

Minimally Invasive Plate Osteosynthesis (MIPO) for Treatment of Delayed or Nonunion of Humerus Shaft Fracture: A New Technique

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Abstract

Introduction: The humerus shaft fracture (HSF) is a typical long bone fracture. Following non-surgical therapy, some patients experience delayed or non-union of the HSF. The most common treatment is open reduction and internal fixation (ORIF) with plates and bone grafts. However, substantial tissue dissection increases radial nerve damage and delays union. Because of its minimally invasive nature, the minimally invasive plate osteosynthesis (MIPO) method may be a suitable replacement technique. MIPO helps in protection of soft tissue and nerves in the area of the fracture.

Methods: All patients were treated with the MIPO method using bone graft implantation. A specific six-hole locking plate was used. Physical examinations and radiological studies were used to monitor the patients' progress. UCLA and the MEPS scoring system assessed shoulder and elbow function. The average follow-up period was six months.

Result: The mean age of patients was 39.8 years (19-73 years). The mean fracture site distance from the elbow joint was 12.1 cm. The mean maximum final rotation was 3.3 degrees. The last rotation alignment was within normal limits. No shortening was detected. Average scores were 35 for UCLA and 100 for MEPS. Radial nerve damage was not reported. Malunion, delayed union, or nonunion did not occur. Mean union time was 2.8 months.

Conclusion: MIPO technique combined with bone transplant causes micromotion at the fracture site, resulting in a better and faster union. Its minimally invasive nature also helps prevent iatrogenic injury to nerves and soft tissue. Less tissue manipulation and dissection help shoulder and elbow function progress more quickly and reduce the rate of malunion. We recommend this method in delayed union and nonunion of HSF patients for better outcomes and lesser complications.

Keywords: Nonunion, Humerus Shaft Fracture (HSF), Open Reduction and Internal Fixation (ORIF), Minimally Invasive Plate Osteosynthesis (MIPO), Radial nerve injury, Humeral diaphyseal nonunion.

Introduction

Humerus bone fractures account for 3% of all fractures which about 20% occur at the shaft of the humerus¹. Humeral shaft fracture (HSF) has a bimodal age prevalence. Most patients are women, with more than 65 years due to low energy trauma and a second rise in young men between the ages of 21 and 30 following high energy traumas. Malunion delayed union and nonunion are potentially devastating complications of the HSF management, regardless of the treatment approach. According to recent studies, the rate of nonunion after nonoperative control ranges from

14-29 %²⁻⁵. Nonunion of the HSF results from insufficient healing of the fracture site mainly due to biological potential⁶.

Open reduction and internal fixation (ORIF) with plate and bone grafting probably is the most common treatment for delayed union and nonunion of the humerus fractures following nonsurgical treatment⁷. Some of this method's complications include a high potential risk of damage to the surrounding tissue, particularly the radial nerve, extensive tissue dissection and vascular disruption as a result of fibrosis tissue

removal, an inappropriate cosmetic outcome, and high blood loss during surgery. Intramedullary nailing (IMN) is another method for treating nonunion of the HSF⁸. However, its use is limited in comparison to the other methods due to higher morbidity such as nonunion rate, shoulder impingement, implant failure, and a higher rate of re-operation⁹.

Minimally invasive plate osteosynthesis (MIPO) is used to treat humerus fractures by inserting a bridge plate through two small incisions on the anterior aspect of the humerus at the distal and proximal ends of the arm^{10, 11}. According to some studies, MIPO had better outcomes than traditional ORIF in nonunion of the humerus fractures. MIPO has less radial nerve injury, less tissue dissection, and shorter operative time^{12, 13}. Based on propounded reasons and the necessity of more protection of soft tissue in delayed union and nonunion of the HSF, we aim to use the MIPO technique in delayed union and nonunion of the HSF to evaluate and compare the outcomes with conventional ORIF.

Methods

All patients signed the testimonial form after receiving the explanation of the study. The study protocol has gotten authorization from the Ethics Committee of Shahid Beheshti University of Medical Sciences.

Study design and participants

It is a case series study accomplished at Taleghani hospital in 2019-2021. Six patients were included in the study who had trauma-induced delayed union and nonunion of the HSF following conservative (non-surgical) treatment. Delayed and nonunion after open surgery, proximal humerus fractures, extended fractures to joint, osteomyelitis, pathological fractures, and patients who did not sign the testimonial form were excluded. Three men and women were included, with a median age was 39.8 years. All of the fractures occurred in the patient's left arm. Based on the Orthopedic Trauma Association (OTA) classification, two patients have A3, and others have A1, A2, B1, and B2 fractures¹⁴.

Operation

A single surgeon performed all of the surgeries in a single unit. Patients were positioned in the supine posture, and the upper limb was placed on a table next

to the bed for procedures. After anesthesia and prep and drep, primarily, an iliac crest bone graft was taken through a 2 cm incision from the contralateral iliac crest in each patient. Then, under surveillance and protection of the radial nerve, we attempted to access the nonunion site by making a minor 3-5 cm oblique incision on the lateral side of the nonunion site. Subsequently, we cleaned and debrided the fibrotic tissues and tried to refresh the edges. Afterward, we make two 2-4 cm small incisions to access the Humerus bone. A proximal incision was made on the anterior surface of the arm between the anteromedial border of the deltoid muscle and the lateral border of the biceps muscle (distal part of the deltopectoral approach) (Fig 1-5). Then the deltopectoral tendon path was dissected 5 cm from the acromion process to reach the humerus bone. The distal 2-4 cm incision was made on the anterior surface of the arm between the lateral border of the biceps muscle and the middle part of the brachialis muscle, starting 2-3 cm from the elbow crease to the proximal. We can access the humerus bone by splitting the middle of the brachialis muscle. The muscular function would be unaffected due to the brachialis muscle's binary innervation. The forearm should be supinated, and the elbow bent to 70 degrees for the distal incision. Following the appearance of the periosteum at the distal incision, an extra periosteum tunnel should be constructed under the brachialis muscle from distal to proximal, as well as the same tunnel from proximal to distal by a thin periosteum elevator. It is never a good idea to use a Bennett to split a muscle because it raises the risk of radial nerve injury. A special plate (a locking plate with six holes) was slowly passed at the anterior surface and under muscles from proximal to distal through these two minor incisions (Fig 4). Subsequently, two or three screws were used in the proximal incision and two or three screws in the distal incision to fix the plate on the Humerus bone. This method eliminates the need to fully open the nonunion site and dissection the soft tissue and bone periosteum. This method allows for adequate biological milieu and vascularization while avoiding harm to the radial nerve, which may be attached to the humerus bone. The cancellous iliac bone graft was then inserted via a surgical incision on the lateral side of the nonunion site with the protection of the explored radial nerve. We are optimistic that this auto bone graft would improve the rate of the union. In patients with high radial nerve

palsy (HRNP), neurolysis operation and radial nerve evaluation were done to free up some space for the radial nerve and, if necessary, repair or graft it to protect the radial nerve from entrapment in future callus formation. Muscle fibers were used to cover the nonunion site and bone graft, creating a muscle barrier between the nerve and the nonunion site. Then the subcutaneous and dermal tissues were sutured together. There will be no need for a brace or splint. The day after surgery, movement of the shoulder and elbow joints begins.

Following surgery, the patients were visited at the end of the second week and then monthly to assess union and complications using a physical examination and radiologic investigations. Union is defined as the absence of pain at the fracture site and the trabecular bone formation in three of the four cortexes. Upon the surgery, radiologic examinations paired with computer software were used to assess malalignment in the anterior-posterior (sagittal) and the medial-lateral

(coronal) planes, and the maximum degree was recorded as the final union angle. A different surgeon measured range of motion, elbow, shoulder function, and nerve and vascular tests at each appointment. The University of California Los Angeles (UCLA) shoulder score and the Mayo Elbow Performance Score (MEPS) were used to measure shoulder and elbow function in this study. The UCLA shoulder score assesses pain, function, active forward flexion, forward flexion strength, and patient satisfaction. The MEPS score evaluates pain, range of motion, stability, and elbow joint function¹⁴.

Results

All Characteristics of the study population were shown in Table 1.

Table 1. Demographic characteristics of patients

patients	age	sex	Time from fracture (week)	Union time (months)	Fracture site from elbow (cm)	UCLA	MEPS	OTA	Operation time (minutes)
1	71	female	56	2	12.5	35	100	B1	180
2	21	male	14	3.5	11.3	35	100	B2	180
3	19	female	9	2	10.8	35	100	A3	180
4	73	female	5	3.5	17	35	100	A1	60
5	31	male	72	4	10	35	100	A3	75
6	24	male	9	2	11.2	35	100	A2	240

The fracture mechanism in our patients was a pedestrian-car accident in three cases, a fall in two cases, and a motor vehicle accident in one case. The average distance between the distal point of the fracture and the center of the capitulum in lateral radiographic view was 12.1 cm.



Figure 1: Preoperative radiograph

All procedures were performed by the same plate. The average surgery took 140 minutes. The mean coronal malalignment was 2.1 degrees, and the mean sagittal malalignment was 0.6 degrees based on the first post-operative radiological examinations (on the surgery day), and no shortening was identified. Five patients had no rotational deformity based on physical examination of internal and external rotation of the shoulder. Because of the coincidence of the shoulder dislocation with HSF and Hill-Sachs lesion formation in one patient, the humerus distal part was stabilized in 20-degree external rotation relative to the proximal portion of the humerus. It prevents engaging Hill-Sachs to the posterior glenoid rim in external rotation, and follow-up studies revealed a 20-degree limitation in internal rotation. Average scores were 35 for UCLA and 100 for MEPS.

Radial nerve injury was discovered during surgeries in 5 patients with preoperatively HRNP, and neurolysis was

performed as described. Radial nerve repair was performed on one patient due to a 20% rupture and severe contusion in the radial nerve. During follow-ups, the radial nerve sensory and motor function were entirely regained in all patients. The average length of union service was 2.8 months. (Table 2).

Table 2- Result of malalignment subsets.

patients	Malalignment (sagittal)	Malalignment (coronal)	Malalignment (rotational)
1	0	5.5	0
2	0.5	1	0
3	3	2	0
4	0.5	0	20
5	0	2	0
6	0	2.5	0



Figure 1: Small incisions of surgery.



Figure 2: Appearance of surgical scars.



Figure 3: Final postoperative radiograph.



Figure 4: Left: Conventional plate, Right: Plate design for MIPO.

Discussion

Long bone diaphysis, such as the humerus shaft, has a higher rate of delayed union and nonunion than other parts of the bone. Damage to the periosteum and surrounding tissues due to extensive surgical dissection, which is inevitable in ORIF, is a proven cause of delayed union and nonunion. Because of anatomical changes, bone callus, and fibrosis formation, the damage rate in delayed or nonunion may be significantly higher. Notwithstanding significant tissue injury and risk of radial nerve damage, ORIF is the conventional method for delayed or nonunion in HSF^{7,15}. IMN is another method for the treatment of nonunion of the HSF^{8,9}. Based on some studies, IMN is a better approach due to its less invasive nature. This approach is superior to ORIF because it has fewer surgical consequences such as radial nerve injury, operative time, intraoperative hemorrhage, and a quicker recovery period¹⁶. According to other studies, IMN in nonunion of the HSF had a higher rate of implant failure, intraoperative fracture comminution, re-operation, shoulder impingement, and restriction of shoulder movement^{9,17,18}.

In some studies, the MIPO has been used on HSF and has shown better outcomes than the traditional ORIF. In our study, we used the MIPO technique in patients who, following a nonsurgical treatment, experienced delayed or nonunion of the HSF. In 2016, a meta-analysis of nine studies evaluated ORIF with MIPO in humerus shaft fractures. Although the union rate, union duration, and elbow and shoulder function were the same in this study, the operation time and radial nerve injury were reduced in the MIPO group¹². In another study, Roberto et al conducted MIPO on one patient with HSF nonunion. They used the MIPO technique to fix the bone and an arthroscopic burr to clear the fibrous tissue at the nonunion site. The bone graft, which was sourced from the iliac bone, was placed under a fluoroscopic guide, and the union was achieved in three months¹³. In 2019, Suda et al. published their results of two patients with HSF nonunion treated with the MIPO technique without using a bone graft. Union was established after one year. Nuclear scintigraphy was used in their study, and enhanced absorption at the fracture site was discovered. They hypothesized that rotational instability is the primary cause of nonunion in the humerus, and there is enough biological activity around the fracture site to

avoid using bone graft⁷. In 2012, Roberto et al. conducted the MIPO method on 15 patients with nonunion using two small anterior incisions. In 12 cases, there was a gap at the fracture site, indicating atrophic nonunion, so they used an iliac crest bone graft, and after three months, all of the patients were entirely recovered with no complications such as infection, radial nerve injury, or screw failure. The use of bone graft was suggested, in this study, based on the atrophic or hypertrophic state and the size of the gap in the radiological investigation⁶.

This procedure doesn't necessitate the use of expensive or difficult-to-access equipment such as a nuclear scan, arthroscope, or burr. Burr isn't always available in clinics, and its usage near the humerus shaft may cause radial nerve damage. Direct vision of the humeral bone has also reduced the need for radiologic examinations such as the C-arm during surgery. This graft is inserted at a nonunion site under direct vision through a small incision without extensive dissection. Although opening the nonunion site and altering the biological environment would disturb the MIPO concept for bone healing, the usage of bone grafting in nonunion of HSF may overcome its disadvantages. UCLA and MEPS scores were used to assess shoulder and elbow function. Patients' joint function was regained quickly after surgery due to less manipulation during surgery. Allende et al., in nine patients, used the MIPO technique through a lateral approach with two incisions, one in proximal lateral trans deltoid and the other in distal humerus shaft by radial nerve exploration. Union was obtained at a mean of 4.8 months¹⁹. Contrary to this study, an anterior method was used to stabilize the bone in our research. The lateral approach increases nerve damage. It can easily injure the axillary nerve in the proximal incision and damage the radial nerve during distal dissection and plate placement on the lateral side of the humerus shaft. In our study, a bridging plate with three locking holes was used at the two ends of the plate to facilitate plate insertion in the MIPO technique, reduce tissue growth through the multiple holes in the conventional plate designs, and expedite plate removal. In this technique with this plate, there is a micromotion in the fracture site without tissue manipulation, which helps to improve the histological function of bone, ameliorating the microvascular environment, obtaining better and faster union, and decreasing device failure in these patients. As previously stated, this procedure

reduces radial nerve injury during surgery and allows us to neurolysis and explore the radial nerve in HRNP patients. Direct reduction reduced the risk of malunion in our patients' follow-ups.

Conclusion

For orthopedic surgeons and patients, delayed or nonunion of the HSF are challenging conditions. According to our findings, the use of the MIPO technique combined with open bone grafting is a safe and effective treatment for HSF nonunion and delayed union. This approach involves micromotion at the fracture site, which leads to faster union. Its minimally invasive nature aids in the prevention of iatrogenic nerve and soft tissue injury. It results in less bleeding and a more pleasing cosmetic effect. Using a special plate with fewer holes facilitates plate extraction while causing minimal tissue damage and device failure. We recommend using this method in delayed union and nonunion of the HSF patients. More studies such as an RCT comparing conventional approach and MIPO with more sample size are warranted.

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Conflict of Interest Disclosures

None.

Funding Sources

None.

Authors' Contributions

All authors contributed in this study equally.

Ethical Statement

All patients signed the testimonial form after receiving the explanation of the study. The study protocol has gotten authorization from the Ethics Committee of Shahid Beheshti University of Medical Sciences.

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