	11	100	16.5	140	Y	Y
49/F	C1	Slip and fall	5	85	13.2	140	N	Y
47/M	C1	Sports	16	85	16.5	130	N	Y
39/M	C1	Slip and fall	9	100	13.5	150	Y	Y (Non-office job)
53/F	C2	Slip and fall	23	80	17.3	130	N	Y
35/M	C2	Traffic accident	5	85	11.3	130	N	Y (Non-office job)
66/F	C2	Unknown	0	100	8.2	150	N	No occupation
28/M	C2	Sports	0	100	5.1	120	N	Y
44/M	C2	Slip and fall	9	90	11.9	130	N	Y
32/F	C2	Slip and fall	0	95	16.3	70	N	Y
35/F	C2	Sports	2	95	14.1	120	N	Y
69/F	C2	Slip and fall	43	75	10.1	130	N	No occupation
64/F	C2	Slip and fall	55	55	11.3	120	Y	No occupation
57/F	C2	Slip and fall	25	75	5.5	130	N	Y

OTA: Orthopaedic Trauma Association, Q-DASH: Quick-Disabilities of the Arm, Shoulder and Hand, MEPS: Mayo Elbow Performance Score, Y: yes, N: no.

including 5 patients with type 13C3 fractures, Ali et al.[16] concluded that the paratricipital approach was an invaluable approach for fixation of intercondylar humeral fractures, which did not negatively affect triceps strength. They did not, however, recommend the approach for multi-fragmentary type 13C3 fractures. In another study, Gosal and Singh[26] achieved favorable surgical outcomes using a modified paratricipital approach for intercondylar

Table 3. Functional Outcomes of AO/OTA Type 13C1 and 13C2 Fractures

Outcome	AO/OTA type		*p*-value
	13C1 (n = 19)	13C2 (n = 10)	
Elbow range of motion (°)*	129.5 ± 21.5	123.0 ± 20.6	0.20
Q-DASH score	12.6 ± 11.7	16.2 ± 19.8	0.60
MEPS	92.9 ± 8.5	85.0 ± 14.1	0.09
Carrying angle (°)	11.9 ± 3.7	11.1 ± 4.1	0.55

Values are presented as mean ± standard deviation.
OTA: Orthopaedic Trauma Association, Q-DASH: Quick-Disabilities of the Arm, Shoulder and Hand, MEPS: Mayo Elbow Performance Score.
*Flexion to extension.

Table 4. Comparisons with Previous Studies Using the Paratricipital Approach for 13C1 to 13C3 Distal Humeral Fractures

Variable	Study			
	Ali et al. (2008)[16]	Gosal and Singh (2015)[26]	Singh et al. (2019)[9]	This study
No. of patients	22	23	27	29
Mean age (yr)	33	33	40	51
Mean follow-up (mo)	30	28	21	29
Fracture type (n)	C1, 6; C2, 11; C3, 5	C1, 16; C2, 7	C1, 13; C2, 8; C3, 6	C1, 19; C2, 10
Range of motion (°)	NA	113	111.3 ± 22.5	127.2 ± 21.0
Mean flexion (°)	120 ± 8	122	120.6 ± 15.2	129.3 ± 20.3
Extension loss (°)	6	7	9.8 ± 8.0	2.1 ± 3.4
MEPS	84	93	81.7 ± 12.9	90.2 ± 11.2
Q-DASH score	NA	NA	NA	13.8 ± 14.7

Values are presented as mean ± standard deviation unless otherwise indicated.
NA: not analyzed, MEPS: Mayo Elbow Performance Score, Q-DASH: Quick-Disabilities of the Arm, Shoulder and Hand.

fractures of the humerus. Singh et al.[9] reported 9.8° mean loss of extension, 120.6° mean flexion, 111.3° mean ROM, and 81.7 mean MEPS in patients with type 13C fractures. However, their outcomes were poor in patients with 13C3 fractures. In the present study, satisfactory functional outcomes (ROM, MEPS, and Q-DASH score) were achieved, with no significant differences between type 13C1 and 13C2 fractures. Our results for type 13C1 and 13C2 fractures were comparable to those of other studies using the paratricipital approach. When considering all patients in the current study, mean extension loss was 2.1°, mean flexion was 129.3°, and mean ROM was 127.2°. MEPS was graded as excellent in 63% of the patients and good in 29% of the patients, with an overall mean MEPS of 90.2 for all study participants (Table 4).

We additionally compared functional outcomes between implant removal (n = 9) and non-implant removal (n = 20) groups. Interestingly, ROM was significantly greater in the implant removal group than in the non-implant removal group, although other functional results were similar between groups (Table 5). Because of the relatively small size of this study, it is unclear whether implant removal is necessary for optimal elbow ROM in patients with 13C1 or 13C2 fractures. However, we speculate that the greater ROM may have been attributed to reduced implant irritation by removing the plate in the periarticular area, rather than to decreased joint stiffness.[27]

This study has some limitations. First, we evaluated only patients with a type 13C1 or type 13C2 distal humeral fracture. Although we did not examine type 13C3 fractures, it is unrealistic to use the paratricipital approach for this type of fractures because of the presence of multiple

Table 5. Functional Outcomes of Non-implant Removal and Implant Removal Groups

Characteristics and outcome	Non-implant removal group (n = 20)	Implant removal group (n = 9)	*p*-value
Age (yr)	52.2 ± 17.1	49.3 ± 12.5	0.64*
Range of motion (°)	123.0 ± 21.1	136.7 ± 18.5	0.04*
Q-DASH score	10.7 ± 12.4	20.8 ± 17.8	0.07*
MEPS	91.0 ± 8.7	88.3 ± 16.0	0.94*
Carrying angle (°)	11.6 ± 3.9	11.8 ± 3.7	0.89*
AO/OTA type			0.11†
13C1	11	8	
13C2	9	1	

Values are presented as mean ± standard deviation or number.
Q-DASH: Quick-Disabilities of the Arm, Shoulder and Hand, MEPS: Mayo Elbow Performance Score, OTA: Orthopaedic Trauma Association.
*Mann Whitney *U*-test. †Fisher's exact test.

intra-articular comminuted fragments. Second, bone quality, such as the presence of osteoporosis, of each patient was not considered. Future studies with more patients and long-term follow-up may be warranted. Third, it has a relatively small sample size and a lower statistical power of tests.

In conclusion, the paratricipital approach has been associated with insufficient visibility for achieving anatomic reduction and firm fixation in AO/OTA type 13C2 distal humeral fractures. Compared with AO/OTA type 13C1 distal humerus fractures, 13C2 fractures showed no statistically significant differences in clinical outcomes. The paratricipital approach may thus need to be considered for both types of distal humeral intra-articular fractures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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ORCID

Soonchul Lee https://orcid.org/0000-0002-8425-6673
Eugene Baek https://orcid.org/0000-0003-2672-961X
Minwook Kim https://orcid.org/0000-0002-7584-2400
Junhan Kim https://orcid.org/0000-0001-7569-8579
Hyunil Lee https://orcid.org/0000-0002-0957-0988
Do Kyung Kim https://orcid.org/0000-0002-2462-2846
Yoon Jang https://orcid.org/0000-0001-9600-9971
Soo-Hong Han https://orcid.org/0000-0002-8951-650X

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