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Functional and clinical outcome of minimally invasive anterior bridge platting in humerus shaft fractures

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Abstract
Introduction: To assess the functional and radiological outcomes of minimally invasive anterior bridge plating (ABP) for mid-shaft humerus fractures. This study is done to evaluated the clinical, radiological, and functional outcome of mid shaft humerus fractures in 30 patients, all of which were managed with MIPPO. over an average follow up period of 12 months.
Materials and Method: 30 patients fulfilling inclusion criteria were treated with ABP by using a 4.5-mm dynamic/locking compression plate and followed for a period of 12 month. Functional outcome was assessed using the UCLA & Mayo elbow scores. Range of motion (ROM), subjective strength, and radiographic union were assessed.
Results: Out of the 30 patients in the study, 24 were males and 6 were females. The mean age was 36 years (range 26 to 65 years). 22 out of 30 patients (73%) had the dominant side fractured. Mean surgical time in minutes was 60 min (range: 35-80 min).The mean fracture union (radiological) time was 10.6 weeks (range: 08–16 weeks). However Shoulder function was excellent to good in 28 cases (93.3%) and fair in 2 case (6.7%) on the UCLA score and excellent in 28 cases(93.3%) and fair in 2 cases (6.7%) on mayo elbow score.The majority of patients (28 patients, 93.3%) who fell in the excellent or very good category according to our questionnaire were extremely satisfied. There were 2 cases (6.7%) of non-union.
Conclusion: ABP is fundamentally different from traditional open posterior plating or conventional intramedullary nailing. It works on the principal of relative stability with union taking place by callus formation, and a longer plate on the tensile surface ensures that the humerus can withstand greater amount of rotational and bending stresses. The minimally invasive nature preserves the soft tissue envelope and, if done correctly, causes no damage to the vital structures in proximity. ABP for mid-shaft humerus fractures is a safe and effective treatment modality yielding high rates of union, excellent functional recovery, minimal biological disruption, better cosmesis, and superior satisfaction rates.

Keywords: Humerus fractures, anterior bridge plating, minimally invasive surgery

Introduction
Humerus shaft fracture can successfully approached by a variety of methods for fracture fixation including functional bracing, platting, and intramedullary nailing [1-5]. Plating can be performed using a classic open approach (posterior and anterior) or minimally invasive methods. Notably, many humeral fractures can be successfully managed conservatively due to the wide range of acceptability for reduction as shoulder and elbow have wide range of movements.
Anterior bridge plating (ABP) which utilizes the minimally invasive approach known as the minimally invasive percutaneous plate osteosynthesis (MIPPO) technique can be considered the novel and newest in this list.
MIPPO has the advantages of less soft tissue dissection, lower nonunion rates and low risk of iatrogenic radial nerve palsy, unlike open surgical procedures [6]. It allows earlier functional treatment and higher postoperative range of motion in adjacent joints [7, 8].
The traditional open posterior plating preserves the rotator cuff; however, biological disruption of soft tissue, poor cosmetic scarring, and direct handling of the radial nerve have been of concern. On the other hand, the classical intramedullary nailing is minimally invasive, but it has the main drawback of potentially damaging the rotator cuff and causing shoulder impingement [1, 3, 5, 9].

The ABP is designed to combine the best features of these two techniques: therefore, it is minimally invasive and cosmetic friendly and causes minimal manipulation of vital structures [9].

So, in our study we analized the clinical and functional outcome of such patients treated with ABP and got excellent results by this method.

Materials and Methods

30 patients with fractures of humerus shaft were treated with Minimum invasive Anterior Bridge plating technique in a case series of study between Jan 2021 and Jan 2022 at our center. The cases were followed for a period of 12 months. These fractures were reduced and fixed with 4.5mm locking compression plate (LCP/LCDCP). Institutional Ethical Committee approved the study.

The inclusion criteria are as follows: (1) mid-shaft humeral fractures (2) skeletally mature; (3) minimum 1-year follow-up. Exclusion criteria included fracture on both the limbs, higher grade of compounding, concomitant other medical illness such as malignancy, vascular insufficiency of the upper limb, poly trauma patients, drug addict patients (alcohol and others).A preoperative clinical examination of the affected arm was carried in all aspects like abrasions, swelling, contusion, puckering and neurovascular deficit(chiefly Radial nerve status). Antero posterior (AP) and lateral (Lat) radiographs of the humerus, of the patient were evaluated. These radiographs were also used to decide the appropriate length of implant and planning the surgery. Functional outcome where analyzed by UCLA & Mayo elbow score (table no 1&2).

Table 1: UCLA Shoulder Rating Scale

Measure	Finding	Points
Pain	no pain	10
	occasional and slight pain	8
	pain with heavy or particular activities only; uses salicylates occasionally	5
	none or little at rest; occurs with light activities; salicylates frequently	4
	constant but bearable; strong medications occasionally	2
	constant, unbearable; strong medications frequently	1
Function	normal activities	10
	slight reduction in function; able to work above shoulder level	8
	most housework, washing hair, putting on brassiere, shopping, driving	5
	light housework or most daily living activities (ADL)	4
	very light activities only	2
	unable to use arm	1
Muscle power and motion	normal muscle power; motion near normal	10
	muscle power good or normal; elevation 140°; external rotation 20°	8
	muscle power fair to good; elevation 90°; internal rotation 90°	5
	muscle power poor to fair; elevation less than 60°; internal rotation < 45°	4
	ankylosis with good functional position	2
	ankylosis with deformity	1

Score for each measures	Interpretation
10	Excellent
8	Good
4/5	Fair
1/2	Poor

Table 2: Mayo Elbow Performance Score (MEPS)

Parameters	Description	Points
Pain (Max 45 points)	None	45
	Mild	30
	Moderate	15
	Severe	0
Arc of Motion (deg)(Max 20 points)	Arc >100	20
	Arc 50-100	15
	Arc 50<	5
Stability (Max 10 points)	Stable	10
	Moderately unstable	5
Function (Max 25 points)	Grossly unstable	0
	Comb hair	5
	Feed	5
	Hygiene	5
	Wear shirt	5
	Wear shoes	5

Interpretation	Score
Excellent	>90
Good	75-89
Fair	60-74
Poor	60<

Surgical Technique

After a routine pre-anesthetic check-up, patients were sent for submuscular, extraperiosteal anterior humeral bridge plating using a standard technique performed in the supine position under fluoroscopic guidance. The shoulder was abducted to 30°–60°, the elbow was flexed to about 90°, and the forearm was supinated throughout the procedure. Indirect reduction maneuvers were used when needed for optimal fracture reduction. The proximal part of incision was about 2–3 cm long between the deltoid and biceps and as proximal as possible in this intermuscular plane, whereas the distal incision of a similar length was made as distal as possible while ensuring that the plate ended proximal to the supracondylar region, and the brachialis was split to reach the anterior surface of the humerus. The biceps and underlying neurovascular bundle were retracted medially while the lateral part of the split brachialis muscle protected the radial nerve. Undue forceful retraction was avoided for fear of neuropraxia. As described by Wang *et al.* [10]. 15° of angulation in any plane and 1 cm migration of fracture ends were the threshold of acceptability and anything more than that merited a second attempt for reduction. The cortical step sign and diameter difference sign described by Krettek *et al.* [11]. were used to minimize malrotation during fixation.

The longest possible 4.5-mm dynamic/locking compression plate (DCP/LCP) was chosen depending on the humeral anatomy. During insertion of the distal screws on the anterior surface, care was taken to the proximity of the radial nerve laterally and brachial artery and musculocutaneous nerve medially. Simple cortical screws were used in all cases (two proximally and two distally) except when the bone was extremely osteoporotic where locking screws were used.

Postoperatively, all patients were discharged after 48 hours with the affected side immobilized in a simple sling. Pendulum exercises and elbow, wrist, and hand range of motion (ROM) exercises were started immediately postoperatively as tolerated by the patient. Passive and active assisted shoulder ROM exercises were started under supervision of a physiotherapist at 2 weeks after surgery. Active abduction beyond 90° and active rotation were allowed at 3–4 weeks after surgery. The patient was allowed to gradually resume preoperative activities with muscle

strengthening and return to full spectrum of activities at 9–12 weeks after surgery. Patients with no signs of radiographic/clinical union at more than 180 days or 6 months after surgery were subsequently treated for nonunion.

Fig 1: (Pre op)

Fig 2: (Post op)

Fig 3: Incision

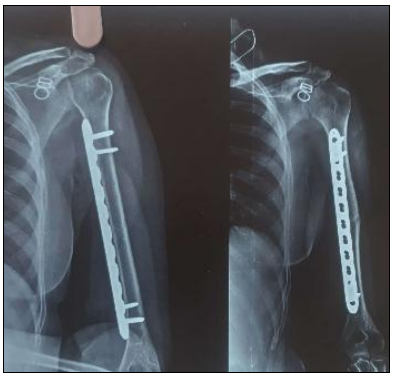

Fig 4: (followup)

Fig 5: ROM

Fig 6: ROM

Results

Patients were assessed for functional and radiological outcomes at 1 year after surgery. Serial radiographs were obtained immediately after surgery, at 6 weeks, 3 months, and 6 months after surgery, and finally at 12 months after surgery. Radiographic assessments included callus formation, fracture alignment, delayed union, and nonunion. The functional outcome was assessed using the Mayo's elbow score and UCLA score. The ROM of the affected limb was evaluated for abduction, external rotation (ER) in 90° of abduction and elbow flexion, internal rotation (IR) with the arm placed adjacent to the chest and elbow flexed to 90°, and forward elevation (FE) using a hand-held goniometer. The strengths of the shoulder abductors, rotators, and forward elevators and elbow flexors and extensors were assessed.

The patients shoulder and elbow function were analyzed using the UCLA shoulder score and the Mayo elbow performance score (MEPS). Of the 30 patients assessed, all but two united successfully without additional intervention. These 2 cases of nonunion were treated with autologous iliac crest bone grafting at 6 months after surgery and further recovery was uneventful in both of them, with the fracture uniting 8 weeks afterwards.

The mean fracture union (radiological) time was 10.6 weeks (range: 08–16 weeks). However Shoulder function was excellent to good in 28 cases (93.3%) and fair in 2 case (6.7%) on the UCLA score and excellent in 28 cases (93.3%) and fair in 2 cases (6.7%) on mayo elbow score. The majority of patients (28 patients, 93.3%) who fell in the excellent or very good category according to our questionnaire were extremely satisfied. There were 2 cases (6.7%) of non-union

Discussion

While the majority of humerus shaft fractures are successfully treated by conservative methods [15, 16]. Controversy regarding the ideal option of surgical fixation remains. The patient's clinical condition and activity level, fracture type and localization and the surgeon's experience are important determinants in deciding the most suitable alternative. Minimal invasive methods gained popularity with bridging plate osteosynthesis in the last decade. However, few studies have reported on humerus fractures. In 2004, Livani and

Belangero concluded that MIPPO is a feasible, safe and efficient method with no major complications in the treatment of humerus shaft fractures [17]. Better results have also been reported with MIPPO compared to the conventional surgical techniques in terms of providing a shorter recovery time by early stabilization with minimal soft tissue damage [7]. Aksu *et al*. reported early return of function in adjacent joints to the fracture site and reduced fracture healing time after MIPPO in humerus fractures [18]. However, further clinical studies are needed to state the proven benefits of MIPPO in the treatment of humerus shaft fractures. In the present study, remarkable improvement in both objective and subjective measures was observed.

The primary advantage of ABP is the combination of stability with minimal soft tissue and periosteal disruption [4, 19, 20, 21]. Unlike the posterior plating option, it requires a small incision and adheres to the MIPPO principle, which is biologically and cosmetically preferable. In addition, the rotator cuff is spared preventing any major shoulder pathology later on, which is the case in humeral nailing [22]. The ABP follows the principle of relative and elastic stability instead of the absolute rigidity in the open reduction and internal fixation (ORIF) achieved by a posterior approach. In the former, healing takes place by secondary healing and callus formation, which is stronger, whereas in the latter, it is done by primary healing without callus formation [4, 23, 24]. The purpose of using a long plate in ABP is to decrease the stress per unit area as by distributing over a larger surface area [25]. So this plate, which is placed on the 'anterior tensile surface,' can withstand a larger amount of rotational and bending stresses than the shorter plate.

Union of the humeral shaft fractures in this series presents good results with fixation through indirect reduction aims at maintaining bone alignment through mini incision and replacing absolute stability by relative stability. The present technique through its less tissue dissection and periosteal stripping makes a promising modality of treatment.

On the downside, the procedure has a steep learning curve and should not be attempted by inexperienced surgeons without supervision. Although we did not carry out a formal study, the amount of intraoperative fluoroscopy exposure required was greater than posterior plating or intramedullary nailing. Though increased risk of radial nerve injury is one of the issues with ABP, our study had no such an event. As described in multiple cadaveric studies, an important thing is to keep in mind the course of radial nerve near the distal end of the plate, which usually lies a few centimeters distal to the point where the nerve pierces the lateral intermuscular septum [19, 26]. Sliding of the plate in a wrong fashion, careless drilling for the distal screws, or over-zealous retraction can lead to potentially catastrophic damage. Two cases of forearm tingling in our series were most probably due to neuropraxia caused by one of the above factors. Similarly, the musculocutaneous nerve that lies below the biceps muscle should be meticulously handled.

Another matter of controversy with ABP is whether to use locking or simple cortical screws. Though there have been no formal studies with this regard, we felt that locking screws might make the construct too stiff increasing the risk of nonunion [27, 28]. We used locking screw only in 2 cases (4.17%) with poor bone quality because we were apprehensive about backing out of simple cortical screws. Comparison between these two types of fixation could be an area of further research.

Our study has certain limitations. Firstly, there was no control group to compare our results. Secondly, the malrotation of the humerus after union could not be accurately calculated as no postoperative computed tomography scans were done. So, humeral retroversion angle as described by Boileau *et al*. [29] was not evaluated. However, intraoperative reduction was visually confirmed as per the criteria by Krettek *et al*. [11].

Conclusion

In conclusion, ABP for mid-shaft humerus fractures is a safe and effective treatment modality yielding high rates of union, excellent functional recovery, minimal biological disruption, better cosmesis, and superior patient satisfaction. Though the technique is complex, requiring a relatively long learning time the results are good and reproducible.

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