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ORIGINAL PAPER

Anterior plating as a surgical alternative in the treatment of humeral shaft non-union

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Abstract This study included 15 patients with humeral shaft fractures who had no clinical, radiological or bone scan signs of healing after eight months. The patients were followed for a mean of 35.8 months. No patient was lost to follow-up. Anterior plating of humeral shaft nonunion via an anterior approach was performed using a straight plate and compression for well-vascularised non-unions and wave plating with a tricortical graft for poorly vascularised non-unions. All non-unions healed within 6–18 weeks (mean, nine weeks) without local complication. One patient had a mild decrease in elbow and shoulder range of motion. No neurovascular injury was observed. Anterior plating is a simple, safe and effective treatment for humeral shaft non-union. As this approach avoids the need for radial nerve visualisation and extensive soft-tissue dissection, and the healing time is similar to that of other methods, we suggest this treatment as an alternative option.

Introduction

Humeral shaft fractures are common and constitute 3–5% of all fractures [1, 2]. As Charnley stated, the humerus "is perhaps the easiest of the major long bones to treat by conservative methods" [3]. While anatomical reduction is usually not achieved with nonoperative treatment of these injuries, it is rarely necessary due to the wide range of motion of the shoulder and elbow, such that angulatory, axial, or rotational malunion is easily accommodated and functional limitation is minimal [1].

Nevertheless, specific operative indications have been shown to influence the outcome of the fracture [1]. These include open fractures, multiple injuries, bilateral humeral fractures, associated neurovascular injury, pathological fractures, delayed union, and pseudoarthrosis [4, 5]. Plate osteosynthesis remains the gold standard for the operative fixation of humeral shaft fractures, despite advances in implant technology. It is associated with a high union rate, low complication rate, and rapid return to function [1, 3, 6–9]. For pseudoarthrosis specifically, plate osteosynthesis is the gold standard [10–14]. It is generally accepted that the best face of a long bone for plate placement is the tension face; theoretically, this is the posterior face of the humerus [10, 15]. However, some authors have reported excellent results for plate osteosynthesis when using an anterolateral approach and placement of the plate on the lateral surface of the humeral shaft [16, 17]. Both situations are technically demanding and require extensive surgical dissection with risk of injury to the radial nerve, which invariably crosses the surgical field. Since 2000, many articles have described the safe and effective use of minimally invasive plate osteosynthesis (MIPO), in which the plate is placed on the anterior surface of the humeral shaft [18–25]. This approach avoids radial nerve identification, making the procedure simpler, faster, and safe.

This paper reports our experience with conventional plate osteosynthesis for the treatment of humeral shaft non-union, but with placement of the plate on the anterior surface of the humeral shaft.

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Patients and methods

This study was approved by the ethics committee of our institution. It included all patients with humeral shaft fractures who had no clinical, radiological or bone scan signs of healing after eight months. All patients had indications for open reduction and internal fixation (ORIF) to correct the union failure, based on recommendations in the literature [10]. All provided informed consent.

We treated 15 patients (ten men and five women) with 15 humeral shaft nonunions. Three were the result of open fractures and we classified these according to the Gustilo and Anderson classification [26]. The patients had a mean age of 37.53 years (range, 18–74 years) and ten injuries involved high-energy trauma. Five patients experienced low-energy trauma, including simple falls in three patients, a low velocity gunshot in one patient, and direct trauma in one patient.

Of the 15 humeral shaft fractures, 12 were initially treated using conservative methods. One patient (patient number 4) developed a radial nerve palsy after closed reduction of the fracture and underwent surgical exploration and a minimally invasive plate osteosynthesis using bridge plating (MIPO) [18–20]. He later developed non-union and then underwent anterior plating. Non union developed in 11 other patients initially treated nonoperatively.

Initially, three patients had their fractures treated surgically. Two of these had open fractures and underwent MIPO after debriding contaminated or devitalised tissue and irrigating the wound: one patient had implant failure after falling two weeks postoperatively and the other developed non-union. The remaining patient had a closed fracture, underwent MIPO, and later developed non-union. The remaining patient with an open fracture had a grade I fracture and was managed conservatively after irrigation and debridement, but later developed non-union.

The indications for ORIF with anterior plating were non-union in 14 cases and implant failure in one case. Two patients had radial nerve palsy at the initial presentation after the trauma and one patient developed a radial nerve palsy after closed reduction of the fracture. This patient had indications for radial nerve exploration and underwent MIPO. No nerve damage was observed upon surgery. All three patients recovered completely within two weeks. Twelve patients underwent conventional osteosynthesis using a straight plate and compression; the plate was placed on the anterior humerus (Figs. 2 and 4). An anterior wave plate was necessary in three patients (Fig. 3). The follow-up period ranged from 12 to 68 months (mean, 35.8 months) and no patient was lost to follow-up. The preoperative patient characteristics are summarised in Table 1.

Surgical technique

The patient was placed in the supine position on a conventional operating table with the arm beside the body. The entire arm was prepared for surgery with the shoulder and elbow exposed. We made a straight incision at the lateral border of the biceps brachialis muscle, with sufficient length for an 8- to 10-hole 4.5-mm dynamic compression plate (DCP) or a 10- to 12-hole 4.5-mm DCP. The longer plate was chosen when wave plating was performed.

Table 1 Preoperative aspects

Patient	Age	Gender	Mechanism of trauma	Open fracture	Neurological deficit	Initial management	Evolution
1	23	M	Traffic accident	No	No	Conservative	Non-union
2	64	M	Gunshot	GIIIA	After initial trauma	MIPO + D + I	Implant failure
3	29	M	Traffic accident	No	No	Conservative	Non-union
4	22	M	Traffic accident	No	After closed reduction	Conservative (then MIPO)	Non-union
5	22	M	Traffic accident	No	No	Conservative	Non-union
6	26	M	Traffic accident	No	No	Conservative	Non-union
7	23	F	Traffic accident	No	No	Conservative	Non-union
8	18	M	Traffic accident	GIIIA	No	MIPO + D + I	Non-union
9	21	F	Traffic accident	GI	No	D + I + Conservative	Non-union
10	34	M	Traffic accident	No	No	Conservative	Non-union
11	74	F	Fall	No	No	Conservative	Non-union
12	54	M	Fall	No	After initial trauma	Conservative	Non-union
13	34	F	Traffic accident	No	No	MIPO	Non-union
14	55	F	Fall	No	No	Conservative	Non-union
15	64	M	Direct trauma	No	No	Conservative	Non-union

M male, *F* female, *G* grade, *MIPO* minimally invasive plate osteosynthesis, *D* debridement, *I* irrigation

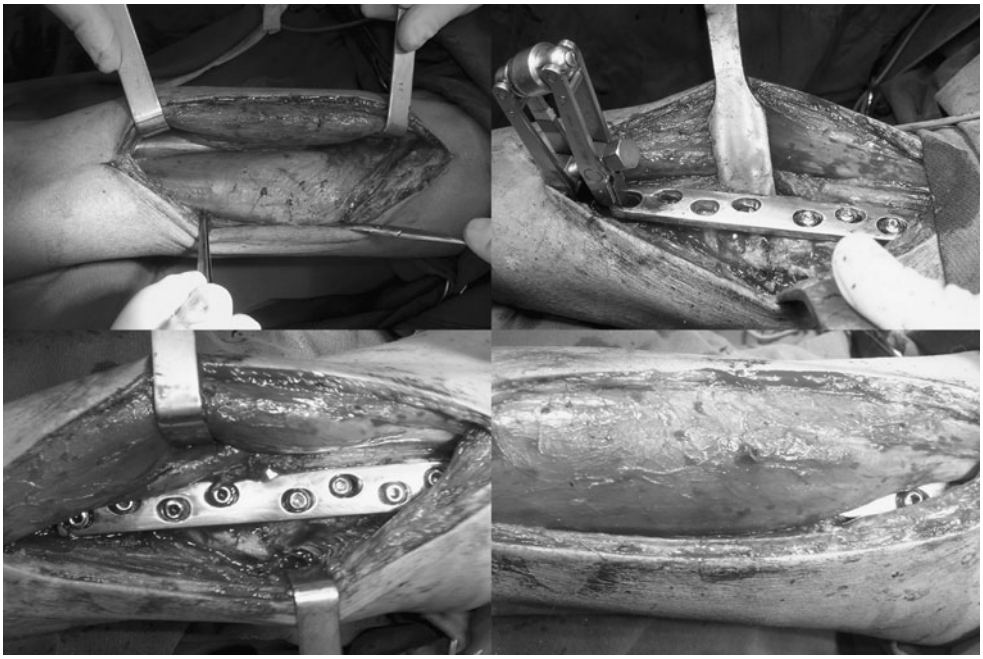

Fig. 1 Intraoperative view of anterior plating of patient number 5. *Top left* interval between biceps and brachialis muscles, *top right* DCP plate on the anterior surface of the humerus with external tension device and bone decortication, *bottom left* plate and screws, *bottom right* final view

After identifying the space between the biceps brachialis and brachialis muscles, the lateral cutaneous nerve of the forearm (a muculocutaneous nerve branch) was visualised and protected medially. Splitting of the brachialis muscle was performed longitudinally throughout its lateral third. Traumatic manipulation of the soft tissues and bone devitalisation were avoided. The non-union was treated as described by Phemister and Judet [3] and the implant was placed over a thin layer of soft tissue between the bone and plate. The DCP was placed on the anterior face of the bone and fixed to one side of the fracture, and an external tension device was attached (Fig. 1).

Fig. 2 One-year postoperative radiography of patient number 4. *Left* panoramic lateral view, *right* lateral view with zoom showing fracture healing

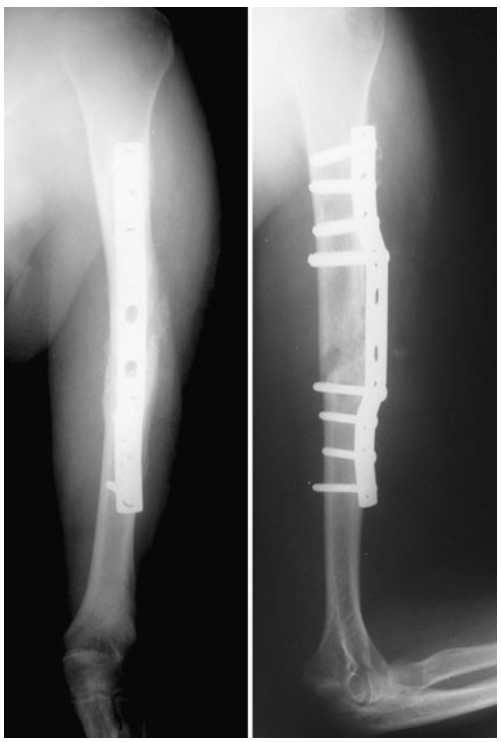

Fig. 3 Case number 15. Final postoperative radiography of a wave plate osteosynthesis

With a well-vascularised non-union, which usually occurs after the failure of conservative treatment or after surgical treatment with the MIPO technique, conventional osteosynthesis was performed with a straight plate and compression. With a poorly vascularised non-union, which occurs after open fractures or soft tissue interposition, we performed wave plating with a tricortical graft [17, 27]. The decision regarding the type of plate to use was made intraoperatively based on the surgeon's experience and, preoperatively, based on the radiological and scintilographic aspects of the non-union. To avoid varus fracture deviation, the arm was positioned in 60 degrees of abduction at the moment of plating. The wound was closed without drains or external immobilisation. The operating time ranged from 60 to 90 minutes. There was no significant blood loss. All surgical procedures were performed by the first author.

Postoperative care followed the principle of early mobilisation. The patients were allowed to move the elbow and shoulder freely soon after surgery, and were encouraged to use the arm for daily activities, such as feeding and personal hygiene. The patients were followed up weekly for the first two weeks and then monthly to assess the range of motion of the shoulder and elbow joints. Callus formation and cortical continuity were observed on radiographs as evidence of radiological union.

Results

No infection or any other clinical complication developed. All three initial cases of radial palsy (related to initial trauma or closed treatment follow-up) were transient. Two patients had radial nerve palsy after the initial trauma and one developed a radial nerve deficit after closed reduction of the fracture. However, all three showed complete spontaneous recovery and all patients had normal neural function at the final follow-up. There were no iatrogenic neurovascular injuries.

All fractures healed within six to 18 weeks (mean, nine weeks; Figs. 2, 3 and 4). Callus formation and cortical continuity were observed on radiographs as evidence of radiological union. The clinical assessment revealed good

Fig. 4 Case number 7. From *left* to *right*: non-union; immediate postoperative anteroposterior (AP) and lateral radiographs; six weeks postoperative AP and lateral radiographs of a conventional plate osteosynthesis

functional outcome in all patients who returned to work with no limitations on daily activities. One patient had some limitation, as shown in Table 2. Other postoperative aspects are summarised in Table 2.

Discussion

Humeral shaft fractures have a bimodal distribution. In the elderly, the predominant causes include simple falls or rotational injuries, whereas high-energy mechanisms are usually involved in younger patients, including motor vehicle accidents, assaults (direct blows or gun shots), falls from a height, and throwing injuries [1]. Most of these fractures are managed conservatively, which typically leads to a high rate of fracture union and good functional outcomes and is generally accepted as the best treatment for isolated closed fractures of the shaft of the humerus [16]. However, in some circumstances, internal fixation of such fractures is indicated. The choice of operative treatment depends on many factors. McKee [1] divided the indications into three categories: (1) fracture indications, (2) associated injuries, and (3) patient indications. While some of these indications are absolute, such as an associated vascular injury or an associated higher grade open wound, many are relative and both patient and fracture features must be considered before deciding on treatment [1].

Operative treatment involves ORIF using plates and screws, external fixation, or minimally invasive methods, such as intramedullary nailing or MIPO [28]. However, plate osteosynthesis remains the gold standard for the fixation of humeral shaft fractures and non-union, against which other methods must be compared [1, 3, 10]. As established classically, osteosynthesis with plates and screws should follow the tension band principles. It is generally accepted that the best face for placing a plate is the tension face of a long bone; for the humerus, this is theoretically the posterior surface [10].

Although the entire humeral shaft can be exposed through the anterolateral approach described by Henry [28, 29], without the need to visualise the radial nerve, the placement of a plate on the lateral face involves a potential risk to the nerve during the retraction of the soft tissues or by the implant itself, especially when it is placed over the middle to distal thirds of the shaft, where the radial nerve is in intimate contact with the bone. The reported global incidence of iatrogenic radial nerve injury is 12% when plates are placed on the lateral or posterior face of the humerus [4, 30, 31].

The radial nerve has a helical path. From the proximal to middle third, it runs posteriorly to laterally and, at the transition of the middle to distal thirds, it runs laterally to anterolaterally after piercing the lateral intermuscular septum. The only totally safe region (i.e, no risk of radial nerve injury) is the anterior aspect of the humerus. Because anatomical features facilitate free access to this safe corridor, recent techniques for minimally invasive surgery with a bridging plate (e.g. MIPO) have been developed, placing the plate on the anterior surface of the humerus [18, 22].

Table 2 Postoperative aspects

Patient	Radial palsy	Plate	Healing time (weeks)	Complications	Follow-up (months)
1	No	Straight	6	No	24
2	No	Wave	8	No	42
3	No	Straight	6	No	18
4	No	Straight	6	No	19
5	No	Straight	7	No	12
6	No	Straight	6	No	62
7	No	Straight	6	No	12
8	No	Straight	18	No	68
9	No	Straight	10	No	60
10	No	Straight	6	No	38
11	No	Straight	16	No	44
12	No	Straight	12	No	48
13	No	Straight	8	No	32
14	No	Wave	8	No	42
15	No	Wave	12	Elbow flexion deficit (10°); elbow varus (10°); shoulder elevation 120°, moderate deficit of shoulder MR	16

MR medial rotation

Since 2000, we have used the MIPO technique to treat humeral shaft fractures. When non-union develops, there is a dilemma: should the two incisions joined to remove the plate and a new posterior approach used, which seems senseless, or should it be placed on the lateral face of the humerus where the soft tissues and periosteum are untouched? This second option does not seem ideal because the anterior face already has the impression of a plate, which suggests that placement of a new plate in this same region avoids additional trauma to the vasculature of the humeral shaft. Because the radial nerve does not cross this region, in the cases where there is need for a wave plate with tricortical bone grafting, there is no risk of nerve compression by the implant, which is prominent at the site of the molding wave. There is also no risk of nerve damage if the implant requires removal or modification, making additional procedures safer if they become necessary.

As far as we know, Jupiter's [32] is the only report in the English literature in which the plate was placed on the anterior surface of the humerus via a medial approach. Although this approach is appropriate when a vascularised bone graft is used, we believe that it places the humeral vasculature at risk, because the nutrient artery enters the humerus medially, as described by Laing [33] and when there is no need for a vascularised bone graft, a simpler, easier, and safer approach is advised.

All of our cases healed in about the same time as other methods classically used for treating humeral shaft non-union, which leads us to believe that placing a plate over the tension face of the humerus is of little clinical significance. The biological benefits of less damage to the soft tissues via an approach that uses a plane between nerves certainly contributed to our good results. There was no infection and all cases achieved fracture union.

Anterior plating is a simple, safe, and effective treatment for humeral shaft nonunion. It does not require radial nerve visualisation or extensive soft tissue dissection, and the healing time is similar to that of other methods used for treating humeral shaft non-union. Given our results, we are confident in suggesting this alternative approach to osteosynthesis of humeral shaft non-union, in which the plate is placed on the anterior surface of the bone.

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