

RESEARCH ARTICLE

Outcomes of the Pin and Plate Technique in Complex Fractures and Nonunions of Distal Humerus

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Abstract

Objectives: This study investigates outcomes and complications of the pin and plate fixation technique, which was suggested for distal humerus fractures. It also reports the results of its application in nonunions for the first time.

Methods: Forty-nine fracture and 17 nonunion cases who underwent surgery using the technique and were followed for at least 18 months were assessed through the range of motion (ROM), Quick Disabilities of the Arm, Shoulder, and Hand Score (Quick-DASH), Mayo Elbow Performance Score (MEPS), four-category verbal rating scale (VRS-4), and complications.

Results: At the last follow-up, the mean scores of flexion, extension deficit, supination, and pronation ranges in fracture cases were 116.7, 22.9, 90.0, and 90.0 degrees, respectively. These values in nonunion cases were 112.2, 26.4, 86.7, and 85.5 degrees, respectively. The average ROM in fracture cases was 93.8, while it was 85.8 degrees in nonunion cases. The mean Quick-DASH in fracture and nonunion patients were 25.2 and 31.1, respectively. According to the MEPS, 77.5% of fracture and 64.7% of nonunion patients had excellent and good results. In fracture cases, the mean scores of VRS-4 at rest, light activity, and hard activity were 1.3, 1.8, and 2.3, respectively. These values in nonunion cases were 1.8, 2.2, and 2.5, respectively. The most common complications were device prominence and ulnar neuropathy.

Conclusion: An acceptable union rate and proper elbow function can be expected by using this technique. Owing to the promising results of this study, further high-quality studies are recommended. Hereby this technique is called Persian Fixation.

Level of evidence: IV

Keywords: Fracture fixation, Humeral fractures, Humerus, Humerus nonunion, Orthopedic fixation devices

Introduction

Distal humerus fractures account for about 2% of all adult fractures and 30% of humerus fractures.^{1,2} It is more common in young males due to high-energy trauma and old females with osteoporosis due to falls.³ Treatment goals include proper joint function, normal limb alignment, and 30-130 degrees of range of motion (ROM).^{1,3,4} The treatment is difficult and challenging, and complications are common.¹ Currently, surgical fixation is

the standard treatment, with 86% of the results being good and excellent.⁵ In the low distal fracture line, comminution at the fracture site, or poor bone quality, fixation with conventional methods will be difficult or impossible.⁶

Nonunion incidence has been reported to be 2%-10% after distal humerus fracture.⁷ Several surgical techniques have been performed for the treatment, including open reduction internal fixation (ORIF) with plate and screw,

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external fixator, joint replacement, allograft reconstruction, arthrodesis, and resection arthroplasty.⁸ However, commonly associated problems, such as poor bone quality, small articular fragments, and inadequate local exposure, make distal humerus nonunion management more challenging.^{7,9}

So far, several novel methods have been proposed to fix distal humerus fracture and nonunion.^{1,9} Kamrani et al. have introduced pin and plate fixation as a new fixation technique in very low and/or comminuted distal humerus fractures and in cases of osteoporotic bone to achieve proper stability and early elbow movements.^{10,11} In the present study, the results and complications of this technique in patients with fractures or nonunions of the distal humerus were investigated. This study reported the results of the application of the pins and plate fixation in nonunions for the first time.

Materials and Methods

Study design and setting

A retrospective study was enrolled to determine the pin and plate fixation technique results and its complications on patients with fractures or nonunions of distal humerus bone from March 2005 to June 2019. Patients from the previous two studies^{10,11} were included in this study, provided they had a new follow-up.

The Ethics Committee of Tehran University of Medical Sciences, Tehran Iran, approved the study protocol with an approval number of IR.TUMS.CHMC.REC.1398.127.

Patients

All sequential patients presenting to Shariati Hospital, Tehran, Iran, with low distal humerus fracture or nonunion, who underwent surgical fixation by the pin and plate method, were included in the study, provided that the distal growth plate had been closed and each patient at the report time had been followed for at least 18 months. Nonunion was defined as a fracture persisting for at least 9 months without healing signs for 3 months. Diagnosis of nonunion was by plain radiographs, and in the case of equivocal exams, a computed tomography scan was applied. On the other hand, patients with pathologic fractures, open fractures, associated neurovascular injuries, infected nonunion, and those with inadequate follow-ups (<18 months) were excluded.

Assessments

For all patients studied, plain X-rays were taken preoperatively, 0, 3, and 12 months postoperatively, and on the last visit.

Demographic data (e.g., age, gender, dominant hand, smoking, and underlying disease), injury mechanism, involved side, fracture classification according to the AO classification system,¹² surgical technical points, information on surgery results, and complications were retrospectively collected from the institution information system and patients medical records. The surgery types included pin and plate fixation alone or in combination with Tension Band Wiring (TBW). The outcome measures included ROM; Quick Disabilities of the Arm, Shoulder, and Hand Score (Quick-DASH); and Mayo Elbow Performance Score (MEPS).^{13,14} Based on the MEPS, scores below 60

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were considered poor results, 60-74 were fair results, 75-90 were good results, and above 90 were excellent.¹⁴ Surgical complications included device prominence, infection, olecranon bursitis, failure of the union (radiologically diagnosed) or malunion (union in an abnormal or faulty position; radiologically diagnosed), pin-related problems, stiff elbow, and neurological problems (loss of sensory or motor function of the nerve for more than 48 h continuously).¹⁵ Patients reported their pain severity by the four-category verbal rating scale (VRS-4), with 0, 1-4, 5-7, and 8-10 scores indicating no, mild, moderate, and severe pain, respectively.¹⁶

Surgical technique

The pin and plate fixation was done according to the technique previously described by Kamrani et al. Briefly, through a posterior midline incision, after creating skin flaps and securing the ulnar nerve, by using chevron olecranon osteotomy, the fracture fragments were exposed, reduced, and secured transversely to each other by 0.054 or 0.062-inch K-Wires, and the end of the pins was bent over the bone of distal humerus to take the contour of this part of the bone. Afterward, to prevent the pins from pulling out, they were placed under the reconstruction plate, transversely fixed on the humerus with two screws at a 3- to 4-cm distance from the fracture line [Figures 1, 2].¹⁰



Figure 1. Left, low distal humerus nonunion X-ray. Center and right, post-operative X-rays



Figure 2. Fixation of the nonunion in Figure 1 with the pin and plate technique

This technique can be done in two ways: Delta and L methods. In the Delta method, about one-third of the pin length comes out of the opposite cortex, and the pin bends on both the medial side and the lateral side of the elbow. However, in the L method, the pin bends on the humerus from one side after involving the opposite cortex.¹¹

Active elbow motion began on the day after surgery. Gentle passive movements were performed by a physiotherapist after 2 weeks, and if necessary, passive physiotherapy was performed more aggressively after 6

weeks.

Statistics

The statistics were calculated using IBM SPSS statistics 25 (IBM corporation, Armonk, NY, USA). For statistical analysis, the categorical variables were presented as the number and percentage of patients, while continuous variables were reported as mean \pm standard deviation (SD). Statistical analyzes were performed to investigate the relationships of gender, age, smoking, diabetes (all by using independent samples t-test), fracture mechanism, fracture classification (both by using one-way ANOVA), and number of physiotherapy sessions (using regression) with outcomes (e.g., ranges of flexion, extension deficit, supination, and pronation), Quick-DASH, MEPS, ROM, and VRS-4 at rest, light activity, and heavy activity. Chi-square was used to analyze the relationship of the incidence of complications (in general and each complication separately) with gender, being older than 40 years, diabetes, smoking, fracture mechanism, and fracture classification. In addition, independent samples t-test was employed to analyze the relationship of complications with age and the number of pins. A p-value of less than 0.05 was considered significant.

Results

Participants

By reviewing the records of outpatients and hospitalized patients during the mentioned period, 87 patients were treated with the pin and plate fixation technique, of which 4 cases were excluded due to death and 14 cases due to defects in the information of contacting the patient. Three patients were excluded from the study, one due to pathological fractures and two due to open fractures. Table 1 provides basic information about patients [Table 1]. This study assessed 49 patients with distal humeral fractures and 17 nonunion cases. The age of patients ranged from 18 to 75 years.

Table 1. Baseline patients' demographic information

| Item | Fracture cases (n=49) | Nonunion cases (n=17) |
|--------------------------|--------------------------|--------------------------|
| Mean age | 47.1 \pm 14.2 | 49.7 \pm 15.8 |
| Females | 25 | 10 |
| Right-handed patients | 42 | 13 |
| Diabetics | 4 | 3 |
| Smokers | 7 | 2 |
| Surgery on dominant hand | 25 | 11 |

The fracture classification in patients is given in Table 2 based on AO classification [Table 2]. The fracture mechanism in 21 fracture patients was due to an accident, 22 fracture patients had simple falls, and 6 fracture patients had a fall from a height. These numbers in nonunion patients were 6, 8, and 3, respectively. For 12 fracture and 5 nonunion patients, only the pin and plate fixation was performed. In 20

fracture and 6 nonunion patients, TBW was also used on one or both sides. In 13 fracture and 5 nonunion patients, anatomical plates were also used for column fixation in addition to the pin and plate fixation. The pin and plate fixation, TBW, and anatomical plates were all used in four fracture patients and one nonunion patient. A total of 14 pins with size 1, 47 pins with size 1.5, and one pin with size 2 with a mean of 4.43 (\pm 1.76) pins in each surgery for fracture patients were used. The mean number of pins used in each surgery of nonunion patients was 4.06 (\pm 2.35), of which 17 were size 1.5 and one was size 2.

Table 2. Fracture classification based on the AO

| Classification | A2 | B1 | B2 | B3 | C1 | C2 | C3 |
|--------------------|----|----|----|----|----|----|----|
| Number of patients | 2 | 2 | 1 | 3 | 12 | 13 | 16 |

The mean scores of the interval between the start of movement and surgery in fracture and nonunion patients were 2.86 (\pm 2.07) and 11.71 (\pm 5.75) days, respectively. None of the patients required immobilization for more than 7 days. The average numbers of physiotherapy sessions performed in fracture and nonunion patients were 36 and 22, respectively. The mean duration of follow-ups in fracture and nonunion patients were 59.6 (\pm 34.6) and 83.5 (\pm 33.6) months, respectively.

Outcomes

At the last follow-up, 17 patients had flexion of more than 130 degrees and an extension deficit of fewer than 30 degrees, 3 patients had no restriction in extension, and 36 patients had an elbow extension limit of fewer than 20 degrees [Table 3]. The mean scores of ROM in patients with a fracture and nonunion patients were 93.81 (\pm 22.01) and 85.82 (\pm 21.02) degrees, respectively.

The mean Quick-DASH in patients with fracture was 25.29, and in nonunion cases was 31.18. In fracture cases, 25 patients had excellent results, 13 had good, 10 had fair, and 1 had poor results, based on MEPS. These numbers in patients with nonunion were 5, 6, 3, and 3, respectively.

In females with fracture, the mean extension deficit was significantly lower ($P=0.02$), mean ROM was significantly higher ($P=0.01$), mean MEPS was significantly higher ($P=0.00$), and mean VRS-4 in heavy activity was significantly lower ($P=0.04$) than males. There was no significant difference between genders in terms of flexion, supination, and pronation ranges and Quick-DASH and VRS-4 at rest and in light activity in patients with fractures ($P>0.05$). Moreover, no significant difference between genders was observed in patients with nonunion in these variables ($P>0.05$).

Fracture patients aged 40 years and under had lower Quick-DASH ($P=0.00$), higher MEPS ($P=0.03$), and lower pain intensity at rest ($P=0.03$), light activity ($P=0.01$), and heavy activity ($P=0.01$) than older patients; nevertheless, there were no differences in ROM and ranges of flexion, extension deficit, supination, and pronation ($P>0.05$). Younger nonunion patients had more extension deficit ($P=0.01$) and

lower ROM ($P=0.01$) and did not differ from older patients in

Being a smoker did not worsen any of these outcomes ($P>0.05$), and having diabetes only led to a higher Quick-DASH ($P=0.04$) in patients with nonunion. Furthermore, fracture mechanism in fracture and nonunion patients and

terms of other variables ($P>0.05$).

fracture classification in fracture patients had no statistically significant relationship with any of these outcomes ($P>0.05$). In addition, the number of physiotherapy sessions in fracture and nonunion patients had no significant correlation with any outcome ($P>0.05$).

Table 3. ROM, Quick-DASH, MEPS, and VRS-4 at the last visit

| Item | Fracture | | | | Nonunion | | | | |
|------------|-------------------|--------------------|---------|---------|----------|--------------------|---------|---------|-----|
| | Mean | Standard deviation | Minimum | Maximum | Mean | Standard deviation | Minimum | Maximum | |
| ROM | Flexion | 116.73 | 15.48 | 70 | 140 | 112.29 | 11.94 | 95 | 130 |
| | Extension deficit | 22.92 | 11.57 | 0 | 60 | 26.47 | 19.98 | 0 | 70 |
| | Supination | 90.0 | 0 | 90 | 90 | 86.76 | 11.03 | 45 | 90 |
| | Pronation | 90.0 | 0 | 90 | 90 | 85.59 | 12.73 | 45 | 90 |
| Quick-DASH | 25.29 | 11.72 | 11.72 | 15 | 31.18 | 11.32 | 11.32 | 15 | |
| MEPS | 86.63 | 13.63 | 13.63 | 50 | 79.41 | 15.60 | 15.60 | 50 | |
| VRS-4 | Rest | 1.31 | 1.72 | 0 | 5 | 1.88 | 1.99 | 0 | 5 |
| | Light activity | 1.80 | 2.38 | 0 | 8 | 2.24 | 2.58 | 0 | 8 |
| | Hard activity | 2.33 | 2.46 | 0 | 8 | 2.53 | 2.45 | 0 | 8 |

ROM: Range of motion; Quick-DASH: Quick Disabilities of the Arm, Shoulder, and Hand Score; MEPS: Mayo Elbow Performance Score; VRS-4: Four-category verbal rating scale.

Complications

During the treatment process, 36 fracture patients and 14 nonunion patients developed at least one complication, 35 of which were in people over 40 and 25 in people over 50 years old. As follows, most of these complications were minor, and most of them improved during follow-up. In fracture and nonunion patients, gender, being older than 40 years, diabetes, smoking, fracture mechanism, and fracture classification (only in fracture patients) had no significant relationship with the occurrence of side effects, either in general or each complication separately ($P>0.05$). Additionally, age and the number of pins, both the total number and the number of each size, were not related to the occurrence of complications in fracture and nonunion patients ($P>0.05$).

Minor complications

All complications are listed in [Table 4]. The most common complication was device prominence as 28 fracture and 12 nonunion patients in total complained of this problem. The device was removed in 15 patients with fractures and 8 nonunion patients, all of whom complained of prominence. The time interval between the fixation surgery and the device's removal was 14.43 (range, 9-24) months in fracture patients and 18.87 (range, 6-36) months in nonunion patients. There was no statistically significant relationship between the occurrence of device prominence complications and the number of pins, both the total number and the number of each size, in patients with fractures and nonunions ($P>0.05$).

The second most common complication was ulnar neuropathy, observed in 15 patients with fractures and 7

nonunion patients. Except for two cases, the rest were transient and improved during the follow-up. In those two patients, partial injury remained until their last follow-up, which was 23 and 30 months postoperatively. In one case, after surgery, the patient developed weakness in the finger flexion and anterior interosseous nerve damage, which improved in follow-up without the need for surgery. A nonunion patient treated with the pin and plate fixation method and a lateral anatomical plate suffered radial nerve palsy after removing the device; the symptoms were relieved without surgery.

At the last follow-up visit, 52 patients reported no pain at rest, and none reported pain that disturbed their sleep. During the activity, 50 patients were painless, while 5 reported severe pain.

Table 4. Complications

| Complication | Fracture cases | Nonunion cases |
|--------------------------|----------------|----------------|
| Device prominence | 28 | 12 |
| Ulnar neuropathy | 15 | 7 |
| Superficial cellulitis | 7 | 2 |
| Skin complication | 0 | 2 |
| Olecranon bursitis | 1 | 1 |
| Heterotopic ossification | 1 | 0 |
| Failure of union | 0 | 2 |
| Olecranon nonunion | 0 | 2 |

Major complications

During follow-up, no nonunion was seen in patients with fractures. In two patients with nonunion, failure of the union

was diagnosed at follow-ups, both of which were successfully treated with triple plating and bone graft. In patients undergoing olecranon osteotomy, two nonunion and no delayed union were observed in nonunion cases, and no nonunion and delayed union in fracture cases. One patient with olecranon nonunion refused the treatment, and the other one was treated through plating with final good results and union of the osteotomy site. It should be noted that only in one patient anatomical plate was used to fix olecranon osteotomy, and in the other patients, TBW was used.

Discussion

In the current study, 49 patients with fractures and 17 patients with nonunion of the distal humerus, treated with the pin and plate fixation method, were studied with an average follow-up of 67 months. In the following, the results of this study are compared with previous studies, and its acceptability is discussed from various aspects.

Range of motion

The average elbow flexion in fracture patients was 117, and the extension deficit was 23 degrees. In a study by Theivendran et al. on patients with complex distal humeral fractures, the average flexion was 132 degrees, and the average extension restriction was 29 degrees after internal fixation using pre-contoured anatomic plates.¹⁷ Lustenberger et al. reported a median extension restriction of 15 degrees and a median flexion restriction of 5 degrees studying 39 patients with complex elbow fractures.¹⁸ The findings of a study by Patel et al. demonstrated an average elbow flexion of 115.8 degrees and an average deficit in the extension of 19 degrees after internal fixation of intraarticular distal humerus (AO type B & C) fractures.¹⁹ In this comparison, the cases' complexity was not considered, as 11 patients included in this study had articular surface fractures. Even so, most patients had a functional ROM.

Mayo Elbow Performance Score

In this study, the mean MEPS in patients was 84.77. In a study by Theivendran, the mean MEPS was reported to be 72.3, using a double-column parallel plating technique.¹⁷ In our study, 73% of the patients had excellent and good results. In another study conducted by Sanchez-Soletto et al. on 32 patients with complex distal humeral fractures using internal fixation with parallel-plate technique, 11 patients had excellent results based on MEPS criteria, 16 patients had good results, 2 patients had fair results, and 3 patients had poor results.²⁰ In the research by Patel et al., the mean MEPS was 87.9, and excellent and good results were reported in 90% of patients. However, this number was reported to be less than 80% using internal fixation with a principle-based parallel-plate technique in previous studies.^{19,20}

Complications

The most common complications associated with the pin and plate fixation technique in this study were device prominence (60%) and ulnar neuropathy (33%). In the study performed by Sanchez-Soletto, a deep infection was observed that resolved without removing the device.²⁰ There

was no infection in Theivendran's study, and 2 out of 16 patients complained of device prominence and pain. They could not remove all screws after removing the implant.¹⁷ Complications of using the anatomically pre-contoured locking compression plate system included nonunion, superficial infection, device prominence, and ulna neuropraxia.¹⁹ Vazquez et al. stated that 10.1% of 69 patients with intact ulnar nerve function before surgery developed symptoms of ulnar neuropathy immediately after the surgery.²¹ Fracture, surgery, edema, scar tissue, fibro-osseous tunnel thickening, or delayed ulna injury can cause neuropathy; therefore, the exact rate of ulnar neuropathy caused by distal humeral fracture has not been determined.³ According to previous studies, transposition during surgery is ineffective in preventing ulnar neuropathy, and it is better to use in situ release.²² It is concluded that device prominence and transient neuropathy complications were more prevalent in the technique performed in this study.

Pain

In this study, 56.1% of patients reported no pain, and 13.6% reported mild pain at rest. In Sanchez-Soletto's study, 28 of the 34 patients had no pain or complained of mild pain.²⁰ In the study conducted by Patel et al., 20 of the 31 patients did not report any pain, whereas 11 reported mild pain during daily activities.¹⁹

Nonunion as a complication

In this study, in none of the patients with fractures, nonunion was seen after the surgery. In a study by Theivendran et al. on 16 patients with complex fractures, no nonunion was observed after parallel pre-contoured anatomic plates (double-column parallel plating technique).¹⁷ However, in the study by Patel et al., which was carried out on 31 patients to evaluate open reduction and angular stable internal fixation using an anatomically pre-contoured locking compression plate system on treating type B and C fractures, two nonunion cases were reported.¹⁹ It seems that despite the distal and comminuted nature of the studied cases, the pin and plate method has provided sufficient stability for the union.

The results of studies have shown that the nonunion of the olecranon is up to 11.9%, and this complication has been greater in the use of TBW than in the plate.³ The failure of union of primary fracture or nonunion and olecranon nonunion was observed in two patients with nonunion after treatment.

Surgery methods in nonunion patients

In a study conducted by Donders et al. on 62 patients with nonunion and delayed union treated with internal fixation and bone grafting, the union was achieved in 51 patients. The mean union time was 6.8 months, the mean ROM was 86 degrees, 4 cases of infection were observed, and 7 cases of neuropathy were reported.²³ Another study examined 24 patients with distal humeral nonunion who underwent ORIF and noted that the union was found in all patients. The average ROM of these patients was 98 degrees, and 16

patients did not report any pain. In six patients, the device was removed due to the patients' discomfort.²⁴ The use of successful in the elderly with low bone quality, although the evidence has not been strong.^{25,26}

Cost

A significant advantage of this technique is its cost. In Figure 3, the tools used in the left figure cost \$3,250 (2,500+3×250) in Iran, while in the right one (i.e., using the pin and plate technique) cost \$57 (22+7×2.5+7×2.5) in Iran [Figure 3].

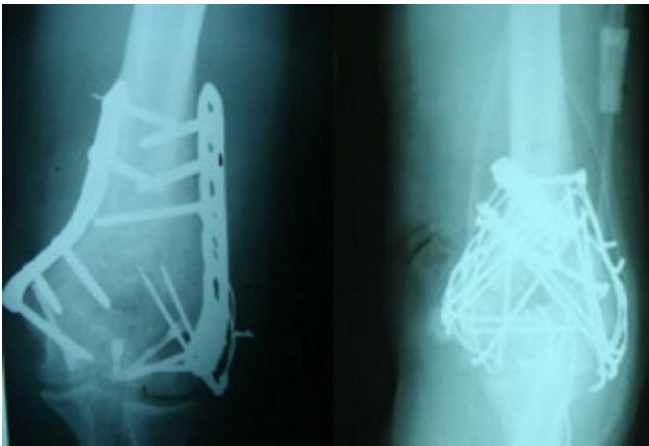


Figure 3. Left, \$3,250 spent on tools; Right, \$57 spent on tools

Limitations

Despite the advantages of this study, such as the complete collection of information and complete examination of complications, some limitations need to be mentioned. First, in this study, only the results of the pin and plate fixation technique were reported and this method was not compared with other fixation methods; therefore, it is not possible to evaluate it accurately and completely. Second, the study was

osteosynthesis by ORIF, joint contracture release, and autogenous bone-grafting in nonunion patients has been retrospective, and patient information was collected using registered files. More detailed information can be obtained by designing a prospective study.

Conclusion

The pin and plate technique is a surgical method that is easy for the surgeon and cost-effective for the patient and health system, resulting in acceptable and comparable ROM, elbow function, union rate, and complications. Hereby this technique is called Persian Fixation.

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