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Comparative study of functional outcome of distal humerus intra-articular fracture treated with parallel plates and with orthogonal plates (A study of 30 cases)

Dr.Daljinder Singh[1], Dr Akashdeep Singh[2] Dr Sanjeev Sareen[3], Dr Annie Sandhu[4]

[1]Assistant Professor, Government Medical College, Patiala, Punjab, India;
[2]Junior Resident, Government Medical College, Patiala, Punjab, India;
[3]Associate Professor, Government Medical College, Patiala, Punjab, India;
[4]House surgeon ED, AIIMS, Rishikesh, India

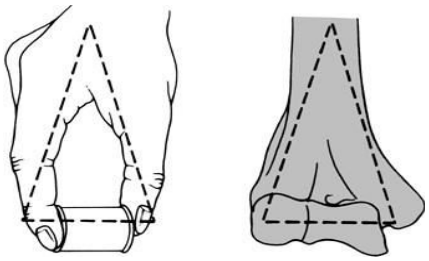
Corresponding author:
Dr Kuldip Singh Sandhu, Assistant Professor, Department of Orthopaedics, Government Medical College, Patiala, Punjab, India, Email: kd27sand@gmail.com

ABSTRACT:
Intra-articular distal humerus fractures remain one of the most difficult injuries to manage. These fractures comprises 2-6% of all fractures and have bimodal age distribution. The majority of these fractures occur either as low energy falls or high energy trauma. Most fractures in elderly patients are intra- articular with bi-columnar involvement. They are commonly multifragmental and occur in osteopenic bone. High energy injuries occur in adults, which are accompanied with other associated injuries. The elbow is anatomically a trocho-ginglymoid joint in which distal humerus bifurcates into two divergent cortical columns, termed as medial and lateral columns. The articular segment functions architecturally as a tie arch. The elbow is one of the most constrained joints of the body and tolerates immobilization poorly and any alteration within the architecture of the joint has the potential to limit motion and compromise function.Treatment outcomes are often related to elbow stiffness, weakness and pain. Meticulous planning is required in obtaining an anatomic intra-articular reduction, and creating a fixation construct that is rigid enough to tolerate early mobilization. Usually, 70% of patients that sustain an elbow fracture, fall directly on to the elbow because they are unable to break their fall with an out stretched arm. This randomized, prospective study was undertaken to compare the functional outcomes of distal humerus intra-articular fractures in adults treated with parallel plates and orthogonal plates. From a clinical perspective, a parallel plating method appears to provide better rigid fixation that is adequate for obtaining bone union. However, no statistical significant differences were observed between the orthogonal and parallel double plating methods in terms of clinical outcomes and complication rates. If meticulously applied, with suitable plates, both parallel and orthogonal positioning can provide adequate stability and anatomic reconstruction of the distal humerus fractures.
Keywords: humerus fractures, orthogonal plates, open reduction and internal fixation.

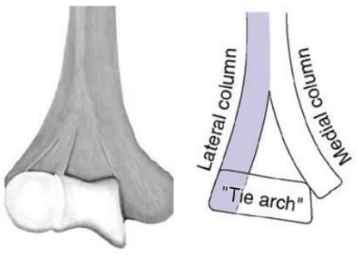
INTRODUCTION

Intra-articular distal Humerus fractures remain one of the most difficult injuries to manage.These fractures comprises 2-6% of all fractures and have bimodal age distribution. The majority of these fractures occur either of two ways, low energy falls or high energy trauma.Most fractures in elderly patients are intra- articular with bi-columnar involvement[1].They are commonly multifragmental and occur in osteopenic bone. The

elbow is anatomically a trocho-ginglymoid joint.The complex shape of the elbow joint having sparse soft tissue envelope and the adjacent neurovascular structures combine to make these fractures very difficult to treat. The elbow is one of the most constrained joints of the body and tolerates immobilization poorly and any alteration within the architecture of the joint has the potential to limit motion and compromise function.[2] Treatment outcomes are often related to elbow stiffness, weakness and pain. An easy, stable and mobile elbow joint is desired because it allows the hand to conduct the activities of daily living, most notably personal hygiene and feeding. Meticulous planning is required in obtaining an anatomic intra-articular reduction, and creating a fixation construct that is rigid enough to tolerate early mobilization.[1] The most common cause is straightforward fall in forward direction. Usually, 70% of patients that sustain an elbow fracture fall directly on to the elbow because they are unable to break their fall with an out stretched arm. High energy injuries like motor vehicle collisions, sports, and fall from height and industrial accidents are the causes of most intra-articular distal humerus fractures in young adults. These mechanisms are also related to a higher likelihood of accompanying injuries, like open fractures, soft tissue injuries, neurovascular injuries and other associated fractures.[1]
The distal humeral shaft is triangular shaped in cross section with it apex directed anterior. As the shaft approaches the distal humerus it bifurcates into two divergent cortical columns, termed the medial and lateral columns. The trochlea, which is shaped like a spool with a central sulcus, is the intervening segment of bone between the terminal ends of the medial and lateral columns that articulates with the greater sigmoid notch of the ulna, creating an arc of about 270 degrees[3].The articular segment functions architecturally as a tie arch.[1]



Truncated spool distal humerus

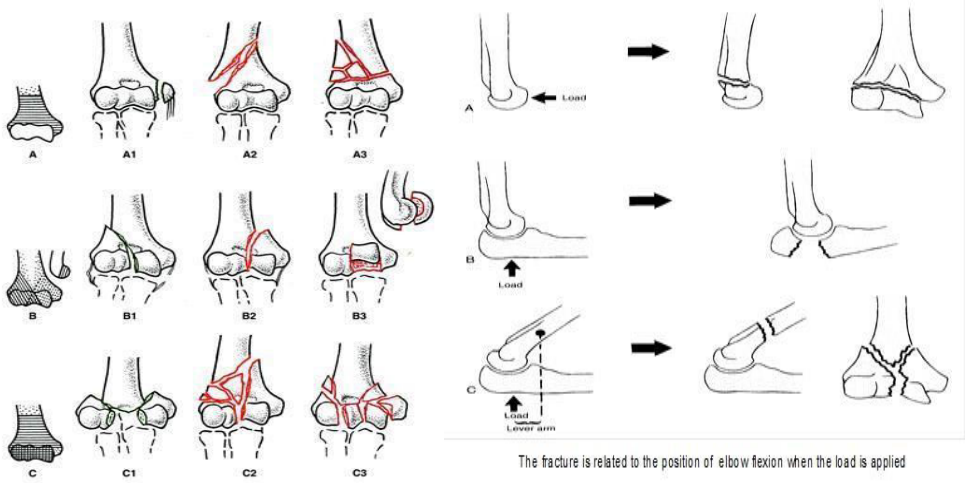


Tie arch

The main stability in both flexion-extension is provided by the collateral ligaments as well as capsule. The forearm muscles act as dynamic stabilizers with flexors one and a half times as strong as extensors.[1]Most fractures in elderly patients are intra- articular with bi-columnar involvement.[3]. Large Joint reaction forces are produced during various activities which increases 4 to 6 fold during assisted standing from seated position.[3] Intra articular fractures of the distal humerus are caused by the impact of proximal ulna against trochlea forcing apart the two condyles of distal humerus.[4]

TREATMENT OPTIONS: Earlier consensus favoured non-operative management due to poor operative results. Modern orthopaedic implants and surgical techniques permitting rigid fixation and early motion, achieves painless functional range of motion at elbow and any treatment that needs extended immobilization of elbow leads to a stiff joint. Closed methods like cast immobilization, traction, bag of bones technique are recommended for those fractures which are deemed unsuitable for internal fixation in elderly patients and for those whose medical conditions prohibits surgery.[5] In 1913, AlbinLambotte challenged conservative management for intra-articular distal humerus fractures and advocated an aggressive approach of open reduction and internal fixation. He described the principles of osteosynthesis and believed restoration of anatomy correlated with a far better return to function.

The AO/OTA classification is given below:



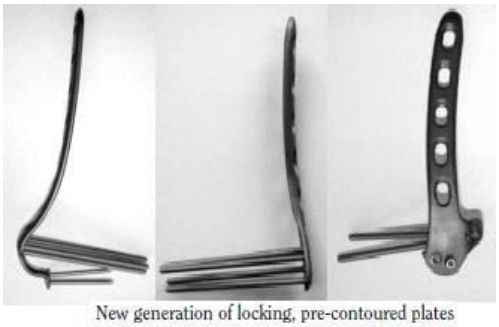
The fracture is related to the position of elbow flexion when the load is applied

OPEN METHODS:

The biology of the bone and soft tissue also must be taken under consideration. An important factor is an honest assessment by the surgeon of his ability to perform stable internal fixation without the need of prolonged post-operative immobilization.[6]

- **Open reduction and internal fixation (ORIF):** The goals of open reduction and internal fixation are anatomic reduction, stable fixation and early post-operative mobilization.[7] Relative contraindication for open reduction and internal fixation include severe comminution or elderly patients with marked osteopenia.[8] The selection of operative approach depends on the degree of articular involvement and surgeon's experience.[2] Variety of implants are recommended but the main aim is to ensure that fixation is stable enough to permit early post-operative mobilization.[9]

- **Primary elbow arthroplasty:** Distal humeral replacement or total elbow arthroplasty (TEA) as a primary treatment in fractures of distal humerus is suggested for elderly and low demand patients with associated systemic joint diseases. TEA has a wonderful result in fractures having very small fragments.[10] The durability in otherwise young and healthy individual is way poor exhibiting high rates of loosening and material failure. Procedure for severely comminuted intra-articular fracture is total elbow arthropasty but disadvantages of this procedure notably are inevitable failure of prosthesis and potential devastating complications like deep infection and osteolysis.



New generation of locking, pre-contoured plates

Pre-contoured locking plates designed by AO group is new and effective method of fixation in intra-articular distal humeral fractures and simpler in osteoporotic bone [2]. In elderly,anatomic articular reduction and rigid internal fixation, allow for rapid healing and early postoperative range of motion.

In younger patients, open reduction and internal fixation of intra-articular distal humerus fractures using modern fixation principles is considered the gold standard. In elderly patients, in which rigid internal fixation cannot be achieved to permit early range of motion, resultant prolonged immobilization often results in poor outcomes.
Various criteria wereused to assess the outcome: Bickel and Perry method (1963), Riseborough and Radin's method (1964)[8]Cassabeum's method (1969)[11]Jupiter's criteria (1985)[12]

AIMS AND OBJECTIVES: The present study will be undertaken to compare the functional outcomes of distal humerus intra-articular fractures in adults treated with parallel plates and orthogonal plates with following aims and objectives:-

- To achieve stable internal fixation and fracture union with early elbow joint function.
- To compare range of motion and functional outcome of operated patients.
- To assess specific and general complications encountered in both groups.

MATERIAL AND METHODS: This randomized, prospective study was carried out in Department of Orthopaedics, Govt. Medical College, and Patiala. 30 cases of fracture intra-articular distal humerus divided randomly into two groups - Group 1 Patients treated with parallel plates and Group 2 Patients treated with orthogonal plates.

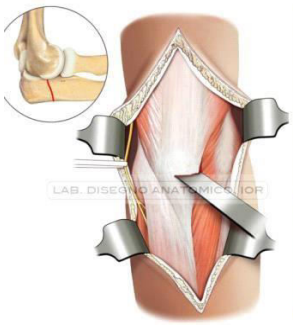
Inclusion Criteria:

- Closed intra-articular fractures of distal humerus reporting within three weeks (AO B&C type).
- Patient more than 15 years of age.
- Patients medically fit for surgery

Exclusion Criteria:

- Anterior coronal fracture of capitellum or trochlea.
- (B3)Open fractures reporting after 24 hours.
- Fracture in patients less than 15 years of age.
- Patients not medically fit for surgery.
- Old neglected distal Humerus fractures.
- Any previous surgery around elbow joint.
- Presence of septic focus.
- Vascular injury

Pre-Operatively:After taking the history, detailed clinical and radiological examination with CT scan of injured elbow was conducted. Primary treatment in the form of splintage of limb, analgesics and anti-inflammatory drugs was given to patient.Routine investigations and medical fitness for surgery ascertained. Pre-anaesthetic check-up was done. Preoperative planning and CT scan was done to assess the size of plates and placements of screws. General anaesthesia or regional anaesthesia was as per the anaesthetist recommendation.



ADVANTAGES:
- Intraop. choice ORIF / DHH
- Triceps insertion respected
- Possibility to conserve ligaments insertion
- Good exposure for plating columns

DISADVANTAGES:
- osteotomy may not heal
- Less landmarks for DHH

Surgical Approach: There are several surgical approaches described for exposure and fixation of intra-articular distal humerus fractures, but in this study the trans-olecranon posterior approach was used. Olecranon osteotomy approach is most commonly used AO/OTA type B&C fractures, which require superior visualization of the articular fragments for anatomic reduction and internal fixation. Disadvantages are non-union and hardware prominence related to osteotomy and linked visualization of anterior articular surfaces[12]

Surgical Technique: Patient was placed in a lateral decubitus or supine position and a midline posterior incision was made over the distal humerus, with or without curving around the tip of olecranon. The ulnar nerve was identified and protected. An olecranon chevron osteotomy was used for adequate exposure of the joint surface.

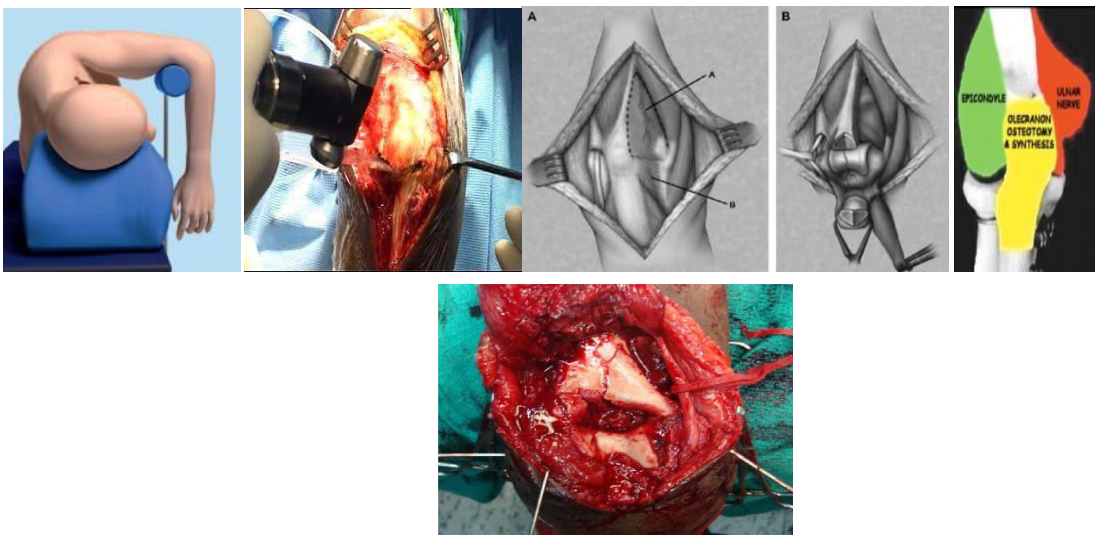


Figure showing ulnar nerve isolation, articular reduction and provisional fixation with K wires

The articular fragments were reduced and fixed provisionally with Kirschner (K) wires placed subchondrally in a way not interfering in plate placement. These fragments were held with a partially threaded cancellous screw or cortical screws. They were then secured to the columns.
In group 1 patient slightly under-contoured 3.5mm reconstruction plates were placed on medial and lateral ridges in a way that both end at different levels at the shaft region and at least 3 screws were placed in shaft. A (first proximal) screw was placed in one of the proximal hole of each plate but not fully tightened, leaving some freedom for the plate to move proximally later during compression. K wires were used in distal fragments for provisionally fixation.

Articular fixation: Long medial and lateral distal screws fixing maximum fragments were applied.

Supra condylar compression: The proximal screw on one side was backed out and a large bone clamp was applied distally on that side and proximally on the opposite cortex to eccentrically load the supracondylar region. A second proximal screw was inserted through

the plate in compression mode, and then the backed out screw is retightened. This step repeated for other column also. Diaphyseal screws were applied to achieve residual compression through under-contoured plates.

Provisional K wires in the distal fragment were removed and replaced with screws. After fixing the fracture segments, Tension band wiring (TBW) of osteotomized olecranon was carried out with two K wires. In group 2 patients one reconstruction plate (3.5mm) and other locking plate was used. Reconstruction plate was placed on medial column and the locking one on the posterior aspect of the lateral column (90^{o} to each other)

Figure showing Parallel Plate Placement with both plates ending at different levels

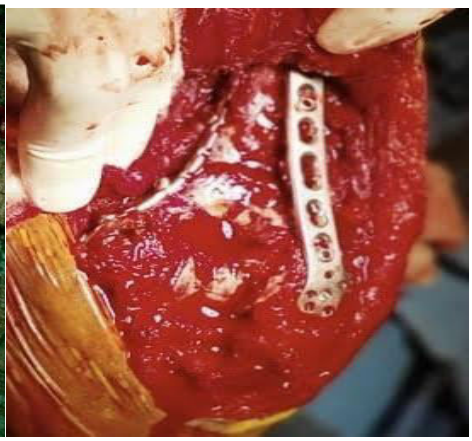


Figure showing orthogonal plate placement

Plates applied on distal humerus at right angle to each other create a 'Girder like effect' which strengthen fixation construct. Plates should end at different levels on humerus shaft to minimize the 'stress riser' effect. Each plate should have at least 3 bi-cortical screws proximal to metaphysealcomminution.[1]They should also pass through a plate. Each screw should be as long as possible and engage as many articular fragments as possible also engage a fragment on the opposite side that is also fixed to plate. As many screws as possible should be placed in the distal fragments. Plates should be applied such that compression is achieved at the supracondylar level for both columns. Plates used must be strong and stiff enough to resist breaking or bending before union occurs at the supracondylar level.[13]In both group 1 and 2 after fixing the fracture segments, TBW of osteotomized olecranon was carried out with two K wires and meticulous repair of soft tissues was done in layers.

Post-Operative: Patient was advised for gentle active or active-assisted exercise as soon as pain permits. Limb elevation and active finger movements were advised.

Follow up: All patients were followed up at monthly intervals for 6 months. During this period patient was motivated for physiotherapy. Fracture union was assessed clinically and radio-logically. Elbow function on the operated side was evaluated and compared with the normal side as per Mayo Elbow Performance Score(MEPS).

TABLE 1: AGE INCIDENCE

Age group (years)	Type of plating				Total	
	P		O			
	No.	%age	No.	%age	No.	%age
20-30	4	26.67	5	33.33	9	30.00
31-40	4	26.67	2	13.33	6	20.00
41-50	2	13.33	2	13.33	4	13.33

51-60	2	13.33	3	20.00	5	16.67
61-70	3	20.00	3	20.00	6	20.00
Total	15	100.00	15	100.00	30	100.00
Mean age	43.93±16.85		43.33±16.51		43.63±16.40	

p-value: 0.922

TABLE 2: Mode of Injury

Mode of injury	**Type of plating**				**Total**	
		P	**O**			
	No.	**%age**	**No.**	**%age**	**No.**	**%age**
Assault	1	6.67	2	13.33	3	10.00
Fall	4	26.67	5	33.33	9	30.00
RSA	10	66.67	8	53.33	18	60.00
Total	15	100.00	15	100.00	30	100.00

X^2: 0.667; df:2; p=0.717

TABLE 3: Fracture type

Injury type	Type of plating				Total	
		P	**O**			
	No.	**%age**	**No.**	**%age**	**No.**	**%age**
B1	0	0.00	1	6.67	1	3.33
C1	6	40.00	4	26.67	10	33.33
C2	6	40.00	7	46.67	13	43.33
C3	3	20.00	3	20.00	6	20.00
Total	15	100.00	15	100.00	30	100.00

P=0.668

TABLE 4: LOSS OF EXTENSION

Loss of extension	Type of plating				Total	
		P	**O**			
	No.	**%age**	**No.**	**%age**	**No.**	**%age**
0	1	6.67	2	13.33	3	10.00
10-20	8	53.33	12	80.00	19	63.33
21-30	6	40.00	1	6.67	8	26.67
Total	15	100.00	15	100.00	30	100.00

X^2: 4.705; df:2; p=0.095

TABLE 5: Flexion at the elbow

Type of plating	Flexion		Pvalue
	Mean	**SD**	
P	119.66	8.95	0.583
O	122.00	13.60	
Total	120.83	11.37	

TABLE 6: Range of Movement:

Pain	Number of patients in parallel plating method Group 1	Number of patients in perpendicular plating method Group 2
None	5	7

Mild	10	8
Moderate	0	0
Severe	0	0

TABLE 7: Stability

Type of plating	ROM mayo 20pts		Pvalue
	Mean	**SD**	
P	17.000	2.5355	0.069
O	18.663	2.2898	
Total	17.830	2.5200	

Type of plating	Stability mayo 10 pts		p-value
	Mean	**SD**	
P	10.000	.0000	1
O	10.000	.0000	
Total	10.000	.0000	

TABLE8& 9: Function: In most of the cases functional arc of motion was preserved

Type of plating	Function mayo 25 pts		p-value
	Mean	**SD**	
P	23.667	3.5187	0.508
O	22.667	4.5774	
Total	23.167	4.0436	

Function	Number of patients in parallel plating method Group 1	Number of patients in perpendicular plating method Group 2
Comb	13	11
Feed	15	15
Personal	15	15
Shirt	15	14
Shoes	13	13

TABLE 10: Mayo Elbow Performance Score:

Type of plating	MEPS 0-100		pvalue
	Mean	**SD**	
P	85.667	11.1590	0.540
O	88.333	12.3443	
Total	87.000	11.6412	

Table 11

FUNCTION	Definition	Group 1	Group 2
PAIN (**Maximum 45 points**)	None (45)	5	7
	Mild (30)	10	8
	Moderate (15)		
	Severe (0)		
ROM (**Maximum 20 points**)	>100 (20)	6	11
	50 TO 100 (15)	9	4

	<50 (5)		
Stability (**Maximum 10 points**)	Stable (10)	15	15
	Moderately (5)		
	Unstable (0)		
Function (**Maximum 25 points**)	Comb (5)	13	11
	Feed (5)	15	15
	Personal (5)	15	15
	Shirt (5)	15	14
	Shoes (5)	13	13

TABLE 12:

FUNCTION	MEAN SCORE OF GROUP 1	MEAN SCORE OF GROUP 2
Pain	35	37
Range of motion	17	18.6
Stability	10	10
Function	23.6	22.6
Mean Total	85.6	88.3

TABLE 13: Post-operative complications:

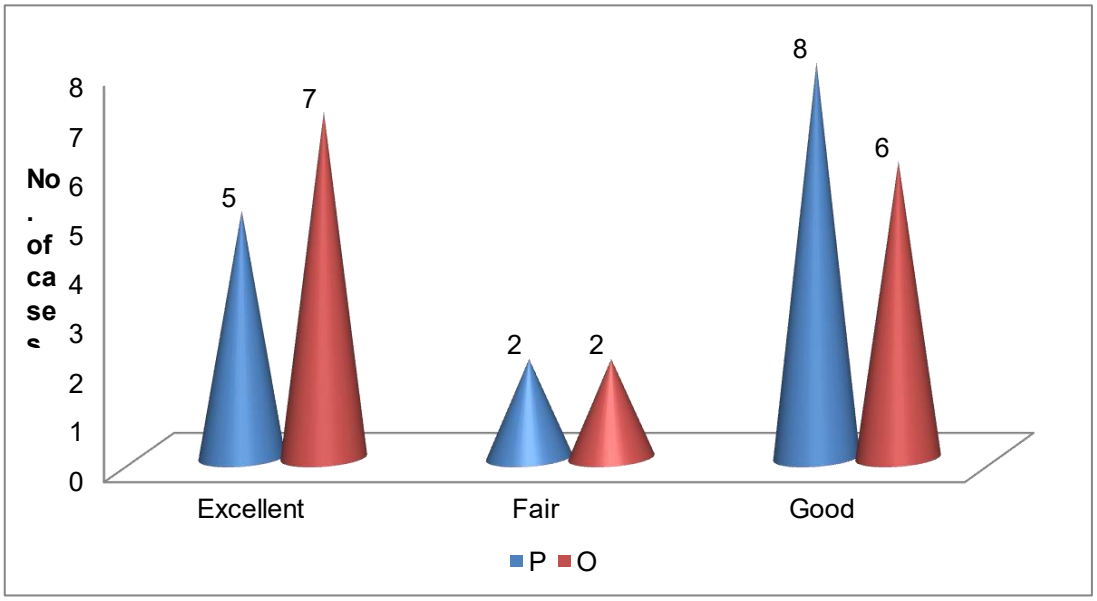
Complications	Type of plating				Total	
		P	**O**			
	No.	**%age**	**No.**	**%age**	**No.**	**%age**
No complication	8	53.33	9	60.00	17	56.67
Isolated PH	2	13.33	1	6.67	3	10.00
Isolated SI	1	6.67	1	6.67	2	6.67
SI with HF	1	6.67	0	0.00	1	3.33
SI with PH	1	6.67	3	20.00	4	13.33
Isolated TN	1	6.67	0	0.00	1	3.33
TN with ES and HF	0	0.00	1	6.67	1	3.33
TN with PH	1	6.67	0	0.00	1	3.33
Total	15	100.00	15	100.00	30	100.00

X^2: 5.392; df:7; p=0.612

TABLE 14: Final Functional Outcome

Result	Type of plating				Total	
		P	**O**			
	No.	**%age**	**No.**	**%age**	**No.**	**%age**
Excellent	5	33.33	7	46.67	12	40.00
Fair	2	13.33	2	13.33	4	13.33
Good	8	53.33	6	40.00	14	46.67
Total	15	100.00	15	100.00	30	100.00

X^2: 0.619; df:2; p=0.734

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DISCUSSION

Distal intra-articular fractures of humerus are difficult to treat and are frightened with complications and it is not uncommon for unpredictable results.In current study the mean age was of 43.63 years. Thus, average age in our study was comparable to other studies.

Study	Parallel plagroup 1	group 2	p value
Shin et al[14] (2010)	56	52	.929
Lee et al[15] (2013)	58	55	.94
Tian et al[16](2013)	38	39	.953
Present study	43.9	43.3	.922

In the present study there were 17 males and 13 females (7 females in group 1 and 6 females in group 2). The M:F ratio in group 1 was 8:7 and in group 2 was 9:6 which was comparable to Tian et al[16]. In the present study mean elbow flexion in group 1 was 119.6^0 and group 2 was 122^0 which was comparable to other reviewed studies as shown:

Study	Mean Flexion in Parallel plating group 1	Mean Flexion in Perpendicular plating group 2	p value
Shin et al[14] (2010)	121^0	119^0	.887
Lee et al[15] (2013)	121^0	119^0	.88
Tian et al[16] (2013)	119.6^0	120.8^0	.82
Present study	119.66^0	122^0	.58

In the present study mean loss of extension in group 1 was 17.3^0 and group 2 was 14^0 which was comparable to Tian et al[16].

In the present study mean loss of extension in group 1 was 17.3^0 and group 2 was 14^0 which was comparable to Tian et al[16].

The mean MEPS was 85.6 points in group 1, which corresponded to an excellent result in 5 elbows, a good result in 8, and a fair result in 2. The mean MEPS was 88.3 points group 2, which corresponded to an excellent result in 7 elbows, a good result in 6, and a fair result in 2. Mean MEPS in both groups was comparable to other studies reviewed as shown:

Study	Mean MEPS in Parallel plating group 1	Mean MEPS in Perpendicular plating group 2	p value
Shin et al[14] (2010)	94.3	91.5	.928
Lee et al[15] (2013)	89.7	85.1	.78
Tian et al[16] (2013)	90	89.6	.935
Present study	85.6	88.3	.540

In the present study, 44% patients had complications. The notable complications were painful hardware, superficial infection and transient ulnar nerve palsy. Post-operatively,8 patients had painful hardware for which was removed after the bony union. 7 patients had superficial infection which got treated with antibiotics and dressings and 3 patients had transient ulnar nerve neuropraxia which recovered subsequently. Other complications encountered in our series were hardware failure in 2 patients for which broken K wire/ stainless steel wire was removed, elbow stiffness in 1 patient who achieved functional range of motion with physiotherapy and 17 patients had no complication at all.

SUMMARY AND CONCLUSION:

From a clinical perspective, a parallel plating method appears to provide better rigid fixation that is adequate for obtaining bone union. However, no statistical significant differences were observed between the orthogonal and parallel double plating methods in terms of clinical outcomes and complication rates. If appropriately applied with suitable plates, both parallel and orthogonal positioning can provide adequate stability and anatomic reconstruction of the distal humerus fractures.

Study	Mean Loss of extension in Parallel plating group 1	Mean Loss of extension in Perpendicular plating group 2	p value
Shin et al[14] (2010)	10^0	13^0	.977
Lee et al[15] (2013)	9^0	13^0	.98
Tian et al[16] (2013)	14.6^0	14.6^0	1.00
Present study	17.3^0	14^0	.095

Limitation of study: Long term follow-up in terms of restoration of pre injury status and secondary arthritis may not be possible.

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