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Case Series

Mid-term outcome of minimally invasive anterior bridge plating *versus* conventional posterior plating for diaphyseal fracture humerus- A prospective randomized trial

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Abstract

Background: The present study aims to assess the mid-term outcome in patients with diaphyseal humerus shaft fractures treated with minimally invasive anterior bridge plating versus conventional posterior plate.

Methodology: 60 consecutive patients with closed diaphyseal fracture shaft humerus were included between February 2016 and January 2019 at a tertiary care center. Patients with compound fractures, neurovascular injury, ipsilateral limb injuries, were excluded from the study. The patients were block randomized into group I (anterior bride plating) and group II (posterior plating).

Results: The mean age of the patients was 48.16 ± 8.66 in group I and 45.10 ± 9.56 years in group II respectively. AO-OTA type 12A was most commonly seen fracture type. The mean surgical time in group I was 55.80 ± 6.23 minutes while it was 85.31 ± 7.67 minutes in group II was significant ($p<0.001$). Patients in group I had shorter hospital stay ($p=0.018$). Group I has a mean union rate of 14.57 ± 1.72 while group II had a rate of 15.67 ± 2.41 weeks ($p=0.046$). One patient in each group had non-union. One patient in group I had lateral antebrachial cutaneous nerve injury with some residual sensory loss. There was a significant improvement in DASH scores in both groups ($p=0.0043$). Conclusion: The anterior bridge plating is a reliable and reproducible technique with shorter operative time, hospital stay, early radiological union and better outcome as compared to traditional posterior compression plating.

Keywords: anterior bridge plating, posterior plating, diaphyseal humerus fractures, DASH

INTRODUCTION

Diaphyseal fracture of the humerus accounts for 1%-5% of the fractures with a predilection towards young males and elderly females [1,2]. The treatment of these fractures has always been a matter of debate owing to the ability of shoulder girdle to withstand the deformities in various planes [1]. The most successfully used conservative method for these fractures is Sarmentio functional brace [3]. Nonetheless, surgical interventions have gained popularity in the past few decades due to some disadvantages of conservative treatment namely long-term immobilization, skin and soft tissue compromise and risk of non-union [3-5].

The two most commonly used surgical modalities are intramedullary nailing or plating with their own pros and cons. On one hand, the intramedullary nailing has biomechanical advantage and also, the benefits of preserving fracture hematoma, on the other hand, plating helps in achieving anatomical and stable reduction [5,6].

The conventional Posterior Plating (PP) has been considered as the gold standard treatment, nonetheless, it is associated with extensive periosteal stripping which can lead to disruption of periosteal blood supply, and risk of iatrogenic radial nerve palsy or even non-union which can be between 3% and 20% [5,7,8]. Moreover, intramedullary nailing can be associated with complications such as compromised shoulder or elbow function, rotator cuff violation, increased radiation exposure or non-union [5-9] Recently, Minimally Invasive Plate Osteosynthesis (MIPO) using Anterior Bridge Plate (ABP) has gained popularity because of the advantages like less soft tissue damage, preservation of the blood supply yielding good functional outcomes [8,10,11].

The aim of present study was to assess the mid-term radiological and functional outcome in patients with diaphyseal humerus shaft fractures treated with minimally invasive anterior bridge plating versus conventional posterior plate.

Our hypothesis was that the anterior bridge plate would be associated with better radiological and functional outcomes.

MATERIALS AND METHODS

STUDY DESIGN AND PARTICIPANTS

The present trial was performed using the CONSORT checklist for randomized control trials [12]. Institutional ethical committee approval was obtained prior to the commencement of the study (N-EC/2016/02/2016)

A parallel group trial design was used in the present study. An allocation of 1:1 was attempted. This prospective randomized study was conducted at a tertiary care trauma center at Navi-Mumbai, Maharashtra, India between February 2016 and January 2019.

INCLUSION CRITERIA

All the skeletally matured patients with closed diaphyseal shaft humerus fractures. Patients with compound fractures, neurovascular injury, pathological fractures, history of previous humerus fracture, patients with ipsilateral upper limb injuries, patients who were lost to follow-up and patients with pre-existing shoulder or elbow pathology which would affect the post-operative rehabilitation were excluded from the study.

INTERVENTIONS

All the eligible patients were divided into two groups. Patients in group I were treated with anterior bridge plating while the patients in group II were operated using the posterior plating technique. The primary outcome was to compare the functional and radiological results using Disability of Shoulder, Arm and Hand (DASH) scores between both the techniques. The secondary outcome was to assess the variables like surgical time, union rate and complications associated with both the techniques.

SAMPLE SIZE DETERMINATION

Based on a previous study [13], to achieve 80% power with an alpha error of 5%, the required sample size of 29 patients per group was determined.

PARTICIPANT INCLUSION AND RANDOMIZATION PROCESS

A total of 75 patients with diaphyseal fracture humerus presented to the emergency department between February 2016 and January 2019. Of these, 63 patients were found to be eligible for the study of which 2 denied to consent for the study. Group I had 31 while group II had 30 patients respectively. However, there was 1 lost to follow-up at 104 weeks in group II which left us with 29 patients in group II (Figure 1). A block randomization technique was used in the present study (block 4 randomization). The operating surgeon was asked to open a closed opaque envelope after the anesthesia was administered. The randomization process was done by a single person (a technician working in the hospital) at all the instances who was not a part of the study. All the surgeries were performed by two surgeons (G.S. and A.S.).

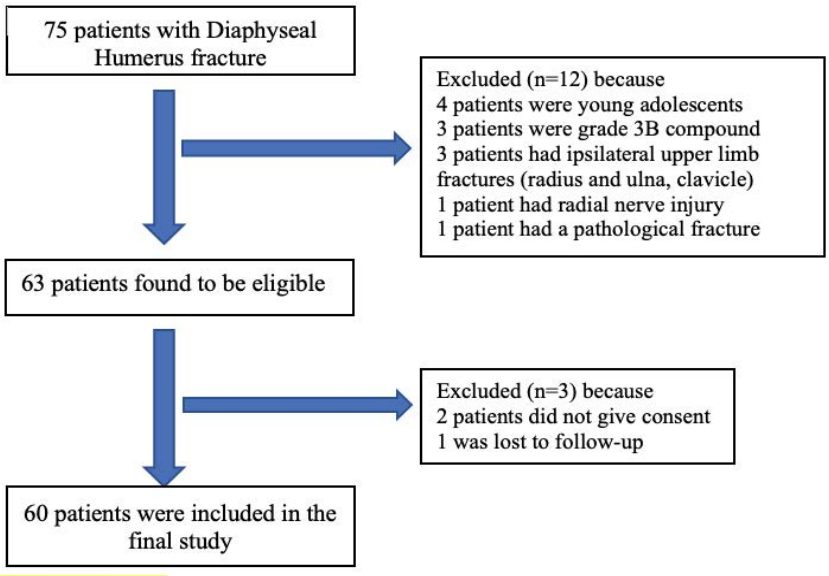

Fig. 1. Flowchart showing inclusion of the participants

SURGICAL TECHNIQUE

ANTERIOR BRIDGE PLATING

All the surgeries were performed in supine position under general combined with regional anesthesia. The procedure was performed as described by Livani, et al. [14]. The affected upper extremity was kept on an arm board with 50º-60º abduction at the shoulder and elbow flexed to 90º and forearm held in supination to achieve linear traction. The reduction of the fracture was attempted in indirect fashion by traction-counter traction technique to correct the sagittal plane deformities and varus and valgus force at fracture site to correct the coronal plane deformities respectively. A 3 cm-5 cm distal incision was made starting at the lateral border of biceps. After superficial dissection, the biceps brachii was retracted medially and the lateral antebrachial cutaneous nerve was identified between the biceps brachii and brachialis muscle. The brachialis muscle was the separated anteriorly in two halves to obtain access to the anterior part of distal humerus. Another proximal window of 3 cm-5 cm was made between deltoid laterally and biceps tendon medially. A 4.5 mm stainless steel narrow dynamic compression plate (Sorath©, Gujrat, India) was used in all the cases. The plate was slide from proximal to distal direction. The distal fragment was then held with a 4.5 mm cortical screw following which the fracture was reduced by applying linear traction. The varus deformity was found to be common for which the proximal fragment was pushed slightly medially. The plate was fixed with 2-3 screws on either side of the fracture. Care was taken at all levels to avoid injury to the lateral antebrachial cutaneous and radial nerve distally. The wound was closed over layers and compression dressing was applied.

POSTERIOR COMPRESSION PLATING

All the surgeries were performed in lateral position under general combined with regional anesthesia. The triceps split approach was used in all the cases. A longitudinal midline incision of around 10 cm-12 cm was made centered at the fracture site. The triceps fascia was incised vertically and a plane between long head of triceps medially and lateral head of triceps was retracted laterally. The deep dissection involved retracting medial head of triceps medially and identifying and mobilizing the radial nerve and accompanying profunda brachii artery. The fracture fragments were exposed and then cleared of the hematoma. The reduction was held with bone holding forceps. A 4.5 mm dynamic compression plate (Sorath©, Gujrat, India) was used in all the cases. A lag screw was used either through the plate or independently whenever required. The reduction was checked under image intensifier and the wound was closed over layers without suction drain.

POST-OPERATIVE CARE AND FOLLOW-UP

Similar post-operative protocol was followed in both the groups. A check dressing was done in all the patients on post-operative day 2. All the patients were kept in an arm sling for a period of 3 weeks which was removed during the time of physiotherapy. Gentle pendulum exercises, wrist and elbow mobilization with arm by the side was begun in the immediate post-operative period. Active assisted forward elevation was started under supervision at 2 weeks post-operative. Active abduction and rotation were allowed after 3-4 weeks of surgery. All the patients were allowed to return to activities of daily living and resume pre-operative status by the end of 3 months post-operatively. All the patients were followed up regularly at 3, 6, 12 and 24 months after the surgery.

OUTCOME MEASUREMENT

The final outcome was calculated using the Disability of Shoulder, Arm and Hand (DASH) score [15] by a senior resident who was not a part of the randomization process. DASH is a validated set of 30 item self-reported questionnaire which assesses the patient's disability due to upper limb disorders and helps to monitor the symptoms and function over a week's time. The final score is calculated based on the patient's response to all the 30 items on a Likert scale of 1-5. The minimum score of 0 indicates no disability whereas, the highest score of 100 means most severe disability. A minimum of 27 items should be answered in order to get a final result.

STATISTICAL ANALYSIS

All the data with categorical variables were presented in percentage and the continuous data was described as mean and standard deviation. The statistical difference between both the interventions based on the scores were calculated using independent t test while the descriptive analysis within each group was assessed using the repeated measured ANOVA test and interval plot at various intervals. The analysis was done using the Epi-info software (V 3.5.4) and Microsoft Excel 2013 (Microsoft Office version 15.0). Chi square test was applied whenever required. The p value <0.05 was considered to be statistically significant.

RESULTS

The demographics were as summarized in Table 1. The mean age of the patients was 48.16 ± 8.66 years in group I and 45.10 ± 9.56 years in group II respectively. In group I, the average time between injury and presentation was 6.22 ± 3.90 days, whereas in group II, it was 5.17 ± 2.72 days which was not statistically significant (p=0.236).

The most commonly seen fracture pattern as per the AO- OTA (Arbeitsgeminschaft für Osteosynthesefragen- Orthopaedic Trauma Association) was type 12A with 27 (45%) patients followed by type 12B with 22 (36.7%) and 12C with 11 (18.3%) patients respectively.

The mean surgical time in group I was 55.80 ± 6.23 minutes while it was 85.31 ± 7.67 minutes in patients of group II respectively which was statistically significant (p<0.001).

Similarly, the average stay in hospital was 3.80 ± 1.30 and 4.65 ± 1.39 days in patients of group I and II respectively which was statistically significant (p=0.018).

RADIOLOGICAL OUTCOME

The union was said to occur when the anterio-posterior and lateral radiographs showed signs of healing (Figures 2 and 3). All the radiographs were assessed by all the four operating surgeons and a

Table 1. Demographic characteristics

Variable		Group I n=31 (%)	Group II n=29 (%)	Total n=60 (%)
Sex	Male	17 (54.84)	15 (51.72)	32 (53.33)
	Female	14 (45.16)	14 (48.28)	28 (46.67)
Side	Right	14 (45.16)	16 (55.17)	33 (55)
	Left	14 (45.16)	13 (44.83)	27 (45)
Dominant side	Right	26 (83.87)	19 (65.52)	33 (55)
	Left	5 (16.13)	11 (37.93)	27 (45)
Mechanism	RTA	23 (74.19)	21 (72.41)	44 (73.33)
	Fall	8 (25.81)	8 (27.59)	16 (26.67)

senior musculoskeletal radiologist who was not a part of the study. The union rate was 96.77% in patients with group I and 93.10% patients in group II respectively. The mean union rate was 14.57 ± 1.72 weeks in patients with group I and 15.67 ± 2.41 weeks in patients with group II which was statistically significant (p=0.046).

FUNCTIONAL OUTCOME

The functional outcome was calculated using the Disability of Shoulder, Arm and Hand scoring system which was statistically significant at 6, 24 and 52 weeks between both the groups (Table 2). There was a significant improvement in each group which was statistically significant (Figure 4). However, the final outcome was at the end of 104 weeks showed no difference amongst both the techniques (p=0.659).

COMPLICATIONS

One (3.2%) patient in group I and 1 (3.4%) patients in group II had non-union. Both patients had AO-OTA type 12C fracture pattern. One (3.2%) patient in group I had delayed union. One (3.4%) patient in group II had post-operative radial nerve neuropraxia that recovered completely within 6 months. One (3.4%) patient in group II had superficial infection which responded well to third generation cephalosporin antibiotics. One (3.2%) patient in group I with injury to

Fig. 2. Radiographic images of anterior bridge plating

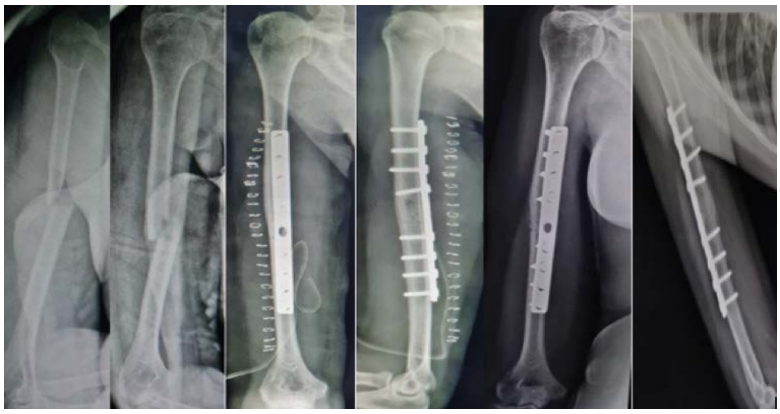

Fig. 3. Radiographic images of posterior plating

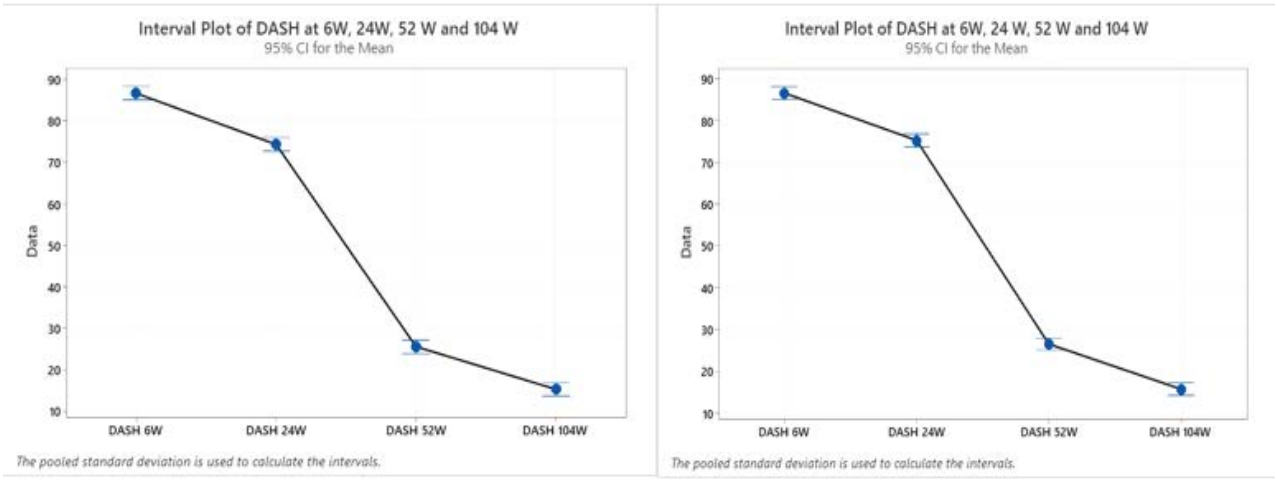

Fig. 4. Interval plot showing comparison of both the groups as per disability of shoulder, arm and hand scoring system

Table 2. Functional outcome by disability of shoulder, arm and hand scoring system

Variable		Mean	SD	t-stat	df	P value
Time between injury and presentation	Group I (n=31)	6.22	3.93	1.19	58	0.236
	Group II (n=29)	5.17	2.72			
Surgical time (minutes)	Group I (n=31)	55.8	6.23	-16.39	58	<0.001**
	Group II (n=29)	85.31	7.67			
Stay in hospital	Group I (n=31)	3.8	1.3	-2.43	58	0.018*
	Group II (n=29)	4.65	1.39			
Union (Weeks)	Group I (n=31)	14.57	1.73	-2.03	58	0.046*
	Group II (n=29)	15.67	2.14			
DASH 6 weeks	Group I (n=31)	84.57	3.23	2.23	58	0.029*
	Group II (n=29)	86.52	3.52			
DASH 24 weeks	Group I (n=31)	72.28	5.18	2.29	58	0.025*
	Group II (n=29)	75.24	4.78			
DASH 52 weeks	Group I (n=31)	23.42	3.67	2.97	58	0.0043*
	Group II (n=29)	26.57	4.53			
DASH 104 weeks	Group I (n=31)	15.81	3.59	-0.44	58	0.657
	Group II (n=29)	15.42	3.16			

*Significant at 5% level, **Significant at 1% level

lateral antebrachial cutaneous nerve following which, the patient had loss of sensation along the lateral aspect of forearm. The patient had some residual sensory loss at the end of 2 years.

DISCUSSION

The ABP was associated with shorter stay in hospital and early radiological union as compared to the conventional PP in the present study. Theoretically, ABP technique works on the principle of relative stabilization that is achieved through MIPO. Moreover, it causes less damage to the soft tissues and also preserves the accessory nutrient arteries which can be affected nearly two times more, in patients where posterior plating is contemplated [16]. These factors along with preservation of the fracture hematoma while performing anterior bridge plating further helps in achieving fracture union. The union rate in the present study was 96.77% among patients with group I with a mean of 14.57 ± 1.73 weeks (SEM 0.311, df 58). Similar were the findings of other studies [14,17,18] and meta-analysis [10,11,16]. Only one (3.2%) patient in group I had atrophic non-union in the present study for which a secondary autologous bone grafting was done after 15.4 weeks from the primary surgery. The fracture united well with good callus formation. Nonetheless, 1 (3.4%) patient in group II had atrophic non-union which required revision surgery with autologous bone grafting at the end of 17.4 weeks. The predicted risk factors for the same could be associated history of smoking, diabetes and type 12C as per AO-OTA classification system which have already been supported by others [19]. Various studies have found the prevalence of non-union after posterior plating to be between 3% and 20% [13,20-25]. The mean time to union in the present study was less in patients with group I (ABP) which was statistically significant (p=0.046). In contrast, few meta-analysis [10,11] have found no significant difference between both, the ABP or PP techniques, however, the union time in patients treated with ABP was shorter. We definitely believe that MIPO technique has an advantage of being less invasive, preserving the hematoma and the soft tissue dissection.

The prevalence of iatrogenic radial nerve injury following ABP is 2.8% while it can be as high as 20% after PP [8,26]. One (3.4%) patient in group II had a post-operative radial nerve neuropraxia in the present study which recovered within 6 months. A meticulous care and surgeon's experience could be a probable reason for the same. There was no case of iatrogenic radial nerve injury in patients with group II. Apivatthakakul, et al. in their cadaveric study highlighted the importance of forearm position and traction use during the MIPO technique through anterior approach. They observed that the radial nerve moves closer to the plate by 0 mm-3 mm when the forearm is held in pronation as opposed to supination. Moreover, excessive lateral traction should be avoided during the procedure to avoid injury to the radial nerve. Both the measures were followed in the present study in patients with group I. The ABP technique is technically demanding and has a steeper learning curve. It also involves greater risk of radiation exposure alike any other MIPO technique. Nonetheless, few meta-analysis [10,11] studies have found the radiation exposure or the risk to iatrogenic radial nerve injury to be statistically insignificant. Although we did not record the risk of radiation exposure in the present study, we observed that the radiation exposure did decrease with the number of cases operated.

In the present study, a record of length of stay in the hospital was made. It was found that the patients in group I (3.80 ± 1.30 days) had shorter stay in hospital as compared to the patients in group II (4.65 ± 1.39 days) which was statistically significant (p=0.018). It could be attributed to the better tolerance of the procedure and less post-operative pain scores in patients with group I.

The union time in patients with group I was 14.57 ± 1.73 weeks, while it was 15.67 ± 2.41 weeks in patients with group II respectively in the present study which was statistically significant (p=0.046). Similar were the findings of few more studies [17,19,20] and some meta-analysis [10,11]. Albeit, few studies [13,18,20] and meta-analysis [10,11] found a shorter union time with MIPO technique as compared to posterior plating, none of them found it to be statistically significant.

The reliability and validity of Disability of Arm, Shoulder and Hand in patients with humerus shaft fracture has already been established in the literature [14]. There was a statistically significant difference (p=0.0043) between both the groups as per the DASH scores with patients in group I having better outcomes (23.42 ± 3.67) than group II (26.57 ± 4.53) patients at the end of 6, 24 and 52 weeks respectively (Table 2). Nevertheless, at the final average follow-up of 104 weeks, the difference was not statistically significant (p=0.657). We believe that the anterior bridge plating owing to its minimally invasive nature, gives better functional outcome in early post-operative period.

This study is not without limitations. Firstly, the study compares the mid-term outcome which can be sometimes inconclusive in assessing the complications such as late shoulder arthritis secondary to mal-alignment that has been mentioned by Wang et al in their study. However, the degree of mal-alignment was not calculated in the present study. Secondly, no rotational mal-alignment was assessed in the present study in regards to shoulder version. The randomized and prospective nature along with good follow-up remains the biggest strengths of the present study.

CONCLUSION

The ABP technique for diaphyseal humerus shaft fractures is a promising, reliable and reproducible technique with shorter operative time, hospital stay, early radiological union and better outcome as compared to traditional posterior compression plating.

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