

Outcome of Open Reduction & Internal Fixation of T-Y Intercondylar Fracture (AO type C) of Distal Humerus in Adults by Bicolumnar Locking Plates

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ABSTRACT

Background: Distal humerus fractures account for 2% of adult fractures and are surgically challenging due to complex elbow anatomy and articular comminution. AO type C intercondylar fractures are especially demanding; conventional implants often fail in small distal fragments. Bicolumnar locking plates in a 90°–90° configuration offer angular-stable fixation and early mobilization. **Objective:** To evaluate radiological and functional outcomes of AO type C distal humerus fractures in adults treated by open reduction and internal fixation with bicolumnar locking plates. **Methods:** A prospective observational study at the Department of Orthopaedic Surgery, Dhaka Medical College Hospital, ran over 18 months with a six-month follow-up. Twenty-two adults with closed AO type C fractures were enrolled. All underwent open reduction & internal fixation (ORIF) via a triceps tongue approach. Radiological union was graded by the Hammer criteria; functional outcome by the Mayo Elbow Performance Score (MEPS). Analysis used SPSS version 26 ($p < 0.05$). **Results:** Mean age was 41.7 years with equal gender distribution. Road traffic accidents were dominant (68.2%) and AO 13C2 was the most frequent fracture type (68.2%). The mean injury-to-surgery interval was 11.9 days. Union was achieved at 19.9 weeks; 59.1% attained Grade 1 union. Mean MEPS was 81.82. Good and excellent outcomes were recorded in 45.5% and 31.8% respectively, giving a satisfactory rate of 95.5%. Age and comorbidities were significant outcome predictors. **Conclusion:** ORIF with bicolumnar locking plates yields reliable union and favourable functional recovery in AO type C distal humerus fractures with minimum

complications.

Keywords: Distal humerus fracture, bicolumnar locking plate, AO type C, ORIF, MEPS.

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INTRODUCTION

Fractures of the distal humerus account for approximately 30% of all humeral fractures and 2% of all adult fractures, representing one of the most technically demanding injuries in orthopaedic trauma surgery [1]. The complex anatomy of the elbow joint, proximity of major neurovascular structures and limited soft tissue envelope render both accurate reduction and stable fixation extremely difficult. The fundamental treatment goal is to restore a stable, congruent elbow with an adequate functional range of motion [1].

In the AO/OTA classification system, distal humerus fractures are designated type A for extra-articular, type B for partial articular and type C for complete intra-articular injuries, where the articular surface is entirely separated from the humeral shaft [2]. Type C fractures—encompassing T- and Y-type intercondylar patterns—are the most complex subset, characterized by simultaneous disruption of both the medial and lateral columns and the articular segment, thereby destroying the stable triangular architecture of the distal humerus [3].

A bimodal age distribution characterizes distal humerus fractures: high-energy mechanisms predominate in younger

patients, while low-energy falls account for the majority of fractures in the elderly [4]. Clinical evaluation must include a thorough neurovascular examination of the ulnar, median and radial nerves, together with anteroposterior and lateral radiographs of the distal humerus. Computed tomography with three-dimensional reconstruction is valuable for delineating articular comminution and guiding preoperative planning [2].

Conventional implants and techniques—including one-third tubular plates, K-wires and tension band wiring—have demonstrated unacceptably high rates of implant failure and poor clinical outcomes in multi-fragmented AO type C fractures, largely because small distal fragments cannot accommodate sufficient screws to achieve an adequate bone-plate interface [5]. The introduction of locking plate technology addressed several of these limitations. By providing angular-stable, fixed-angle fixation through multiple screws engaging the locking construct, distal humeral locking plates confer superior stability in osteoporotic and comminuted bone compared with conventional implants [6].

Single-column plating has been shown to be less load-stable than bicolumnar

constructs in complex distal humeral fractures characterized by a large medullary canal, relative osteopenia and narrow screw-holding cortices [7]. Current evidence and international guidelines endorse double-column plating as the standard for AO type C intercondylar fractures [1, 8]. Both parallel and orthogonal (90°–90°) plate configurations have been advocated; while parallel plating offers certain biomechanical advantages, the 90°–90° arrangement provides superior purchase for distally located fragments and greater versatility in screw placement [8].

Pre-contoured anatomical bicolumnar locking compression plates placed in a 90°–90° orientation have emerged as the current gold standard for managing AO type C distal humeral fractures. This construct facilitates anatomical reduction, provides adequate mechanical stability and permits early elbow range-of-motion exercises, which are central to achieving optimal functional recovery [1, 8]. Despite growing evidence in support of this approach, data from South Asian institutions—where population demographics, injury epidemiology and healthcare-access patterns may differ substantially—remain sparse. This study was therefore undertaken to evaluate the

outcomes of ORIF with bicolumnar locking plates for AO type C intercondylar fractures of the distal humerus in adults at a major tertiary referral center in Bangladesh.

OBJECTIVES

To evaluate the radiological and functional outcomes of adults with AO type C (T-Y intercondylar) fractures of the distal humerus treated by ORIF using anatomical bicolumnar locking plates in a 90°–90° configuration at a tertiary orthopaedic unit in Bangladesh.

METHODS & MATERIALS

This was a prospective observational study conducted in the Department of Orthopaedic Surgery, Dhaka Medical College Hospital (DMCH), Dhaka, Bangladesh, over 18 months with a six-month postoperative follow-up period. Twenty-two adult patients with AO type C intercondylar fractures of the distal humerus were enrolled using purposive sampling, ensuring that each participant met strictly defined eligibility criteria.

Selection Criteria

Inclusion criteria:

- Closed intercondylar fracture of the distal humerus classified as AO type 13C
- Age 18–80 years
- Both sexes
- Presentation within three weeks of injury

Exclusion criteria:

- Open fractures
- Pathological fractures
- Pre-existing neurological deficit in the affected limb
- Previously operated or non-functional elbow

Study Procedure

On presentation, all patients were managed according to Advanced Trauma Life Support (ATLS) principles. A thorough clinical assessment—including

neurovascular examination of the ulnar, median and radial nerves—was performed for every patient. Standard anteroposterior and lateral radiographs of the affected elbow were obtained and computed tomography with three-dimensional reconstruction was used selectively to characterize articular comminution and assist preoperative planning. Fractures were classified according to the updated AO/OTA classification. All patients were immobilized with a long-arm posterior back-slab during the preoperative period.

Surgery was performed under general anaesthesia or brachial plexus block. The patient was positioned in the lateral decubitus or prone position. A posterior midline skin incision was used, with the distal humerus exposed through the triceps tongue approach. The olecranon was not osteotomized. Fracture fragments were reduced anatomically under image intensifier guidance and temporary fixation was achieved with Kirschner wires. Definitive fixation employed pre-contoured anatomical bicolumnar locking compression plates positioned at 90°–90°—one on the posterolateral column and one on the medial column—using 3.5 mm locking and cortical screws. Intravenous antibiotic prophylaxis was administered perioperatively to all patients.

Postoperatively, the limb was rested in a long-arm back-slab for two weeks, after which supervised active-assisted elbow range-of-motion (ROM) exercises were commenced under physiotherapy guidance. Patients were reviewed clinically and radiologically at 2, 6, 12, 18 and 24 weeks after surgery. Radiological outcome was graded using the Hammer et al. (1985) criteria, where Grade 1 denotes complete bridging callus across all cortices and Grade 5 denotes non-union. Functional outcome was assessed at the 24-week final follow-up using the Mayo Elbow Performance Score (MEPS), which evaluates pain (45 points), ROM (20 points), stability (10 points) and daily function (25 points); scores of ≥ 90 are

classified as excellent, 75–89 as good, 60–74 as fair and < 60 as poor.

Ethical Consideration

Ethical approval was obtained from the Departmental and College Ethical Review Committee of Dhaka Medical College. Written informed consent was obtained from every participant after explaining the treatment procedure, expected outcomes, potential benefits and possible complications. Patient confidentiality was maintained throughout the study; all data were anonymized and handled securely. No financial incentive was offered for participation.

Statistical Analysis

Data were recorded on a pre-tested structured questionnaire and analyzed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Categorical variables are reported as frequencies and percentages. Continuous variables are presented as mean $\pm$ standard deviation (SD) with range. The Chi-square test was used to examine associations between categorical variables. Statistical significance was set at $p < 0.05$ with a 95% confidence interval. The proportion of patients with satisfactory outcomes (MEPS ≥ 60) was calculated along with the standard error of proportion and 95% confidence interval.

RESULT

Table I shows the baseline demographic and injury characteristics. Of 22 patients, the majority (50%) were in the 20–39 age group, with a mean age of 41.7 ± 18.5 years. Gender distribution was equal. Housewives constituted the largest occupational group (45.5%). Road traffic accidents were the predominant mechanism of injury (68.2%). Left-sided injuries were marginally more frequent (54.5%). AO type 13C2 fractures were most common (68.2%), followed by 13C3 (22.7%) and 13C1 (9.1%).

Table IBaseline demographic and injury characteristics ($n = 22$).

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	20–39	11	50.0
	40–59	6	27.3
	60–80	5	22.7
	Mean $\pm$ SD	41.7 $\pm$ 18.5	
Gender	Male	11	50.0
	Female	11	50.0
Occupation	Housewife	10	45.5
	Farmer/Student (each)	3	13.6
	Doctor	2	9.1
	Business/Labour/Teacher (each)	1	4.5
Side of injury	Left	12	54.5
	Right	10	45.5
Mechanism of injury	Road traffic accident	15	68.2
	Fall from height	5	22.7
	Physical assault	1	4.5
	Fall on ground	1	4.5
AO fracture type	13C1	2	9.1
	13C2	15	68.2
	13C3	5	22.7

Table II presents the surgical characteristics and radiological outcome. Half of the patients (50%) underwent surgery between 7 and 14 days after injury.

The mean radiological union time was 19.9 $\pm$ 3.87 weeks. At the 24-week final follow-up, 59.1% of patients had achieved Grade 1 (complete) union, 36.4% Grade 2 and 4.5%

Grade 3 union according to Hammer radiological grading criteria.

Table IISurgical characteristics and radiological outcome ($n = 22$).

Variable	Category	Frequency (n)	Percentage (%)
Injury-to-surgery interval	< 7 days	4	18.2
	7–14 days	11	50.0
	>14–21 days	7	31.8
	Mean $\pm$ SD (Range)	11.9 $\pm$ 5.10 days (3–21)	
Duration of radiological union	12 weeks	2	9.1
	18 weeks	11	50.0
	24 weeks	9	40.9
	Mean $\pm$ SD (Range)	19.9 $\pm$ 3.87 weeks (12–24)	
Hammer radiological grade (at 24 weeks)	Grade 1 (complete union)	13	59.1
	Grade 2	8	36.4
	Grade 3	1	4.5

Table III describes the functional outcome according to the MEPS outcome. At final follow-up, 63.6% of patients reported no pain and 36.4% experienced mild pain. A

flexion arc exceeding 100° was achieved by 59.1% of patients. Elbow stability was maintained in 77.3%, with mild instability noted in 22.7% and no case of gross

instability. The mean daily function score was 19.5 $\pm$ 5.09 out of 25.

Table IIIFunctional outcome according to MEPS components ($n = 22$).

MEPS Component	Category (Score)	Frequency (n)	Percentage (%)
Pain (max 45)	No pain (45)	14	63.6
	Mild pain (30)	8	36.4
Range of motion (max 20)	> 100° flexion arc (20)	13	59.1
	50°–100° flexion arc (15)	7	31.8
	< 50° flexion arc (0)	2	9.1
	Stable (10)	17	77.3
Stability (max 10)	Mild instability (5)	5	22.7
	Gross instability (0)	0	0
Daily function (max 25)	Mean $\pm$ SD score	19.5 $\pm$ 5.09	

Table IV outlines the complications and final clinical outcome. The mean MEPS at final follow-up was 81.82 $\pm$ 11.81. A good outcome was achieved by 45.5% of patients and an excellent outcome by

31.8%. Cumulatively, 95.5% of patients attained a satisfactory result (MEPS $\geq$ 60). Only one patient (4.5%) recorded a poor outcome. Complications were recorded in 54.5% of patients; however, these were

predominantly minor, with mild residual pain (36.4%) and elbow stiffness (27.3%) being most frequent. Superficial surgical site infection occurred in 9.1% of patients and was managed conservatively.

Table IVComplications and final clinical outcome ($n = 22$).

Variable	Category	Frequency (n)	Percentage (%)
Complications	No complications	10	45.5
	Mild pain	8	36.4
	Elbow stiffness	6	27.3
	Superficial infection	2	9.1
Mean MEPS ($\pm$ SD)	Final score (max 100)	81.82 $\pm$ 11.81	
Outcome category (MEPS)	Excellent (≥ 90)	7	31.8
	Good (75–89)	10	45.5
	Fair (60–74)	4	18.2
	Poor (≤ 60)	1	4.5
	Satisfactory (Excellent + Good + Fair)	21	95.5

Table V shows the association of functional outcome with age group. Younger patients (20–39 years) achieved significantly better

functional outcomes, with 63.6% attaining excellent results. No patient in this cohort recorded a poor outcome. By contrast, none

of the patients aged 40 years or older achieved an excellent outcome ($p = 0.041$).

Table VAssociation of functional outcome with age group ($n = 22$).

Age group (years)	Frequency (n)	Excellent n (%)	Good n (%)	Fair n (%)	Poor n (%)	p-value
20–39	11	7 (63.6%)	3 (27.3%)	1 (9.1%)	0 (0.0%)	0.041
40–59	6	0 (0.0%)	4 (66.7%)	1 (16.7%)	1 (16.7%)	
60–80	5	0 (0.0%)	3 (60.0%)	2 (40.0%)	0 (0.0%)	
Total	22	7 (31.8%)	10 (45.5%)	4 (18.2%)	1 (4.5%)	

Table VI shows the association of functional outcome with the injury to surgery interval. The association between

fracture type and functional outcome was not statistically significant ($p = 0.168$). AO type 13C2 fractures had the highest rate of

excellent outcomes (46.7%), whereas 13C3 fractures were associated with the only poor result in the cohort.

Table VIAssociation of functional outcome with AO fracture type ($n = 22$).

Fracture type	Frequency (n)	Excellent n (%)	Good n (%)	Fair n (%)	Poor n (%)	p-value
13C1	2	0 (0.0%)	2 (100%)	0 (0.0%)	0 (0.0%)	0.168
13C2	15	7 (46.7%)	5 (33.3%)	3 (20.0%)	0 (0.0%)	
13C3	5	0 (0.0%)	3 (60.0%)	1 (20.0%)	1 (20.0%)	
Total	22	7 (31.8%)	10 (45.5%)	4 (18.2%)	1 (4.5%)	

Table VII presents the association of functional outcome with comorbidities. The interval from injury to surgery did not significantly influence functional outcomes

($p = 0.718$). A slight trend toward higher proportions of excellent outcomes was observed in the 7–14-day group (40%) compared to those operated beyond 14

days (28.6%); however, this difference was not statistically significant.

Table VIIAssociation of functional outcome with injury-to-surgery interval ($n = 22$).

Interval (days)	Frequency (n)	Excellent n (%)	Good n (%)	Fair n (%)	Poor n (%)	p-value
< 7	4	1 (20.0%)	2 (40.0%)	1 (40.0%)	0 (0.0%)	0.718
7–14	11	4 (40.0%)	4 (40.0%)	1 (10.0%)	1 (10.0%)	
>14–21	7	2 (28.6%)	4 (57.1%)	1 (14.3%)	0 (0.0%)	
Total	22	7 (31.8%)	10 (45.5%)	4 (18.2%)	1 (4.5%)	

Table VIII shows the association of functional outcome with comorbidities. Patients without comorbidities achieved markedly better functional outcomes, with

50.0% attaining excellent results and no poor outcomes. In contrast, none of the patients with comorbidities achieved an excellent outcome and 37.5% and 12.5%

experienced fair and poor results, respectively. This association was statistically significant ($p = 0.039$).

Table VIIIAssociation of functional outcome with comorbidities ($n = 22$).

Comorbidities	Frequency (n)	Excellent n (%)	Good n (%)	Fair n (%)	Poor n (%)	p-value
Present	8	0 (0.0%)	4 (50.0%)	3 (37.5%)	1 (12.5%)	0.039
Absent	14	7 (50.0%)	6 (42.9%)	1 (7.1%)	0 (0.0%)	
Total	22	7 (31.8%)	10 (45.5%)	4 (18.2%)	1 (4.5%)	

DISCUSSION

This study evaluated the outcomes of ORIF with anatomical bicolunar locking plates for AO type C intercondylar fractures of the distal humerus in adults. The overall findings demonstrate a satisfactory rate of 95.5%, corroborating the growing body of evidence that supports this fixation construct as a reliable surgical option for these complex injuries.

The demographic profile of the study cohort reflected a bimodal pattern broadly consistent with published literature. The mean age of 41.7 ± 18.5 years and the predominance of patients in the 20–39 age group aligns with the findings of Asfuroglu et al., who reported a mean age of 44.7 years in a comparable series and Rakshith et al., who documented a mean age of 44.15 years [9,10]. Vasishtha et al. similarly noted a mean age of 38.5 years in their prospective cohort [11]. The equal gender distribution observed in the present study contrasts with the male predominance reported by Rakshith et al. (68.1% male) and Vasishtha et al. (65% male). This divergence may reflect differences in the injury epidemiology of the study population in Bangladesh, particularly given the high proportion of housewives (45.5%) in the current cohort, a demographic less frequently represented in studies from other regions.

Road traffic accidents (RTAs) were the predominant mechanism of injury in this study, accounting for 68.2% of cases—a proportion higher than the 53.4% reported by Jagadish et al. and comparable to the 65.2% recorded by Vasishtha et al. [1,11]. This pattern underscores the critical role of road traffic trauma as a source of high-energy distal humerus injuries in South Asian contexts, where road safety infrastructure may be comparatively limited. Falls from height accounted for 22.7% of cases, consistent with findings across most published series. Left-sided injuries were slightly more prevalent in this study (54.5%), a finding that varied from the right-sided predominance reported by Dundar (53.6%) and Vasishtha et al. (73.9% right-sided) [3], but aligned with the left-sided predominance noted by Prakashappa et al. (63.3%) [12,13]. Such variability across studies likely reflects population-specific differences in handedness, occupation and injury mechanisms.

AO type 13C2 fractures predominated in this series (68.2%), with 13C3 comprising 22.7% and 13C1 only 9.1%. This

distribution differs from the findings of Asfuroglu et al., who reported a higher burden of 13C3 fractures (38.5%) and Kural et al., who found a higher proportion of 13C1 fractures (37.5%) [9,14]. The relatively higher frequency of 13C2 fractures in the present cohort may reflect a specific mechanism-based injury pattern in the study population, where RTAs produce a distinct fracture topology compared to the fall-predominant series reported from some other centers.

The mean injury-to-surgery interval of 11.9 ± 5.10 days in this study was longer than the 7.8 days reported by Gupta et al., [3] the 6 days documented by Atalar et al. and the considerably shorter interval of 2.78 days described by Thapa et al. [15,10]. This delay is consistent with patterns observed in resource-limited healthcare settings where referral pathways, patient awareness of injury severity and access to tertiary surgical facilities may contribute to delayed presentation. Although the present study found no statistically significant association between the injury-to-surgery interval and functional outcome ($p = 0.718$), there was a non-significant trend toward higher proportions of excellent results in patients operated within 7–14 days compared to those with longer delays, suggesting that minimizing delay remains a clinically sound objective.

The mean duration of radiological union in this study was 19.9 ± 3.87 weeks, with 59.1% of patients achieving Grade 1 union and 36.4% Grade 2 union at 24 weeks by Hammer criteria. This compares favourably with the 13 weeks mean union time reported by Rakshith et al. and contrasts with the shorter average of 10.3 weeks noted by Dundar [10,12]. The longer union times in the present series may reflect the higher proportion of 13C2 fractures—inherently more comminuted—as well as patient-specific factors such as nutritional status and comorbidity burden. No case of non-union was encountered, consistent with the broader literature confirming high union rates with locking plate constructs.

The mean MEPS of 81.82 ± 11.81 is comparable to the 81.62 reported by Kapil et al. [17] in a series of 54 patients and the 84.55 documented by Rakshith et al. [10]. The satisfactory outcome rate of 95.5% in the present study exceeds the 82% reported by Vasishtha et al. [11] and matches the high rates reported in smaller prospective series by Thapa et al. [16] (average MEPS 83.33) and Gupta et al., where 53.33% of patients

were graded as excellent [3]. Jagadish et al. reported that 47% of patients achieved excellent MEPS scores, with overall satisfactory rates similarly high [1]. The consistency of these findings across multiple independent series reinforces the conclusion that bicolunar locking plate fixation in a 90°–90° configuration reliably delivers acceptable to excellent elbow function in the majority of patients.

The complication profile in this series—predominantly mild pain (36.4%) and elbow stiffness (27.3%), with a superficial infection rate of 9.1%—was broadly consistent with the literature. Gupta et al. documented superficial infection in 10% of their patients and transient ulnar nerve palsy in 6.66% [3]. Mahajan et al. reported superficial infection in 5.53% and neuropraxia in 2.86%, with late complications including screw back-out (5.71%) and stiffness (2.86%) [18]. Rakshith et al. observed deep wound infection and elbow stiffness each in 4.4% of cases [10]. The relatively higher rate of stiffness in the current series may be attributable in part to delayed operative intervention and the severity of the fracture pattern; however, the absence of deep infection, implant failure or non-union is noteworthy and reflects the integrity of the surgical technique and postoperative protocol employed.

Age emerged as a statistically significant predictor of functional outcome in this study ($p = 0.041$). Patients aged 20–39 years achieved excellent results at a rate of 63.6%, whereas no patient aged 40 years or above attained an excellent score. This finding is consistent with the general understanding that advancing age is associated with diminished bone quality, reduced physiological reserve and impaired rehabilitation capacity, all of which may limit recovery. The presence of comorbidities was also significantly associated with inferior outcomes ($p = 0.039$): patients without comorbidities achieved 50.0% excellent outcomes, whereas those with comorbidities recorded no excellent results and higher proportions of fair and poor outcomes. By contrast, fracture type and injury-to-surgery interval did not significantly influence functional results in this cohort ($p = 0.168$ and $p = 0.718$, respectively), though the limited sample size may restrict the power to detect clinically meaningful differences.

CONCLUSION

Open reduction and internal fixation using anatomical bicolumnar locking plates in a 90°–90° configuration is an effective surgical treatment for AO type C intercondylar fractures of the distal humerus in adults, yielding satisfactory radiological union in the vast majority of patients and a 95.5% overall satisfactory functional outcome rate as measured by MEPS. The technique provides angular-stable fixation, facilitates early elbow mobilization and carries an acceptable complication profile. Younger patient age and the absence of comorbidities were independent predictors of superior functional recovery, findings that should inform preoperative counselling and postoperative rehabilitation planning in this challenging fracture group.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

ETHICAL APPROVAL

This study approved by the institutional ethical review committee.

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