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Outcomes and complications after open reduction and internal fixation of distal humeral fractures with precontoured locking plates

Anne-Mari N. Rosenlund, MD[a,b,*], Endre Søreide, MD, PhD[a,b], Jan Erik Madsen, MD, PhD[a,b], Gunnar B. Flugsrud, MD, PhD[a,b], Brenton W. Douglass, BA[c], Kaare S. Midtgaard, MD[a,b,d]

Abstract

Objectives: The aim of this study was to evaluate functional and radiographic results after open reduction and internal fixation of distal humeral fractures using precontoured locking plates. Our main hypothesis was that patients older than 65 years have inferior outcomes compared with younger patients.

Methods: All patients treated for a distal humeral fracture with precontoured locking plates between 2006 and 2017 at a level 1 trauma center were identified. Included patients underwent a clinical examination, and new radiographs were obtained. Functional outcomes were evaluated using Quick Disability of the Arm, Shoulder and Hand, Mayo Elbow Performance Score, visual analog scale elbow satisfaction, and range of motion. Complications and reoperations were recorded.

Results: Fifty-seven patients with a median age of 60 years were included in this study. Median Quick Disability of the Arm, Shoulder and Hand was 14, and median Mayo Elbow Performance Score was 85. There was no difference in functional scores in patients younger than 65 years or 65 years or older. However, the median flexion–extension arc was 121 degrees in patients younger than 65 years and 111 degrees in patients 65 years or older ($P = 0.01$). The overall complication rate was 68%, and 24 patients had at least 1 reoperation. Ulnar neuropathy was the most common complication followed by reduced range of motion.

Conclusions: Operative management of distal humeral fractures with precontoured locking plates provides good functional outcome. The patient-reported outcomes were good, independent of patient age. The implant failure rate is low with precontoured locking plates; however, the complication rate remains high, and reoperations are common.

Level of Evidence: Level 4, retrospective study.

Keywords: anatomic locking plates, distal humeral fracture, distal humerus fracture, elbow fracture, fracture management, ORIF, precontoured locking plates

1. Introduction

Treatment of distal humeral fractures poses a great challenge to the orthopaedic surgeon. Distal humeral fractures have a bimodal age distribution consisting of young individuals associated with high injury mechanism and elderly who usually have sustained the fracture after a fall from a standing height.[1] Open reduction and internal fixation (ORIF) is the standard treatment for distal humeral fractures. These injuries are complex, and high complication rates have been reported after ORIF.[2,3] In osteoporotic patients, comminution and fragment deformation can be severe. Therefore, some authors have advocated for the use of elbow arthroplasty in the treatment of elderly patients who have sustained a distal humeral fracture with extensive articular disruption.[4,5] Although an elbow arthroplasty carries a risk for potentially devastating complications, it would allow the patients to have early mobilization, faster recovery, and more reliable final outcome.[4]

Historically, K-wires, one-third tubular plates, and reconstruction plates have resulted in high rates of implant failure and poor clinical outcomes.[6] The introduction of precontoured anatomic implants with locking screws gave hope that these problems would diminish.[7] Although precontoured locking plates have demonstrated superior biomechanical properties compared with K-wires, one-third tubular plates, and reconstruction plates, the literature on clinical outcomes after treatment with precontoured locking plates is limited.[2,7–11]

The aim of this study was to evaluate functional and radiographic results after ORIF of distal humeral fractures with precontoured locking plates with a minimum follow-up of 2 years. We hypothesized that patients 65 years or older at injury

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[a] Division of Orthopedic Surgery, Oslo University Hospital, Oslo, Norway, [b] Institute of Clinical Medicine, University of Oslo, Oslo, Norway, [c] University or Minnesota Medical School, Minneapolis, MN and [d] Norwegian Armed Forces Joint Medical Services, Oslo, Norway.

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**Corresponding author. Address: Anne-Mari N. Rosenlund, MD, Division of Orthopaedic Surgery, Oslo University Hospital, Kirkeveien 166, 0450 Oslo, Norway. E-mail: annemarirosenlund@gmail.com.*

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would have inferior outcomes compared with patients younger than 65 years.

2. Materials and Methods

This retrospective study was conducted at a level 1 trauma and tertiary referral center. After Institutional Review Board approval (No. 17/20333), all adult patients (16 years or older) with a distal humeral fracture treated between 2006 and 2017 were identified in the digital patient register. The list of identified patients was cross-checked with the digital surgical planning software.

For the final evaluation, patients who underwent operative treatment for distal humeral fractures with precontoured locking plates with at least 2 years of follow-up were included. Patients younger than 16 years at time of surgery, patients with bilateral distal humeral fractures, nonoperatively treated patients, and patients treated with other implants or methods such as arthroplasty, isolated screws, or nonlocking plates were excluded. Between 2006 and 2017, 3 patients presented with distal humeral fractures considered not repairable with ORIF. One patient was treated with elbow hemiarthroplasty (EHA) and 2 patients with total elbow arthroplasty (TEA) as a primary treatment. Our initial search identified 179 adult patients with distal humeral fractures. Thirty-five patients were deceased, and 37 patients were excluded, thus leaving 108 eligible patients who were invited to participate in this study (Fig. 1). Fifty-seven of 108 patients, 53% of eligible patients, agreed to participate in this study, and they all provided a written informed consent.

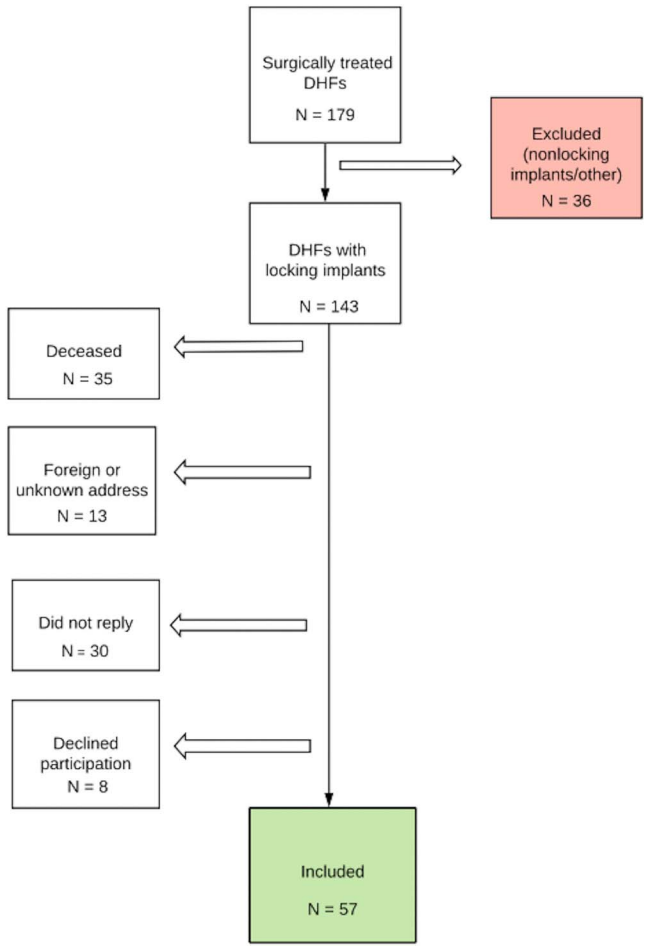

Figure 1. Flow diagram showing the recruitment of patients in this study.

Demographic data including sex, age at injury, injury mechanism, and surgery-related data were collected from the patient charts and supplemented at follow-up. High-energy injury mechanism was classified as a fall from >3 m, a motor vehicle accident, or a bicycle accident.

In our department, patients with distal humeral fractures are routinely operated under general anesthesia. The ulnar nerve is decompressed as part of the surgical approach but only anteriorly transposed if the nerve dislocates anteriorly after decompression. The fractures are reduced, and a precontoured locking plate is placed on each column to ensure sufficient fracture fixation. Temporary external fixation is used in high-energy or open injuries when the patient does not tolerate immediate ORIF.

All included patients were scheduled for a clinical follow-up. An investigator not involved in the surgical procedures evaluated the patients at follow-up. The patients completed the Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) questionnaire.[12] They rated their subject elbow satisfaction on a visual analog scale (VAS) with 100 indicating optimal satisfaction and 0 indicating no satisfaction. Data with particular emphasis on complications and reoperations were collected. A long-arm goniometer was used to measure range of motion (ROM) in both elbows. Flexion and extension were measured with the hand in supinated position. Supination and pronation were measured with 90 degrees of flexion in the elbow. A thorough neurologic examination was performed to evaluate sensory and motor function of the median, radial, and ulnar nerves. Finally, the Mayo Elbow Performance Score (MEPS) was calculated to evaluate elbow function.[13]

Preoperative radiographs and computed tomography images were classified according to the OTA/AO fracture classification,[14] and the fractures were categorized as extra-articular (OTA/AO type A fractures), partial articular (OTA/AO type B fractures), or intra-articular (OTA/AO type C fractures). New anteroposterior and lateral radiographs were obtained at follow-up to evaluate fracture union, post-traumatic arthritis, implant failure, and formation of heterotopic ossification (HO) (Fig. 2). Implant failure was defined by altered location of the screws and/or plates compared with the postoperative radiographs, leading to a displacement of more than 2 mm. Owing to the low interobserver agreement reported with the Broberg and Morrey system for classification of ulnohumeral arthritis, the binary classification system proposed by Lindenhovius et al[15] was used to categorize post-traumatic arthritis as none/slight or moderate/severe. HO was classified as present or absent on the AP or lateral radiographs. Two board-certified orthopaedic surgeons, who had not participated in the surgical treatment, reviewed all the images separately. Cases with disagreement were resolved after being reviewed by a third author (K.S.M.).

The data were analyzed using SPSS software (version 26; IBM, Armonk, NY). Continuous data were tested for normality with the Shapiro–Wilk test in addition to Q–Q plots and visual inspection of histograms. Normally distributed data were reported as means with standard deviation and tested with the Student *t* test. Non-normally distributed data were reported as median with range, and the Mann–Whitney *U* test was used to test continuous data. Categorical data were tested with the χ^2 test or the Fisher exact test (when sample size was <5). Statistical significance was defined as $P < 0.05$.

Figure 2. Anteroposterior (A) and lateral (B) radiographs of a 67-year-old male patient with an open C fracture of the distal humerus. After temporary external fixation, the fracture was stabilized with precontoured locking plates (C, D). At follow-up after 49 months (E, F), he had MEPS 100, QuickDASH 0, and a flexion–extension arc of 110 degrees (informed consent was sought and granted).

3. Results

Fifty-seven patients with a median age at injury of 60 years (range, 17–91 years) accepted the invitation to participate in this study. To test the main hypothesis, the cohort was divided into 2 groups: younger than 65 years and older than 65 years at injury (Table 1). At the time of injury, 38 patients were younger than 65 years and 19 patients were 65 years or older. The median age of the younger group was 50.5 (range, 17–64) years and 72 (range, 67–91) years of the older group.

Median time from injury to definitive fracture treatment was 3 days (range, 0–28 days). The distal humerus was approached using an olecranon osteotomy in 40 patients. Other surgical exposures used in these patients were paratricipital approach in 9 patients, triceps split in 1 patient, lateral in 1 patient, combined lateral and medial in 3 patients, a triceps-reflecting anconeus pedicle approach in 1 patient, and a modified posterolateral approach in 1 patient. The approach was not specified in the surgical report for 1 patient. Orthogonal plating was used in 44 patients, parallel plating was used in 3 patients, and 2 dorsal plates were used in 1 patient. A single locking plate with or without a combination with nonlocking plates or screws (OTA/AO type B fractures) was used in 9 patients.

The median follow-up time was 76 (range, 24–144) months. The median QuickDASH was 14 (range, 0–82), the median MEPS was 85 (range, 50–100), and the median VAS elbow satisfaction was 80 (range, 0–100). There were no statistically significant differences between the age groups for QuickDASH, MEPS, or VAS elbow satisfaction (Table 2). However, the older patients presented statistically significant reduction in extension ($P < 0.01$) and overall flexion–extension arc ($P = 0.01$) at the final follow-up. Eleven patients presented a flexion–extension arc <100 degrees at the final follow-up.

One or more complications were identified in 39 of 57 patients (68%). There were no statistically significant differences in complication rates between the older and younger cohorts ($P = 0.55$). Ulnar neuropathy was the most frequently identified complication (Table 3). At the final follow-up, a total of 15 patients had

TABLE 1

Demographics

Factor	Younger than 65 years	65 years or older	*P*
Sex			0.84
Male	13	6	
Female	25	13	
American Society of Anesthesiology classification			0.32
Grade 1	11	2	
Grade 2	15	10	
Grade 3	12	7	
Dominant side			0.45
Yes	18	7	
No	20	12	
Injury mechanism			0.18
Low energy	21	14	
High energy	17	5	
Fracture type (OTA/AO)			0.42
Extra-articular (A)	6	4	
Partial articular (B)	4	0	
Intra-articular (C)	28	15	
Open fracture	10	2	0.30

neuropathy (ulnar, median, radial, or a combination). Persistent radial neuropathy and median neuropathy were identified in 8 and 5 patients, respectively. Two patients had developed a drop hand: The first patient had undergone tendon transfer surgery to improve function, and the second patient had suffered a dissection of the carotid artery after the primary trauma, which resulted in a paralyzed upper extremity.

Twenty-four patients (42%) underwent at least 1 secondary surgical procedure; however, no difference in rate between age groups was observed ($P = 0.25$). A total of 21 patients had some or all implants removed, in most cases in a combination with other procedures (arthrolysis, ulnar nerve decompression). Five patients had implants removed from only the olecranon. In 13 patients, metal was removed from both the olecranon and the humerus, and 3 patients had implants removed from only the humerus. Six patients underwent decompression and/or transposition of the ulnar nerve because of entrapment. Of note, only 1 of the 8 patients who underwent arthrolysis was older than 65 years at injury. Elbow arthrolysis was indicated in another 3 patients in the older age group. However, this was not possible in 1 patient because of comorbidities while the 2 other patients declined surgery because they believed the risks outweighed the potential benefits of the procedure. One patient underwent total elbow arthroplasty 1 year after primary ORIF because of stiffness and pain.

New radiographs were obtained in all 57 patients. Presence of moderate or severe post-traumatic arthritis was not observed more frequently in patients with OTA/AO type C fractures ($P = 0.07$) (Table 4) and did not influence QuickDASH and MEPS at the final follow-up (Table 5). HO was present in 32 cases (3 type A fractures, 4 type B fractures, and 25 type C fractures). There was no statistically significant difference in observed HO based on fracture type ($P = 0.07$).

Implant failure was seen in 3 patients. In 1 patient with an ipsilateral shaft fracture of the humerus, the medial column of the already fixed distal humeral fracture displaced after nailing. The patient was reoperated with plate fixation on the medial column. The second patient was reoperated with a plate for the olecranon osteotomy after failure of the initial fixation (screw and tension band). In the third patient, one of the distal screws loosened and the patient developed an asymptomatic nonunion of the radial epicondyle.

4. Discussion

The main finding of this study was that the functional and radiologic outcomes after precontoured locking plate fixation of distal humeral fractures were good. Patients older than 65 years showed a reduced extension of 10 degrees compared with the younger patients. This was not reflected in the functional scores. Thus, our main hypothesis that operative management of distal humeral fractures yields an inferior functional outcome in older compared with younger patients was not supported. However, this study confirms previous studies demonstrating that operative management of distal humeral fractures is related to a substantial rate of complications and secondary surgeries.[4,8,16]

Compared with one-third tubular and reconstruction plates, precontoured locking plates have demonstrated superior biomechanical properties in fixation of intra-articular distal humeral

TABLE 2

Summary of Clinical Outcomes at Follow-Up

Parameter	Younger than 65 years	Range	65 years or older	Range	*P*
Days from injury to definitive surgery	3	0 to 28	4.5	0–13	0.38
Follow-up (months)	73	24 to 144	83	24–127	0.93
QuickDASH	15	0 to 82	13	0–66	0.96
MEPS	85	55 to 100	95	50–100	0.99
VAS elbow satisfaction score	80	0 to 00	85	35–100	0.33
Injured elbow					
Flexion (°)	137	110 to 150	135	105–146	0.45
Extension (°)	16	−5 to 45	21	0–60	<0.01
Supination (°)	85	0 to 108	90	60–105	0.50
Pronation (°)	80	0 to 90	78	45–100	0.39
Flexion–extension arc					
Median (°)	121	72 to 155	111	50–145	0.01
Median percent of uninjured side	81	55 to 102	76	33–91	0.06
Supination–pronation arc					
Median (°)	165	0 to 198	166	109–205	0.97
Median percent of uninjured side	98	0 to 119	97	68–107	0.23

All numbers reported as median values.

TABLE 3

Summary of Complications

Complication	Younger than 65 years N = 38	65 years or older N = 19	P
Ulnar neuropathy*	14	5	0.37
ROM <100 degrees	3	8	<0.01
Radial neuropathy*	9	1	0.14
Median neuropathy*	6	0	0.16
Deep infection	3	0	0.54
Implant failure	3	0	0.54
Malposition of implant†	0	3	0.03
Compartment syndrome	2	0	0.55
CRPS	1	1	1.00
Superficial infection	1	1	1.00
Nonunion	1	0	1.00

CRPS, complex regional pain syndrome.

* Transient and persistent sensory and motor neuropathies.

† Screws, K-wires, or cerclages that have penetrated the joint or irritated the ulnar nerve. The malpositioned implants were changed or removed shortly after the primary operation.

TABLE 4

Presence of Post-Traumatic Arthritis at Follow-Up Radiographs

Fracture Type	No or Sight Arthritis	Moderate or Severe Arthritis
Extra-articular (A)	10/10 (100%)	0/10
Partial articular (B)	2/4 (50%)	2/4
Intra-articular (C)	31/42 (74%)	11/42

The Broberg and Morrey rating was converted into a binary classification. The Broberg and Morrey scores of 0 and 1 were defined as no or slight post-traumatic arthritis, and the scores of 2 and 3 were defined as moderate and severe post-traumatic arthritis, respectively.

fractures.[17] The low rate of implant failure in this study suggests that the biomechanical superiority of precontoured locking plates translates to the clinical setting. Korner et al[18] described complications in 13 of 45 patients treated with ORIF using one-third tubular plates and 3.5-mm reconstruction plates. They reported implant failure to be the most frequent complication occurring in 12 patients. Furthermore, a 25% implant failure rate of nonlocking plates was reported by Frankle et al.[19] Both studies had cohorts with elderly patients with an average age of 73 versus 74 years. In younger patients with good bone stock, however, locking devices are probably of less importance, but the plates have to be rigid enough to allow early mobilization.[3]

The high complication rate reported in this study, and reported in previous studies (18%–53%), certainly points out that distal humeral fractures are challenging to treat.[4,8] Elbow stiffness, ulnar neuropathy, malunion, nonunion, and wound infection are the most commonly reported complications.[4,6] It is debatable whether elbow stiffness should be recorded as an outcome or a complication after distal humeral fracture management. Joint stiffness may be a result of the injury itself, the surgical procedure, and/or inadequate rehabilitation postoperatively. The literature is inconsistent in reporting elbow stiffness. In this study, a flexion–extension arc below 100 degrees was recorded as a complication, which may explain the somewhat higher-reported complication rate in this study compared with previous reports. While ulnar neuropathy is more commonly reported after distal humeral fractures, radial and median neuropathies are rare.[11,20,21] Thus, the observation of persistent radial neuropathy or median neuropathy in 8 and 5 patients, respectively, was somewhat surprising. In this study, 22 of 57 injuries were sustained after a high-energy injury mechanism. Four patients with persistent neurologic deficits had ipsilateral fractures. It is uncertain whether the high frequency of neuropathies can be attributed to injury mechanism or that the ulnar, radial, and median nerves were systematically examined at follow-up. In our study, including 57 patients with a median follow-up of 76 months, the incidence of neuropathies should be cautiously interpreted because there could be other reasons than the previous fracture causing this condition, for example, carpal tunnel syndrome. Regarding the high prevalence of decreased sensation in the part of the hand innervated by the radial nerve, no good explanation has been found. Furthermore, some patients have reduced sensory or motor function from the injury itself, whereas others develop symptoms after surgery. Swelling and scarring may also lead to ulnar neuropathy at a later stage. Vazquez et al[22] described the fate of the ulnar nerve after distal humeral fracture surgery; they found that 20% suffered from ulnar neuropathy, although only 10% had symptoms in the immediate postoperative period. At 1-year follow-up, another 7 patients had developed ulnar neuropathy. Routine anterior ulnar nerve transposition has not shown to reduce ulnar neuropathy in patients treated for distal humeral fractures with bicolumnar plate fixation.[21]

Operative management of distal humeral fractures is associated with secondary surgical procedures. Twenty-four patients included in this study underwent at least 1 additional surgery. Implant removal was performed in 21 patients; 45% of the patients operated with an olecranon osteotomy had the implants removed. Symptomatic implant removal after operative treatment of olecranon fractures is frequent, especially if tension band wiring for fracture fixation is performed.[23] Reflecting on the high rate of hardware removal for the olecranon osteotomy in our series, consideration may be given to alternative exposures for these fractures. Previous studies have shown that even C-type distal humeral fractures can be repaired adequately through a triceps split-type approach.[24,25]

Elbow stiffness is a common sequela of distal humeral fractures. Arthrolysis was performed in 8 patients, of whom only 1 patient was older than 65 years. Interestingly, 2 patients older than 65 years declined to undergo arthrolysis because they did not experience any functional limitations with their elbow. This may suggest that older patients may have a higher degree of tolerance for reduced elbow ROM. Six of the 8 patients who underwent arthrolysis achieved a flexion–extension arc >100 degrees, but only 3 patients regained a functional ROM (30–130 degrees).[26] Similar results were presented in the study by Schemitsch et al, in which the patients achieved a better extension–flexion arc after contracture release and implant removal. However, not all gained a functional ROM.[27] Schmidt-Horlohé et al[10] reported that 6 of 39 patients underwent subsequent arthrolysis, which was comparable with our cohort.

TABLE 5

Comparison of QuickDASH and MEPS in Patients With No or Slight and Moderate or Severe Post-Traumatic Arthritis

Outcome Measure	No or Slight Post-Traumatic Arthritis	Moderate or Severe Post-traumatic Arthritis	P
Median QuickDASH (range)	13 (0–82)	24 (2–66)	0.19
Median MEPS (range)	95 (50–100)	85 (65–100)	0.09

Although ORIF is considered the standard treatment of distal humeral fractures in young patients, primary elbow arthroplasty should be considered in elderly patients with severe intra-articular comminution and poor bone stock. Because more studies on EHA and TEA are being published, we see an increase in their use in acute distal humeral fracture management. It has been demonstrated that primary elbow arthroplasty is a reliable alternative with similar outcomes compared with ORIF.[5,28,29] In a randomized controlled trial comparing ORIF with small fragment plates with TEA in management of distal humeral fractures, patients treated with TEA required shorter operating time. Patients with TEA demonstrated quicker functional recovery represented by lower DASH score in the early postoperative period. Overall, TEA patients had better MEPS and better ROM, although the latter was not statistically significant.[4] In Europe, EHA has been used as primary treatment for distal humeral fractures in selected cases. Nestorson et al[5] reported medium-term outcomes after EHA and found comparable results with both ORIF and TEA. Whereas fractures with simple configurations in the elderly may be treated with ORIF, older patients with B3 or B3/C3 fractures with evident osteoporosis where reconstruction is less likely should be considered for primary arthroplasty.[4,28,30]

Moderate or severe post-traumatic arthritis was observed in 13 of 56 patients (23%). There were no statistically significant differences in QuickDASH score or MEPS compared with patients with no or slight arthritis. These findings should be interpreted with caution because of the limited number of patients. The same applies to the findings of HO.

This study has limitations that the reader should be aware of. Most important are the biases inherent to the retrospective study design, assessing a single surgical procedure without a control group or comparison with other treatment modalities. There was a high percentage of eligible study candidates who declined participation, which creates a selection bias. Distal humeral fractures remain one of the rare fracture types, reflected in the somewhat limited study sample. However, this study is based on data from a tertiary hospital, level 1 trauma center, and included patients with a minimum of 2 years of follow-up.

5. Conclusion

Operative management of distal humeral fractures with precontoured locking plates provides good functional outcome. The patient-reported outcomes were good, independent of patient age. Thus, precontoured locking plates seem to be a valid treatment option for most distal humeral fractures. Implant failure is low with these plates; however, the complication rate remains high, and reoperations are common. In selected patients, primary arthroplasty should be considered as a treatment option.

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