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A Prospective Study on the Functional and Radiological Outcomes of AO Type C Distal Humerus Fractures in Adults Treated Surgically with Bicolumnar Fixation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Purpose: To study the functional and radiological outcomes of AO type C distal humerus fractures (DHFs) in adults treated surgically with bicolumnar fixation.
Methods: A prospective study of 30 adult patients with AO/OTA type C fractures of the distal humerus treated operatively with bicolumnar fixation between September 2018 to December 2020 at Sree Balaji Medical College & Hospital, Chennai was performed. Closed distal humerus fractures with intra-articular extension were fixed with bicolumnar plating, with orthogonal or parallel configuration of plate fixation decided intra-operatively. This was achieved in all patients after performing an olecranon osteotomy for better exposure of the fracture site, which was later fixed with either CC screws or K-wires with tension band wiring. The functional and radiological outcomes in this study group were assessed on regular post-operative follow-up. The Mayo Elbow Performance Score (MEPS) was used to evaluate the functional outcomes in our patients.
Results: The mean age of the patients was 44 years, with 18 (60%) males and 12 (40%) females in the study. The right-sided elbow was more frequently involved (57%) in our study. The most

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common mode of injury was Motor Vehicle Accident (MVA) (14 cases; 47%), while domestic fall contributed to 10 (33%) cases. Fall from height and direct trauma to the elbow made up the rest of the cases, with a 10% incidence each. A majority of cases (22 cases; 73%) showed radiological union between 12-16 weeks post-operatively, whereas 8 cases (27%) united between 17-21 weeks. The Mayo Elbow Performance Score (MEPS) used to assess the functional outcome showed excellent results in 25 (83%) cases, good and fair results in 2 (7%) cases each, and a poor outcome in 1 (3%) case.

Conclusion: For satisfactory results in intraarticular fractures of the distal humerus treated with bicolumnar plating, thorough pre-operative planning, posterior surgical approach with adequate exposure via olecranon osteotomy, anatomical inter-fragmentary stabilization by dual plating, and early post-operative mobilization with physiotherapy are important steps to be followed.

Keywords: Distal humerus fractures; bi-columnar plating; olecranon osteotomy; Mayo Elbow Performance Score (MEPS).

1. INTRODUCTION

Distal humerus fractures (DHFs) in adults comprise 2% of all fractures, & roughly 1/3rd of all humeral fractures, with an incidence of 5.7/100000 per year [1]. Fractures of the distal humerus mainly have a bimodal distribution of occurrence [2,3]. Most DHFs in young adults are a result of high-energy trauma sustained during road traffic accidents (RTAs), sports injuries, sideswipe injuries, gunshot wounds, & falls from height, while elderly persons usually have a history of low-energy trauma sustained via simple falls with direct impact on the elbow [4,5] or indirect impact because of a fall on the outstretched hand.

Hence, a global awareness in the more precise treatment of this diverse group of injuries has been generated due to improved knowledge about the complex biomechanics of unstable DHFs in adults. Various challenges like articular surface fragmentation in multiple planes, separation of articular fragments from distal humeral columns, and deficient bone quality are faced by surgeons intra-operatively. DHFs commonly display varying patterns in adults. Complications like malunion and non-union are common, with even slight irregularities of articular surfaces of the elbow causing loss of function, and secondary arthritis.

The guidelines given for orthogonal plating (perpendicular / 90-90 plating) with two plates placed at a 90° angle to one another had been the gold standard technique for the fixation of DHFs till recent times, with authors reporting satisfactory results in 80-85% patients due to stable bi- columnar construct and early mobilization.

Ongoing research for a safer technique has led to the development of the concept of parallel plating (180° plating) [6] which involves the placement of one plate along the medial column & another along the lateral column, with the screws in distal fragment interdigitating with each other, thus restoring the 'tie arch' of the distal humerus [7]. Extensive soft tissue dissection and chances of neurovascular injuries are some of the problems that the surgeon might encounter while using this technique.

Through this study, we will try is to evaluate the functional and radiological outcomes of intra-articular, intercondylar DHFs (AO type C fractures) treated surgically with open reduction & stable internal fixation using bi-columnar plating.

2. MATERIALS AND METHODS

A prospective study of 30 adult patients with AO/OTA type C fractures of the distal humerus treated operatively with bicolumnar fixation between September 2018 to December 2020 at Sree Balaji Medical College & Hospital, Chennai was performed. Closed distal humerus fractures with intra-articular extension were fixed with bicolumnar plating, with orthogonal or parallel configuration of plate fixation decided intra-operatively. This was achieved in all patients after performing an olecranon osteotomy for better exposure of the fracture site, which was later fixed with either CC screws or K-wires with tension band wiring. The functional and radiological outcomes in this study group were assessed on regular post-operative follow-up. The Mayo Elbow Performance Score (MEPS) was used to evaluate the functional outcomes in our patients.

2.1 Inclusion Criteria

1. Male & female adult patients older than 18 years of age.
2. Intra-articular DHFs falling under AO type C classification.
3. Closed injuries.
4. Consenting to the study.
5. Acute fractures < 2-weeks-old.

2.2 Exclusion Criteria

1. Patients younger than 18 years of age.
2. Pathological fractures due to tumours or any other diseases are excluded.
3. Previously operated elbow joint pathologies for either cold or traumatic conditions are excluded.
4. Traumatic cases presenting after > 2 weeks.
5. Cases of open fractures of the distal humerus are excluded.

2.3 Surgical Technique

A thorough clinical examination & radiological assessment was performed to confirm the fracture pattern, deformity, neurovascular status of the limb, & other associated injuries. 3D-CT scan of the affected elbow was done to determine the geometry & configuration of fracture fragments, to help decide about the implants & method of fixation.

The patients were given general anaesthesia & were positioned in lateral decubitus position, with involved limb supported over bolsters on the OT table. Tourniquet was applied for all the patients, as proximally as possible, & the arm draped free after a sterile aseptic wash. The arm was elevated & exsanguinated using Esmarch bandage, and tourniquet inflated to approximately 240 mmHg.

The posterior approach to the elbow [8] was used. To achieve satisfactory exposure, a straight incision posteriorly over the distal humerus, curving around the olecranon laterally & then along the upper fourth of ulna was taken (i.e. a longitudinal incision started 10-15 cm proximal and extending 5 cm distal to the olecranon).

The subcutaneous & deep fascia was incised, & before proceeding further, the ulnar nerve identified & retracted gently with an umbilical cotton tape. The triceps muscle was identified and released on either side from the intermuscular septum.

A fine oscillating saw was then used for making a chevron V osteotomy at level of the waist of the olecranon, & completed with a thin, fine-pointed osteotome at subchondral bone level. The olecranon was gently dissected free from thin surrounding tissues, & along with triceps insertion, lifted proximally as a unit. This enabled the exposure of the posterior & inferior elbow joint surface, & the post. surface of the trochlea (or trochlear fragments).

Provisional fixation of the condyles was achieved with a K-wire while holding the fragments with pointed bone-holding forceps. Once this was accomplished, the two condyles were fixed in a stable manner with a lag screw using 4.0mm cancellous screw. To prevent excessive diaphyseal stress, medial & dorsolateral plates placed were of different lengths. For e.g., 5-holed medial plate used with 8-holed dorsolateral plate. Initially, the dorsolateral plate was applied, & non-locking 3.5 mm cortical screw to fix plate to the bone inserted. The screws were all directed from posterior to anterior. Additional screws were put in a lateral to medial direction for the condyles. Screw placement & length was confirmed with image intensifier during elbow movement to ensure screws were not in the joint. The medial plate was positioned on medial ridge slightly dorsal to intermuscular septum with distal tip reaching down to insertion of medial collateral ligament. The longest possible screws were inserted in distal fragment. Olecranon osteotomy fragment was fixed using K-wires or CC screws along with tension band wiring. Adequacy of the fixation was checked under C-arm guidance at every step.

Post-operatively, the patients were given a posterior splint (i.e. above elbow slab) with a bulky dressing, & neurological status checked every 4th hourly. The patients were given injection Cefazolin for 2 days & converted to oral antibiotics which were continued for 5 days. For prophylaxis against heterotopic ossification (HO), all patients were put on capsule Indomethacin 25 mg TDS for 6 weeks [9].In patients with rigid fixation, active gentle motion of involved limb several times a day in concurrence with the pain was advised. Active physiotherapy was initiated after 3 weeks. Full activity was allowed at 3 - 4 months as fracture consolidation occurred.

Post-operatively, patients were reviewed on a weekly basis for the first two months; monthly for the next 3 months; then every 3 months until fracture healing or full ROM was regained. At each follow-up, patients were assessed clinically, & the functional outcomes were evaluated using the MEPS system.

3. RESULTS

The present study includes 30 cases of distal humerus inter-condylar fractures in adults treated by ORIF with dual plating.

Majority of the cases of DHFs belonged to the 21-30 years age group. The age of the oldest patient was 73 years, & the youngest patient was 25 years old, with 44 years being the mean age in our study group. Females had a higher mean age (49 years) as compared to males (41 years).

Out of 30 patients with DHFs, 17 patients were affected on the right elbow, whereas 13 patients were affected on the left side.

Out of 30 patients who participated in our study, majority of them (14 cases) sustained DHF because of MVAs. Of those 14 patients, majority were young males. Another chief cause of elbow injury resulting in DHFs was a simple fall (10 cases), with patients landing directly on the elbow, or reporting a history of fall on an outstretched hand – of this group, elderly females comprised a major part. 3 cases had a history of fall from height (FFH), whereas the remaining 3 patients sustained a direct trauma (DT) to the elbow.

Table 1. Age & sex distribution

Age Group	Number of Patients		Total	% of Cases
	Male	Female		
21-30 Years	6	3	9	30%
31-40 Years	4	2	6	20%
41-50 Years	4	1	5	17%
51-60 Years	2	2	4	13%
> 60 Years	2	4	6	20%
Total	18	12	30	100%

Table 2. Side affected

Side Affected	No. of Cases	% of Cases
Right	17	57%
Left	13	43%
Total	30	100%

Table 3. Mode of injury

Mode of Injury	No. of Cases		Total	% of Cases
	Male	Female		
MVA	10	4	14	47%
Fall	3	7	10	33%
FFH	3	—	3	10%
DT	2	1	3	10%
Total	18	12	30	100%

Table 4. Type of fracture

AO type C	No. of Cases	% of Cases
Type C1	9	30%
Type C2	16	53%
Type C3	5	17%
Total	30	100%

Out of 30 cases which were classified under the AO type C DHFs, 16 cases were assigned to be AO type C2 fractures, 9 cases were classified under AO type C1, & the remaining 5 cases fell under AO type C3 classification.

Out of 30 cases operated by ORIF with bicolumnar plate osteosynthesis using precontoured distal humeral LCPs, 19 cases were fixed using the orthogonal (perpendicular) plating configuration, whereas for the remaining 11 cases, parallel plate fixation was done.

Of the 30 cases treated by ORIF with chevron olecranon osteotomy, K-wires with TBW (K TBW) was used for 16 cases, whereas Cancellous screw with TBW (C TBW) was used for the remaining 14 cases.

We encountered post-operative complications in 4 out of 30 cases. Ulnar nerve neuropraxia was seen in 2 patients. 1 patient reported wound gaping at the region of the CC screw head (fixed at osteotomy site along with TBW). Post-operative infection at fracture site was seen in 1 patient after 2 weeks – the same patient also showed stiffness of the elbow at the latest follow-up.

Most of the cases (22 patients) of distal humerus AO type C fractures treated by ORIF with bi-columnar plating showed signs of radiological union between 12-16 weeks. 8 patients showed signs of union between 17-21 weeks. All the olecranon osteotomies performed for the surgical approach united uneventfully.

After functionally assessing the patients based on the MEPS on last follow-up, the following results were obtained: 25 patients showed excellent results, good & fair results were attained in 2 patients each, whereas a poor outcome was seen in 1 patient.

Table 5. Type of plate fixation

Type of fixation	No. of Cases	% of Cases
Orthogonal plating	19	63%
Parallel plating	11	37%
Total	30	100%

Table 6. Type of fixation at osteotomy site

Type of Fixation	No. of Cases	% of Cases
K TBW	16	53%
C TBW	14	47%

Table 7. Post-operative complications

Post-operative Complications	No. of Cases	% of Cases
Ulnar Nerve Neuropraxia	2	7%
Infection + Stiffness at the Elbow	1	3.3%
Wound Gaping at Cancellous Screw Head Region	1	3.3%
Total	4	13.6%

Table 8. Time required for radiological union

Radiological Union	No. of Cases	% of Cases
12-16 weeks	22	73%
17-21 weeks	8	27%
Total	30	100%

Table 9. Functional results based on meps

Functional results based on meps	No. of Cases	% of Cases
Excellent	25	83%
Good	2	7%
Fair	2	7%
Poor	1	3%
Total	30	100%

CASE 1

Fig. 1. Pre-op X-ray

Fig. 2. Post-op X-ray

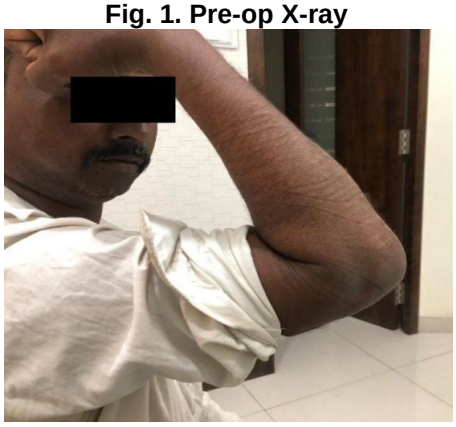

Fig. 3. Elbow flexion

Fig. 4. Elbow extension

4. DISCUSSION

For centuries, DHFs (distal humerus fractures) have been notoriously difficult to treat. Management of DHFs has seen major changes over the years, right from conservative management with the 'bag-of- bones' technique, to bi-columnar plating options available in modern times. Even now, AO type C fractures present a major challenge due to involvement of the articular surfaces of the already complex anatomy at the distal end of the humerus.

In our study, we treated 30 adults with AO type C DHFs by ORIF with bi-columnar fixation. In our study, the mean age of patients was 44 years, which is comparable to the study led by Shin SJ et al. [10] in which the average age of subjects was 42 years. The mean age for females was higher (49 years) as compared to that of males (41 years), although majority of patients (9 patients; 30% cases) in our study belonged to the 21-30 years age group, of which, most were males. This indicates a bimodal pattern of age distribution in DHFs [2,3].

There was a predominance of male patients in our study (60%), as compared to females (40%). This can be attributed to the fact that more males are involved in MVAs or sports-related injuries. MVAs were the chief cause of injuries in males in the 3rd and 4th decades, which is in accordance with literature which states that males belonging to those age groups are more likely to be involved in MVAs. On the other hand, females formed majority of cases (60%) in the older age groups (i.e. > 50 years). The likely cause of this is post-menopausal osteoporosis in females resulting in poor bone stock, which makes them more susceptible to DHFs even after simple domestic falls. Simple falls causing a direct impact on the elbow, or a fall on an outstretched hand was the chief mode of injury seen in older females. Watts AC et al. [11] in their study also concluded that the higher prevalence of DHFs in

females over 60 years old is due greater carrying angle in females, & post-menopausal osteoporosis. Palvanen M et al. [12] established that DHFs after simple falls from standing height were commoner in osteoporotic females older than 60 years of age; in another study [2] they also found that specific injury mechanisms are likely to cause most typical osteoporotic elbow fractures of older adults, like fall causing direct impact at the fracture site. Robinson CM et al. [5] also showed similar results in their study spanning over 10 years which included 320 patients.

In our study, out of the 30 cases classified under AO type C DHFs, maximum cases were assigned to type C2 fractures (16 cases; 53%). We had 9 (30%) cases of type C1, whereas 5 (17%) cases of fractures belonging to type C3. Holdsworth BJ et al. [13] in their study had a comparable distribution of fracture patterns falling under AO type C.

Of the 30 patients of DHFs we treated by ORIF with bi-columnar plate osteosynthesis, 19 (63%) were operated using the orthogonal plating configuration. The remaining 11 (37%) cases were operated by using parallel plate fixation. The type of dual plating configuration to be used was decided intra-operatively after evaluation of the fracture site and ease of fixation. We found that both configurations are suitable for the fixation of these elbow fractures when it comes to eventual functional outcomes, which is in agreement with the study by Ditsios K et al. [14] & others. Besides the type of fixation used, enough screws, both at the condylar as well as metaphyseal levels, with bone grafting, & stiffness of the plate & bone quality, all determine the stability of fixation. Regarding type of fixation, orthogonal plating is recommended in case of anterior shear fracture where antero-posterior fixation provides stability to intra-articular fractures, & parallel plating in case of low humeral condyle fractures where additional stability is provided by supplementary screws in distal fragments. Arnander MW et al. [15] in their study theoretically concluded that a parallel plate construct is significantly sturdier & stiffer compared to a perpendicular plate construct when put through forces of sagittal bending in a DHF model.

The olecranon chevron osteotomy approach was used to operate all the 30 patients in our study. In our experience, this approach is better in comparison to other approaches available for treating DHFs, because it offers a better visualization of the posterior articular surface & fracture site, while also allowing early post-operative rehabilitation. This is in accordance with the studies of [16,17] who reported similar findings. We used K-wire with TBW to fix the osteotomy site in 16 (53%) patients, whereas in 14 (47%) patients, cancellous screw insertion with TBW was done. This method of fixation was mainly decided intra-operatively.

Out of 30 cases in our study, post-operative complications were encountered in 4 patients. Ulnar nerve-related neuropraxia occurred in 2 patients; the same recovered without surgical intervention within 6 weeks. Wang KC et al. [18] recommended routine anterior subcutaneous transposition of ulnar nerve while using the posterior approach. Södergård J et al. [19] reported a complication rate of 12.5% involving the ulnar nerve after fixation of DHFs surgically. Anterior transposition of the ulnar nerve was carried out routinely in all our cases, which contributed to the low rates of post-operative neuropraxia. This was in accordance with a study by Tyllianakis M et al. [20] who recommend ulnar nerve exploration in all such cases. Wound gaping where the cancellous screw head was protruding was seen in one patient; this was managed by secondary suturing & antibiotics. Infection at the operated site was encountered in 1 patient 2 weeks after the surgery, which settled after treatment with I.V. antibiotics – this was followed by stiffness of the elbow in the same individual, resulting in a restricted arc of motion. Stiffness was attributed to the non-compliance of the patient to regular physiotherapy.

Most of the cases (22 patients; 73%) in our study showed signs of radiological union between 12-16 weeks post-operatively, while 8 (27%) cases united between 17-21 weeks. This was in accordance with a study by Ditsios K et al. [14]. All the olecranon osteotomies performed for the surgical approach united uneventfully.

We used the MEPS for evaluation of functional results in the subjects participating in our study since it shares similar characteristics with Jupiter's modification of Cassebaum's scale [21,22]. Also, the MEPS was also found to be more discriminating on validity studies. On last follow- up, an elbow motion flexion-extension arc > 100° was seen in 27 (90%) cases; an arc between 50-100° was seen in 2 patients, & 1

patient had an arc <50°. Our results agree with a study by Athwal GS et al. [23]. Active elbow mobilization in the early post-operative period has been established as a standard protocol towards ensuring an acceptable outcome [24]. Morrey et al. [25] believed most activities of daily living could be accomplished by having a FE arc >100° (30-130°), which can be possible if post-op mobilization is started early. The present study reaffirms the same, as an excellent elbow ROM was attained in most of the patients where mobilization was initiated early following stable internal fixation. A slight loss of extension seen in some patients was similar to that reported by Sanders RA et al. [26].

According to MEPS, all 9 AO type C1 fractures had excellent functional outcomes, 15 out of 16 type C2 fractures had excellent outcomes, while 1 had good outcome. Amongst 5 type C3 fractures, 1 patient had an excellent outcome, 1 had good outcome, 2 had fair outcomes, & one had poor outcome. Overall, we achieved an excellent outcome of 83% in our study. The results of our study are comparable to previous literature on the topic, which concludes that the functional outcomes of intra-articular DHFs are influenced by the fracture geometry.

5. CONCLUSION

From this prospective study we conclude that:

1. Closed intra-articular, intercondylar fractures of the distal humerus classified as AO type C fractures should be treated only by surgical management, unless strongly contraindicated in elderly patients.
2. Open reduction with bicolumnar internal fixation by using either orthogonal, or parallel plate configuration should be the preferred choice of treatment in acute type C fractures.
3. It is preferable to use the trans-olecranon chevron osteotomy approach for these fractures, as it offers a superior visualization of the fracture site in comparison to other approaches. Reconstruction of the complex distal humeral anatomy is facilitated by using this approach.
4. The practicality of the MEPS scoring system makes it a rather handy tool for surgeons in assessing the post-operative functions of the elbow, provided that the patients are compliant with regular follow-ups.
5. The functional outcomes evaluated as per the MEPS system are greatly influenced by the fracture pattern, with type C3 fractures giving slightly inferior results as compared to type C1 & type C2, which give near excellent results in all the cases.
6. Routine anterior ulnar nerve transposition helps in reducing post- operative complications related to neuropraxia significantly.
7. Early post-operative rehabilitation, & mobilization of the elbow with active physiotherapy started as early as 3 weeks, helps considerably in regaining a good arc of elbow motion.

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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