

# Triangular Fixation Technique for Bicolumn Restoration in Treatment of Distal Humerus Intercondylar Fracture

Sung-Weon Jung, MD, Seung-Hoon Kang, MD, Min Jeong, MD, Hae-Seong Lim, MD

*Department of Orthopedic Surgery, Samsung Changwon Hospital, Sungkyunkwan University School of Medicine, Changwon, Korea*

**Background:** Distal humerus intercondylar fractures are intra-articular and comminuted fractures involving soft tissue injury. As distal humerus is triangle-shaped, parallel plating coupled with articular fixation would be suitable for bicolumn restoration in treatment of distal humerus intercondylar fracture.

**Methods:** This study included 38 patients (15 males and 23 females) who underwent olecranon osteotomy, open reduction and internal fixation with the triangle-shaped cannulated screw and parallel locking plates (triangular fixation technique). Functional results were assessed with the visual analog scale (VAS) scores, Mayo elbow performance (MEP) scores and Disabilities of the Arm, Shoulder and Hand (DASH) questionnaires. Anteroposterior and lateral elbow radiographs were assessed for reduction, alignment, fracture union, posttraumatic arthrosis, and heterotopic ossification, and computed tomography (CT) scans were used to obtain more accurate measurements of articular discrepancy.

**Results:** All fractures healed primarily with no loss of reduction. The mean VAS, MEP, and DASH scores of the affected elbow were not significantly different from those of the unaffected elbow ( $p = 0.140$ ,  $p = 0.090$ , and  $p = 0.262$ , respectively). The mean degree of flexion was significantly lower in the affected elbow than in the unaffected elbow, but was still considered as functional ( $p = 0.001$ ,  $> 100^\circ$  in 33 of 38 patients). Two cases of articular step-offs ( $> 2$  mm) were seen on follow-up CT scans, but not significantly higher in the affected elbow than in the unaffected elbow ( $p = 0.657$ ). Binary logistic regression analysis revealed that only Association for Osteosynthesis (AO) type C3 fractures correlated with good/excellent functional outcome ( $p = 0.012$ ). Complications occurred in 12 of the 38 patients, and the overall reoperation rate for complications was 10.5% (4 of 38 patients).

**Conclusions:** Triangular fixation technique for bicolumn restoration was an effective and reliable method in treatment of distal humerus intercondylar fracture. This technique maintained articular congruency and restored both medial and lateral columns, resulting in good elbow function.

**Keywords:** *Humeral fractures, Intra-articular fractures, Fracture fixation*

Distal humerus intercondylar fractures are intra-articular, comminuted fractures involving soft tissue injury.<sup>1)</sup> These

fractures present therapeutic challenges due to the complexity of the local anatomy and are generally treated surgically with parallel or orthogonal plate fixation of the medial and lateral columns. Olecranon osteotomy is regarded as the gold standard technique, because it best exposes articular discrepancies; however, even comminuted fractures can reportedly be anatomically reduced and fixed using paratricipital incisions.<sup>2)</sup> The locking compression plate and distal humerus plate (LCP-DHP) system produces high-quality reconstructions and sufficient stability, thereby enabling early mobilization for distal humerus

Received February 26, 2015; Accepted July 13, 2015

Correspondence to: Sung-Weon Jung, MD

Department of Orthopedic Surgery, Samsung Changwon Hospital, Sungkyunkwan University School of Medicine, 158 Paryong-ro, Masanhoewon-gu, Changwon 51353, Korea

Tel: +82-55-290-6030, Fax: +82-55-290-6888

E-mail: can1204@hanmail.net

Copyright © 2016 by The Korean Orthopaedic Association

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Clinics in Orthopedic Surgery • pISSN 2005-291X eISSN 2005-4408

fractures.<sup>3)</sup> While recent advances in implant design, surgical approach, and fixation techniques have led to good functional outcomes, distal humerus fractures are still associated with several complications. These complications include loss of reduction, implant failure, nonunion, malunion, ulnar nerve neuropathy, elbow stiffness, and heterotopic ossification.<sup>4)</sup> In general, the standard management for most intra-articular fractures is anatomic restoration of the articular surface and stable fixation, followed by early mobilization.<sup>5)</sup>

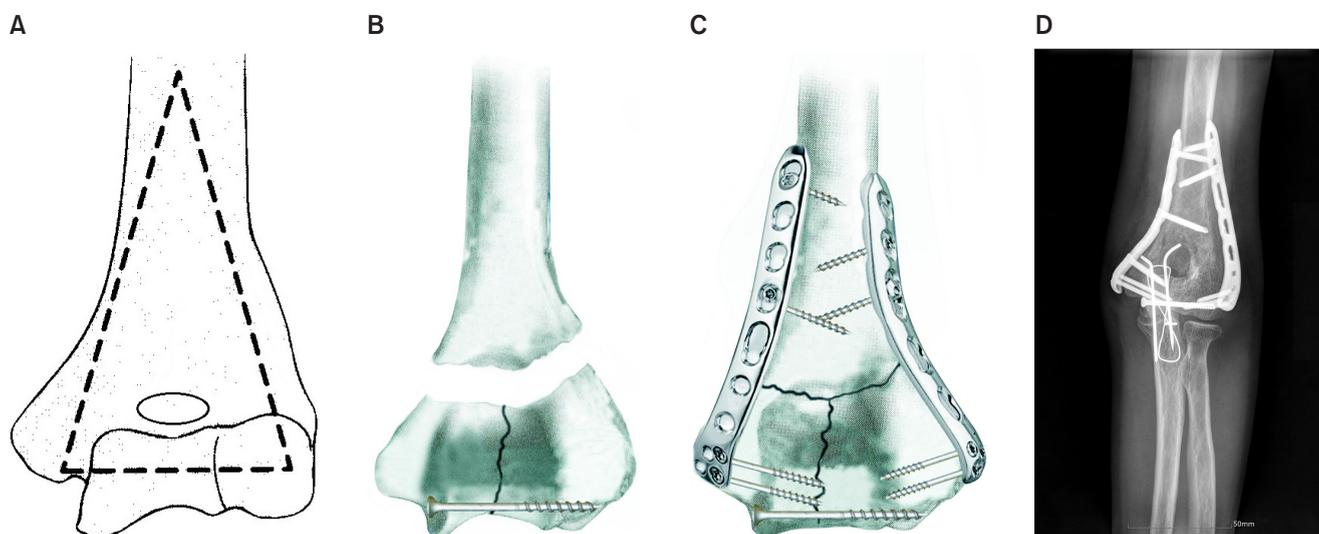
Parallel medial-lateral plating technique follows an arch-keystone concept like the principles of architecture in which 2 columns are anchored at their base and linked together at the top to provides stable fixation.<sup>6)</sup> This technique has been shown to achieve satisfactory function of the elbow joint and high rate of union.<sup>7)</sup> Since there is difficulty in maintaining articular congruity during parallel plating technique, screw fixation first to the intercondylar fragments and parallel plating has been proposed for articular congruity and operation convenience. Green<sup>8)</sup> reported that the distal humerus is composed of lateral and medial columns that diverge distally, with the trochlea situated between these columns to form a stable triangular construct, and the elbow joint is very constrained because of its complex anatomy. As distal humerus is triangle-shaped, parallel plating coupled with articular fixation would be suitable for bicolumn restoration. We hypothesized that bicolumn restoration with triangle-shaped screw and plate fixation (referred to as triangular fixation) (Fig. 1)

would allow excellent healing and good elbow motion for distal humerus fracture. Some studies have described the results of double plate osteosynthesis, but few have reported the results of triangular fixation technique.<sup>9,10)</sup> This study was performed to examine the outcomes of triangular fixation for bicolumn restoration in the treatment of distal humerus intercondylar fracture.

## METHODS

### Patient Selection and Evaluation

Forty-three consecutive patients who underwent olecranon osteotomy, open reduction and internal fixation with the triangular fixation for distal humerus intercondylar fracture from January 2007 to December 2012 at Samsung Changwon Hospital, were included in this study. All surgeries were performed by a single surgeon and elbow replacement surgery was not performed in our series. The inclusion criteria for this study were: (1) a distal humerus intercondylar fracture (Association for Osteosynthesis [AO] type C) exhibiting  $\geq 2$  mm displacement of the articular fragment and 5-mm displacement of the supracondylar fragment; and (2) loss of the medial and lateral metaphysis. Non-displaced fractures, minimally displaced fractures with stability, and fractures involving only the supracondylar area were not considered for treatment with triangular fixation and were thus not included in this study. The exclusion criteria were: (1) an open fracture (1 elbow, Gustilo-Anderson grade I); (2) concomitant neu-



**Fig. 1.** (A) Schematic illustration demonstrates that distal humerus is composed of lateral and medial columns with the trochlea situated between these columns to form a triangular construct. (B, C) Schematic illustrations demonstrate that the articular congruity is first anatomically reduced with a cannulated screw and the columns are stably fixed with double plates (triangular fixation). (D) The postoperative anteroposterior radiograph shows triangle-shaped screw and plate fixation.

rovascular injury (1 elbow, radial nerve injury); (3) previous elbow surgery (1 elbow, a supracondylar fracture as a child); and (4) loss to follow-up (2 elbows). The exclusion criteria were chosen based on their ability to influence functional outcome. Overall, 38 patients (15 males and 23 females) were ultimately included in this study and mean patient age was 59.07 years (range, 31 to 88 years). Fractures were categorized according to the AO classification system. Three-dimensional computed tomography (3D CT) scans were used to confirm the degree of articular involvement in the intra-articular fractures and to help in preoperative planning. Of the type C fractures, 17 were C1, 13 were C2, and 8 were C3. The mechanisms of injury were: falling from standing height, 17; motor vehicle accident, 8; bicycle accident, 3; falling from a height greater than standing, 5; falling from stairs, 2; sports-related injury, 2; and machine-related injury, 1 (Table 1).

All patients attended follow-up examinations for 31.15 months (range, 12 to 72 months). At the final follow-up visit, patients were examined and interviewed to assess functional and radiological outcomes. A standardized testing position was used for all patients to increase the re-

liability of the measurements. The subjects were tested in a seated position with the shoulder adducted, neutrally rotated, and flexed to 90°; the forearm and wrist were placed in a neutral position. The unaffected elbow was examined first and served as a control for each patient. Patients subjectively evaluated the pain according to the visual analog scale (VAS; range, 0 to 10). The range of motion (ROM; flexion, extension, pronation, and supination) of each elbow joint was measured using a goniometer. Functional results were assessed with the Mayo elbow performance (MEP) scores and Disabilities of the Arm, Shoulder and Hand (DASH) questionnaires. The MEP scores assessed the degrees of elbow pain (range, 0 to 45), motion (range, 0 to 20), stability (range, 0 to 10), and function (range, 0 to 25). The MEP scores were used to classify patients into different functional categories, including excellent (> 90), good (75–89), fair (60–74), and poor (< 60). The DASH questionnaire consisted of a 30-item survey aimed at assessing upper extremity health status. The items concerned the degree of difficulty in performing various physical activities (21 items), the severity of each symptom of pain (i.e., activity-related pain, tingling, weakness, and stiffness; 5 items), and the effect on social activities, work, and sleep, in addition to its psychological impact (4 items).

Standardized X-rays (true anteroposterior and lateral views) were used to evaluate for reduction, alignment, fracture union, posttraumatic arthrosis, and heterotopic ossification. An oblique view may be more helpful to visualize the healing process of fracture site than anteroposterior or lateral view, hence, internal and external oblique views were used to evaluate cases of articular step-off and delayed union. However, the standardization of oblique views was difficult and oblique views were not performed in all case; hence, we excluded the oblique view in the standardized X-rays. Follow-up CT scans were used to obtain more accurate measurements of articular discrepancy. Bicolumn restoration was considered successful: (1) the medial and lateral columns were anatomically reduced (malalignment of < 10 in any plane) and stably fixed with 2 sparing plates and (2) the articular cartilage was anatomically reduced (articular step-offs of < 2 mm), as assessed by radiographs and CT scans. Bone mineral density (BMD) was measured using a dual-energy X-ray absorptiometry (DEXA) scanner (Lunar Prodigy, enCORE; GE Medical Systems Lunar, Madison, WI, USA). A DEXA scan is a part of Samsung Changwon Hospital's standard protocol for the fracture treatment of patients over the age of 60 years and DEXA scans were measured in young patients for this study. The lowest T score of the lumbar spine or proximal femur was also recorded. The states of plate re-

Table 1. Patient Baseline Characteristics

Characteristic	Value
Sex (male:female)	15:23
Age (yr), mean (range)	59.07 (31 to 88)
Follow-up (mo), mean (range)	31.15 (12 to 72)
Bone mineral density, mean (range)	-1.78 (1.0 to -3.5)
AO classification	
Type C1 fracture	17
Type C2 fracture	13
Type C3 fracture	8
Injury mechanism	
Fall from standing height	17
Motor vehicle accident	8
Bicycle accident	3
Fall from greater than standing height	5
Fall from stairs	2
Sports-related injury	2
Machine-related injury	1

AO: Association for Osteosynthesis.

moval were also checked. Binary logistic regression analysis was used to evaluate the correlations between good/excellent functional results and other variables. The degree of osteoarthritis was graded from 0 to III (none, mild, moderate, and severe) described by Broberg and Morrey.<sup>11)</sup> All measurements were performed by two examiners. One examiner was an experienced musculoskeletal radiologist who was not involved in this study, and the other examiner was an orthopedic surgeon. In case of disagreement of two examiners' interpretation, it was confirmed by another orthopedic surgeon. This study was approved by the Institutional Review Board of Samsung Medical Center.

### Surgical Technique

All procedures were performed under general anesthesia, and patients were placed in the supine position with the shoulder flexed to 90°, the elbow flexed to 90°, and the forearm in a neutral position. In our experience, the intraoperative image intensifier is useful with the patient in the supine position, and cephalad positioning is an effective method for monitoring the intraoperative state. A skin incision was made beginning at 5 cm distal from olecranon tip and extending approximately 15 cm proximally. Subsequently, full-thickness fasciocutaneous flaps were generated. The ulnar nerve was identified and dissected proximally to the arcade of Struthers and distally to the first motor branch in the flexor carpi ulnaris muscle belly; and the ulnar nerve was then transposed to an anterior subcutaneous position. A standard chevron osteotomy (reverse V-shaped osteotomy) of the olecranon was performed with a sagittal electric saw. The medial and lateral borders of the triceps muscle were elevated from their respective intermuscular septae, freeing the triceps muscle from the posterior aspect of the humerus in an extraperiosteal fashion. This approach enables the visualization of the entire articular surface of the distal part of the humerus. First, because the intercondylar fragments were displaced in most cases, intercondylar fragments were anatomically reduced and fixed with a 3.5-mm cannulated screw under direct visualization. Occasionally, when another articular fragment impacted between the broken condyles, additional Kirschner-wires (K-wires) were helpful, and the articular step-off was used as a template for reduction adequacy. Second, the reconstructed distal articular block was approximated to the humeral diaphysis. The fracture fragments were reduced and temporarily fixed either with reduction forceps or the K-wire fixation method. Then, locking plates were applied along both the medial and lateral columns of the distal humerus. Synthes locking plates (Stratec Medical Ltd., Mezzovico, Switzer-

land) were used in all cases. Care was taken to ensure that a proper fit was maintained between the plates and edges of the medial and lateral borders. Either the most proximal or the second most proximal screw was inserted to place the plate on an edge or a slightly posterior surface of the humeral shaft, and the distal locking screws were inserted in sequence. Totally six screws were inserted into the distal fragment and four to six screws were inserted into the proximal fragments. Finally, the olecranon osteotomy was fixed *via* tension band wiring. Fixation stability and motion arcs were assessed, and correct plate placement, screw placement, and adequate fixation stability were all verified by fluoroscopy prior to closure. To cover the plates, the triceps were sutured to the adjacent muscles, ensuring that the anteriorly transposed ulnar nerve was free from surrounding tissue. The wound was closed, and a bulky dressing was applied with the elbow in 20° to 30° flexion. Low-molecular weight heparin was administered to elderly patients (over 60 years old) for 1 week in order to prevent deep vein thrombosis. On postoperative day 2, the dressing was removed and a full active-assisted elbow motion and grip-strengthening therapy program was initiated. Routine physiotherapy was initiated at 4 to 6 weeks postoperatively, depending on the stability of the fracture. All patients were encouraged to achieve maximum function and elbow motion.

### Statistical Analysis

Measurements were expressed as mean  $\pm$  standard deviation (range), unless otherwise stated. Paired *t*-tests were used to assess the significance of differences in functional parameters between the affected and unaffected sides. The *k*-values were calculated for interobserver and intraobserver reliability to assess levels of agreement, with *k*-values below 0.40 considered poor; between 0.41 and 0.59, fair; between 0.60 and 0.74, good; and 0.75 or higher, excellent. Binary logistic regression analysis was used to evaluate the correlations between good to excellent functional results and other variables, such as sex, age, fracture type, BMD, and the state of plate removal. All calculations were performed using IBM SPSS ver. 21.0 (IBM Co., Armonk, NY, USA). The *p*-values of less than 0.05 were considered statistically significant.

## RESULTS

The mean VAS score was not significantly higher in the affected elbow than in the unaffected elbow (2.13 vs. 1.26, *p* = 0.140). The mean degree of flexion was significantly lower in the affected elbow than in the unaffected elbow

Table 2. Functional and Radiological Results of Bicolumn Restoration with Triangular Fixation

Variable	Affected side	Unaffected side	p-value
Visual analog scale score	2.13 ± 2.18 (1–7)	1.26 ± 0.64 (1–3)	0.140
Range of motion (°)			
Flexion	119.21 ± 16.30 (80–130)	137.11 ± 8.59 (100–135)	0.001
Extension*	10.39 ± 11.17 (0–45)	4.08 ± 8.04 (0–30)	0.187
Pronation	73.26 ± 15.7 (60–90)	77.08 ± 8.13 (70–90)	0.492
Supination	67.89 ± 12.9 (50–80)	70.12 ± 7.12 (60–80)	0.595
MEP score			
Pain	35.39 ± 11.82 (20–40)	42.63 ± 5.54 (30–45)	0.230
Motion	16.84 ± 3.75 (10–20)	19.34 ± 1.71 (15–20)	0.157
Stability	10.00 ± 0.00	10.00 ± 0.00	1.000
Function	22.89 ± 6.22 (15–25)	24.61 ± 1.37 (20–25)	0.108
Total	88.68 ± 20.29 (20–100)	96.58 ± 6.16 (80–100)	0.090
DASH score	14.61 ± 25.42 (0–96.66)	8.78 ± 3.58 (0–12.5)	0.262
Fracture healing	38/38	38/38	1.000
Progression to osteoarthritis			
No sign	28	30	0.778
Mild change	8	5	0.756
Moderate change	2	1	0.668
Severe change	1	1	1.000
Articular step-off > 2 mm	2/38	0/38	0.657

Values are presented as mean ± standard deviation (range) and compared using the paired *t*-test.

MEP: Mayo elbow performance, DASH: Disabilities of the Arm, Shoulder and Hand.

\*Extension means flexion contracture.



**Fig. 2.** (A) Postoperative 1-year computed tomography scan of a 59-year-old woman demonstrates good articular congruency in the coronal oblique view. (B) Follow-up computed tomography scan of a 68-year-old man demonstrates articular step-off in the coronal oblique view.

(119.21° vs. 137.11°,  $p = 0.001$ ); however, the affected elbow was still considered as functional ( $> 100^\circ$ ) in 33 of the 38 patients. The mean degrees of extension, pronation, and supination were not significantly lower in the affected elbow than in the unaffected elbow ( $p = 0.187$ ,  $p = 0.492$ , and  $p = 0.595$ , respectively). The mean intensity of pain, ROM, degree of stability, degree of function, and total MEP score were not significantly lower in the affected elbow than in the unaffected elbow ( $p = 0.230$ ,  $p = 0.157$ ,  $p = 0.337$ ,  $p = 0.695$ , and  $p = 0.090$ , respectively). The MEP scores were classified as excellent in 12 patients, good in 19 patients, fair in five patients, and poor in two patients. One patient with a poor MEP score had an AO type C3 fracture with severe intra-articular comminution, which had progressed to postoperative arthritis with poor ROM by the final follow-up visit. The other patient with a poor MEP score also had an AO type C3 fracture with severe intra-articular comminution and complained of malunion, complex regional pain syndrome, and a restricted ROM at the final follow-up visit. The mean DASH score was not significantly lower in the affected elbow than in the unaffected elbow; however, the DASH scores indicate slight impairment of upper extremity function in the affected elbow, as compared with the unaffected elbow ( $p = 0.262$ ).

While three affected elbows exhibited moderate to severe osteoarthritic changes, two unaffected elbows also exhibited moderate to severe osteoarthritic changes at the final follow-up visit ( $p = 0.668$  and  $p = 1.000$ , respectively). Two cases with a  $> 2$  mm articular step-off were identified on the follow-up CT scans; these two cases were malreduction of the articular surface with respect to the both columns (Fig. 2). But, the number of  $> 2$  mm articular step-offs was not significantly higher in the affected elbow than in the unaffected elbow ( $p = 0.657$ ) (Table 2). Most of the measurements showed fair to good reliability. Interobserver reliabilities were 0.68, 0.74 and intraobserver reliability was 0.62 for the aspects of the articular step-off. Interobserver reliabilities were 0.66, 0.71 and intraobserver reliability was 0.55 for the aspects of the degrees osteoarthritis.

Binary logistic regression analysis was used to evaluate the correlations between good to excellent functional results (as expressed by the MEP score) and other variables. This analysis revealed that sex, age, AO type C1 fracture, type C2 fracture, BMD, and the state of plate removal did not correlate with good to excellent results. Only the presence of an AO type C3 fracture was found to significantly correlate with functional outcome ( $p = 0.012$ ) (Table 3).

All 38 fractures healed without any loss of reduction

(Fig. 3). Complications occurred in 12 of the 38 patients (31.6%), and the reoperation rate due to complications was 10.5% (4 of 38 patients). One patient underwent a revision release due to elbow stiffness. Five patients exhibited less than 100 arcs of motion, and four patients who exhibited approximately 70 to 80 arcs of motion did not want reoperation because they did not experience any discomfort in daily activity. Only one patient who exhibited 60 arcs of motion was offered a revision release.

One patient underwent a revision repair of the lateral collateral ligament due to elbow instability. If an elbow had lateral instability of 10 mm, the patient was offered a ligament repair. Two patients suffered from ulnar neuropathies. Of these, one patient complained a prominent tingling sensation in the fourth and fifth fingers after operation, so nerve release of the transposed ulnar nerve was performed at 3 months postoperatively. After this procedure, the patient's symptoms were resolved. The other patient complained of a mild tingling sensation, and observation was performed in the early recovery period. But, the tingling sensation got worse in addition to atro-

Table 3. Binary Logistic Regression Analysis According to Sex, Age, BMD, Fracture Type, and State of Plate Removal of Patients with Good/Excellent Functional Results

Variable	No. of patients	<i>p</i> -value*
Functional results (MEP score)		
Excellent	12	
Good	19	
Fair	5	
Poor	2	
Sex (male:female)	15:23	0.101
Age (yr), mean (range)	59.07 (31–88)	0.131
Fracture type		
C1	17	0.259
C2	13	0.383
C3	8	0.012
BMD		
$\geq -2.5$	29	0.093
$< -2.5$	9	
Plate removal (removal)	8	0.612

BMD: bone mineral density, MEP: Mayo elbow performance.  
\*Binary logistic regression analysis.



**Fig. 3.** (A, B) Initial anteroposterior and lateral radiographs of a 65-year-old man show a displaced Association for Osteosynthesis (AO) type C2 distal humerus intercondylar fracture. (C, D) Postoperative 1-year anteroposterior and lateral radiographs show bone union and good alignment.

**Table 4.** Summary of Complications

Complication	No. of patients	Reoperation
Elbow stiffness	1	Capsular release
Elbow instability	1	Ligament sutures
Ulnar neuropathy	2	Nerve release
Bullae and partial necrosis	3	Conservative
Screw loosening	2	None
Kirschner-wire loosening	3	None
Total	12/38	4/38

phy in the first web space, for which, nerve release of the transposed ulnar nerve was performed at the time of plate removal. However, the tingling sensation persisted at the final follow-up visit. Three patients with severe swelling and wound-associated bullae exhibited partial skin ne-

erosis; however, the wounds were successfully healed with conservative treatment in all three patients. Two patients exhibited partial loosening of the screw, but these fractures healed without reoperation at postoperative 9 months. After fracture sites were healed, the plate was removed at postoperative 1 year. Three patients exhibited K-wire loosening at the olecranon osteotomy site; one of these cases showed delayed union but had healed after 12 months. No incidences of heterotrophic ossification or infection were recorded; moreover, no revision elbow replacements were performed in our series (Table 4).

## DISCUSSION

Distal humerus fractures are relatively rare (< 2%) but do occur increasingly in the elderly population. Due to the complexity of the local anatomy, the distal humerus fractures remain a therapeutic difficulty. Open reduction and internal fixation is widely accepted as the treatment of choice for distal humerus fracture. The principle goal

in surgical treatment is to effectively stabilize the reduced fracture, in order to maximize functional outcomes. Anatomic restoration of the articular surface and stable fixation are both essential for successful early mobilization. Inadequate reduction with the articular bone loss could result in subsequent loss of fixation particularly in osteoporotic bones.

The bicolumn theory is particularly helpful in understanding the biomechanical rationale for treating distal humerus fracture.<sup>12)</sup> The lateral column, which is composed of the capitellum and the lateral metaphysis, provides radiocapitellar stability through the osseous buttress and the lateral ligamentous structures. The medial column, which is composed of the trochlea and the sigmoid notch, establishes the primary load-bearing surface of the ulnotrochlear joint through the osseous buttress and the medial ligamentous structures. Reducing the articular surfaces of the capitellum and trochlea is a requisite for achieving congruity of the elbow joint. Although articular surface was first anatomically reduced and temporary K-wire fixation was performed under direct visualization, we had encountered loss of articular reduction during screw fixation *via* plate holes in initial cases. Screw fixation of articular fragments was first performed for articular congruity and operation convenience and parallel plate fixation was performed for bicolumn restoration since thereafter. Fixation of major articular fragments is a key practice for restoring articular congruity of major joints. The distal humerus is composed of lateral and medial columns with the trochlea situated between these columns to form a triangular construct. We accordingly hypothesized that triangle-shaped, screw and plate fixation would be suitable for bicolumn restoration. Since no loss of reduction and only minor progression to osteoarthritis (2 of 38 patients) was observed in our series, we concluded that screw and plate configuration provides adequate stability for distal humerus fractures.

Many aspects regarding the treatment of distal humerus fractures are still controversial. Due to the importance of articular congruency, olecranon osteotomy is regarded as the gold standard treatment. However, even comminuted fractures can be anatomically reduced and fixed using paratricipital incisions. Although olecranon-sparing approaches are associated with fewer wound problems, reduction and fixation of the articular fragments are technically more difficult with these approaches, especially when the central fragment between both condyles is depressed or elevated. Parallel plating configurations may have better biomechanical properties, as compared with orthogonal plate configuration. However, clinical case

studies of both techniques have yielded similar functional results, incidences of bone union, and complication rates. While a prospective randomized study that compared parallel and orthogonal plating found no significant differences between the 2 techniques regarding functional results, incidence of union, and complication rate, another study demonstrated that the parallel plating method is superior for resisting axial loading and torsion and provides more stable fixation than the perpendicular plating method.<sup>13,14)</sup>

A common pitfall is that the parallel plating technique requires a certain amounts of soft tissue dissection, sometimes resulting in medial or lateral instability. During the dissection of soft tissue around the lateral supracondylar ridge and epicondyle, collateral ligaments and joint capsules are sometimes injured. One patient complained of lateral instability after triangular fixation technique and underwent a revision repair of the lateral collateral ligament. After experiencing this complication, elbow stability and ligaments injury were more carefully assessed prior to closure. Some clinicians have recommended anterior transposition, but the ability of this technique to reduce postoperative ulnar nerve symptoms has not yet been established.<sup>15,16)</sup> Despite controversies concerning the appropriate treatment of distal humerus fractures, double plating fixation is widely reported to produce satisfactory clinical outcomes, even in patients with complex intra-articular fractures. Reising et al.<sup>17)</sup> treated 46 patients with type B and C fractures with the DHP system and reported a mean MEP score of 84 points after a mean follow-up period of 11 months. The total range of elbow motion reportedly varies from 103° to 112° after double plating fixation of type C distal humerus fractures, regardless of the plate position. Thirty-one of the 38 patients (81.6%) achieved good or excellent functional results after triangular fixation technique, with a mean range of elbow motion of 109° in our series, which was comparable to the results reported in previous studies of AO type C distal humeral fractures. Morrey et al.<sup>18)</sup> studied 15 common activities of daily living and determined that a 100° arc of elbow motion was necessary to accomplish these tasks. Bicolumn restoration with a screw and parallel plate configuration might be advantageous for articular congruency; however, these techniques have yielded similar functional results, incidences of bone union, and complication rates. Even though satisfactory results were reported, complication rates up to 48% have previously been reported for type C distal humerus fractures. Athwal et al.<sup>10)</sup> reported that the high complication rate is not associated with the implant. This high rate results from the complexity of the fractures themselves. We found a high overall complication rate of

31.6% (12 of 38 patients) and a revision rate of 10.5% (4 of 38 patients), but the majority of patients showed good to excellent results, even after revision surgery at final follow-up visit.

Most cases (30 of 38) were accompanied by wound swelling and bullae surrounding the operation site in our series. These observations are probably due to the complex nature of the distal humerus fracture and the use of low-molecular weight heparin for 1 week postoperatively. While three exhibited severe swelling and displayed bullae near the wound that led to partial skin necrosis, conservative treatment (high elevation and exercise) was able to successfully heal the wounds in all patients.

This study had several limitations. First, it was a retrospective case series; thus, additional prospective studies

will be required to validate these findings. Second, further studies comparing olecranon-osteotomy and olecranon-preserving approach are necessary to provide more complete information and to validate the findings of the current study.

In conclusion, triangular fixation technique for bicolumn restoration was an effective and reliable method in treatment of distal humerus intercondylar fracture. This technique maintained articular congruency and restored both medial and lateral columns, resulting in good elbow function.

### CONFLICT OF INTEREST

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

### REFERENCES

- Sanchez-Sotelo J, Torchia ME, O'Driscoll SW. Complex distal humeral fractures: internal fixation with a principle-based parallel-plate technique. *J Bone Joint Surg Am.* 2007; 89(5):961-9.
- Muhldorfer-Fodor M, Bekler H, Wolfe VM, McKean J, Rosenwasser MP. Paratricipital-triceps splitting "two-window" approach for distal humerus fractures. *Tech Hand Up Extrem Surg.* 2011;15(3):156-61.
- Kaiser T, Brunner A, Hohendorff B, Ulmar B, Babst R. Treatment of supra- and intra-articular fractures of the distal humerus with the LCP Distal Humerus Plate: a 2-year follow-up. *J Shoulder Elbow Surg.* 2011;20(2):206-12.
- Pajarinen J, Bjorkenheim JM. Operative treatment of type C intercondylar fractures of the distal humerus: results after a mean follow-up of 2 years in a series of 18 patients. *J Shoulder Elbow Surg.* 2002;11(1):48-52.
- Mansat P, Nouaille Degorce H, Bonneville N, Demez H, Fabre T; SOFCOT. Total elbow arthroplasty for acute distal humeral fractures in patients over 65 years old - results of a multicenter study in 87 patients. *Orthop Traumatol Surg Res.* 2013;99(7):779-84.
- Stoffel K, Cunneen S, Morgan R, Nicholls R, Stachowiak G. Comparative stability of perpendicular versus parallel double-locking plating systems in osteoporotic comminuted distal humerus fractures. *J Orthop Res.* 2008;26(6):778-84.
- O'Driscoll SW. Optimizing stability in distal humeral fracture fixation. *J Shoulder Elbow Surg.* 2005;14(1 Suppl S): 186S-194S.
- Green A. Postoperative management after open reduction and internal fixation of distal humeral fractures. *Instr Course Lect.* 2009;58:535-9.
- Huang JI, Paczas M, Hoyer HA, Vallier HA. Functional outcome after open reduction internal fixation of intra-articular fractures of the distal humerus in the elderly. *J Orthop Trauma.* 2011;25(5):259-65.
- Athwal GS, Hoxie SC, Rispoli DM, Steinmann SP. Precontoured parallel plate fixation of AO/OTA type C distal humerus fractures. *J Orthop Trauma.* 2009;23(8):575-80.
- Broberg MA, Morrey BF. Results of delayed excision of the radial head after fracture. *J Bone Joint Surg Am.* 1986; 68(5):669-74.
- Nauth A, McKee MD, Ristevski B, Hall J, Schemitsch EH. Distal humeral fractures in adults. *J Bone Joint Surg Am.* 2011;93(7):686-700.
- Arnander MW, Reeves A, MacLeod IA, Pinto TM, Khaleel A. A biomechanical comparison of plate configuration in distal humerus fractures. *J Orthop Trauma.* 2008;22(5):332-6.
- Zalavras CG, Vercillo MT, Jun BJ, Otardifard K, Itamura JM, Lee TQ. Biomechanical evaluation of parallel versus orthogonal plate fixation of intra-articular distal humerus fractures. *J Shoulder Elbow Surg.* 2011;20(1):12-20.
- Worden A, Ilyas AM. Ulnar neuropathy following distal humerus fracture fixation. *Orthop Clin North Am.* 2012; 43(4):509-14.
- Ring D, Gulotta L, Chin K, Jupiter JB. Olecranon osteotomy for exposure of fractures and nonunions of the distal humerus. *J Orthop Trauma.* 2004;18(7):446-9.

17. Reising K, Hauschild O, Strohm PC, Suedkamp NP. Stabilisation of articular fractures of the distal humerus: early experience with a novel perpendicular plate system. *Injury*. 2009;40(6):611-7.
18. Morrey BF, Askew LJ, Chao EY. A biomechanical study of normal functional elbow motion. *J Bone Joint Surg Am*. 1981;63(6):872-7.