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CLINICAL RESEARCH

# Addition of a Medial Locking Plate to an In Situ Lateral Locking Plate Results in Healing of Distal Femoral Nonunions

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## Abstract

*Background*   Nonunion of the distal femur after lateral plating is associated with axial malalignment, chronic pain, loss of ambulatory function, and decreased knee ROM. The addition of a medial locking plate with autogenous bone grafting can provide greater stability to allow bone healing and may be used to achieve union in these challenging cases.

*Questions/Purposes*   We wished to determine (1) the proportion of patients who achieve radiographic signs of osseous union for distal femoral nonunions with an in situ lateral plate after treatment with addition of a medial locking plate and autogenous bone grafting, and (2) the frequency and types of complications associated with this treatment.

*Methods*   Between 2007 and 2013, we treated 22 patients for 23 distal femoral nonunions, defined as an unhealed fracture with no radiographic signs of osseous union at a mean of 16 months (SD, 13 months) after injury. During that time, we used a treatment algorithm consisting of treatment in one or two stages. The single-stage procedure performed in 16 aseptic nonunions with a stable lateral plate involved addition of a medial locking plate and autogenous bone graft. A two-stage treatment performed in seven nonunions with lateral plate failure involved placement of a new lateral locking plate followed by addition of a medial locking plate with autogenous bone graft at least 2 months after the first procedure. Of the 22 patients treated, 20 had a median followup of 18 months (SD, 6–94

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months). We defined osseous union by bridging bone on three of four cortices with absence of a radiolucent line or more than 25% cross-sectional area of bridging bone via CT.

*Results*   Twenty of the 21 nonunions attained radiographic signs of osseous union by 12 months. Six of the 20 patients experienced complications: one patient had a persistent nonunion; four patients underwent removal of symptomatic hardware; and one patient experienced skin breakdown at the bone graft harvest site.

*Conclusions*   A very high proportion of patients achieve union when using medial locking plates to treat distal femoral nonunions after lateral plating of the original injury. Addition of bone graft, staged reconstruction, and revision of the initial lateral plate is indicated when the nonunion is associated with fatigue failure of the initial lateral plate.

*Level of Evidence*   Level IV, therapeutic study.

## Introduction

Fractures of the distal femur account for 4% to 6% of femur fractures [1, 2]. Nonunion of the distal femur after initial surgical fixation is a relatively uncommon but potentially devastating complication [20]. The most common distal femoral fracture pattern progressing to nonunion involves metaphyseal comminution, with open fracture as the predominant risk factor for nonunion [9]. Distal femoral nonunions are associated with axial malalignment, chronic pain, loss of ambulatory function, and decreased knee ROM [6, 11]. Lateral locking plate fixation has become an accepted standard treatment for the initial fixation of fractures of the distal femur owing to the improved fixation and increased stiffness provided by the fixed angle construct [7, 14, 18]. Unfortunately, fractures of the distal femur may progress to nonunion despite reduction and fixation with a lateral locking plate [13]. Fixed-angle plating with bone grafting has emerged as the most-frequently used treatment for distal femoral nonunions, and excellent results have been reported [2, 6, 9]. However, specific injury characteristics such as extensive periosteal stripping, metaphyseal comminution, and bone loss may render the lone lateral implant inadequate for the duration required to achieve union [14]. Dual plating of distal femur fractures with a lateral plate and a medial plate has been used to improve fracture alignment and stabilization when a single plate has not been adequate [13, 19].

We believe the addition of a medial locking plate with autogenous bone graft to a distal femur nonunion after failed fracture treatment with a lateral locking plate provides greater stability for a sufficient time to allow bone healing. Failure to heal after one or more attempts at lateral plating may indicate a need for greater stability. However, to the best of our knowledge, a series of distal femur nonunions treated with dual locking plates has not been reported.

We therefore sought to determine (1) the proportion of patients who achieve radiographic signs of osseous union for distal femoral nonunions with an in situ lateral plate after treatment with addition of a medial locking plate and autogenous bone grafting, and (2) the frequency and types of complications associated with this treatment.

## Methods

### Study Design and Setting

Between April 2, 2007 and September 1, 2013, we treated 22 patients for 23 distal femoral nonunions at a mean of 16 months (SD, 13 months) after injury. The distal femur was defined as between the femoral articular surface at the knee and a distance of 5 cm above the metaphyseal flare. Nonunion was defined as an unhealed fracture with no clinical or radiographic signs of progression to healing, believed to have no chance for further healing without additional surgical intervention in the opinion of the treating surgeon [3]. Nonunion was confirmed by plain radiographs, CT, or by a combination of modalities, defined as an unhealed fracture with no radiographic signs of osseous union. During that time, we used a treatment algorithm consisting of treatment in one or two stages (Fig. 1). The single-stage procedure performed in 16 aseptic nonunions with a stable lateral plate involved addition of a medial locking plate and autogenous bone graft. A two-stage treatment performed in seven nonunions with lateral plate failure involved placement of a new lateral locking plate followed by addition of a medial locking plate with autogenous bone graft at least 2 months after the first procedure. The 22 patients represent all patients treated by us during the study period who had distal femoral nonunion associated with an in situ lateral locking plate. Of the 22 patients treated, two were lost to followup before radiographic signs of osseous union could be confirmed, and 20 patients had a median followup of 18 months (SD, 6–94 months).

All 22 patients underwent surgical treatment for the initial injury at outside facilities with a median of 2 (range, 1–7) prior surgical procedures per nonunion. Each patient's medical records and radiographic studies were reviewed and the following data were abstracted: age, sex, soft tissues at the time of original injury (closed vs open), date of injury and initial plating, other prior nonunion treatment, date of presentation for nonunion treatment, nonunion type (atrophic, oligotrophic, hypertrophic, infected), dates and descriptions of all surgeries, postoperative complications

**Fig. 1** The algorithm we used for treatment of distal femoral nonunion after lateral plating is shown.
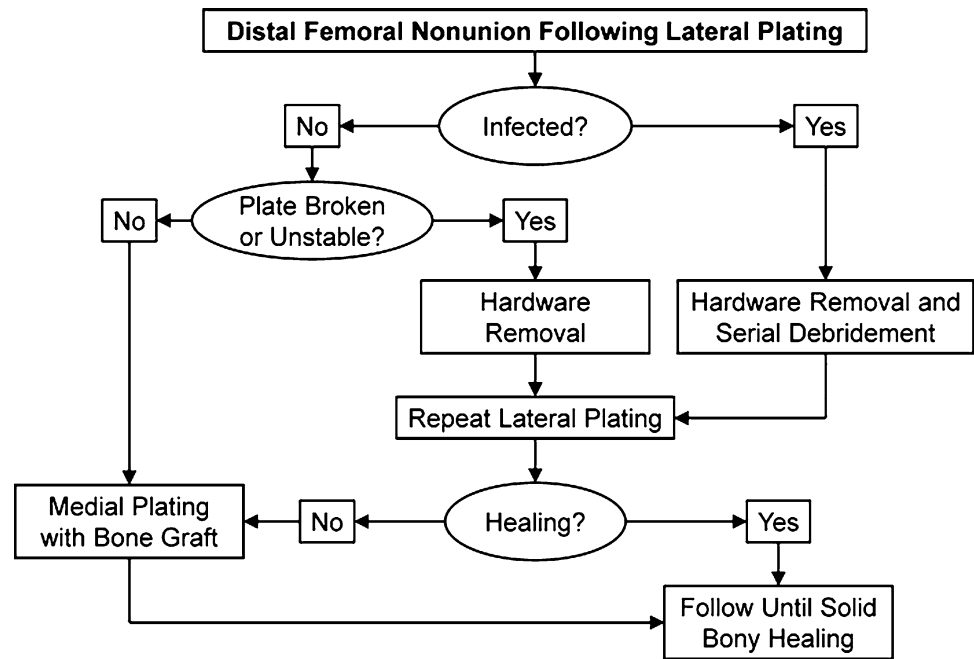


and clinical course, and final weightbearing status and use of assistive devices. Time to union could not be calculated because of inconsistent followup intervals, with many patients returning only after periods of several months between clinic visits. Therefore, we were unable to identify an exact time to union and could identify only that the nonunion had healed on a patient's return to the clinic, in all cases within 12 months from nonunion treatment.

This study was approved by our facility's institutional review board.

Participants/Study Subjects

There were 16 women and six men with an average age of 58 years (range, 35–83 years) who were referred to us at a median of 7 months (range, 0.5–60 months) after their initial injury (Table 1). Eighteen patients were referred to our center after the nonunion was established, whereas four were referred soon after fracture fixation for routine followup and their fractures subsequently progressed to nonunion. Twenty-one of the 23 nonunions were classified as atrophic, with no callus and radiographic signs of bone resorption at the injury site, and two (in Patients 9 and 19) were classified as oligotrophic, with no callus but no radiographic signs of bone resorption at the injury site.

The mean duration of nonunion, defined as the time from the initial fracture treatment to our first surgical nonunion treatment, was 16 months (SD, 13 months) (Table 1). Preoperatively, all patients had disability and unremitting pain. Sixteen of the patients were

nonweightbearing and six were partially weightbearing on the injured extremity. Thirteen patients used some type of assistive device to ambulate and nine were wheelchair bound.

The initial fracture was a closed injury in 13 patients (14 nonunions) with one patient having nonunion develop after a distal femoral osteotomy performed at an outside facility. Eight patients with nonunions initially had an open distal femoral fracture.

Four patients had prior surgical treatment of a distal femoral nonunion. Two of these patients had undergone repeat open reduction and internal fixation (ORIF) with a lateral locking plate, whereas the other two received repeat ORIF with autogenous bone graft. One patient who underwent autogenous bone graft had a subsequent revision ORIF with allograft and an implanted bone stimulator. Three patients had a periprosthetic nonunion above a TKA.

Description of Experiment, Treatment, or Surgery

Many of the patients in our cohort had a poor soft tissue envelope about the distal femur related to the severity of the initial injury or previous surgical dissection. No patient in this series had the medial and lateral plates implanted during one surgical session. If the in situ lateral plate was intact, a single surgical procedure to implant a large fragment medial locking plate was performed. If the in situ lateral plate had failed, we used a two-stage approach to reconstruct the nonunion. First, the in situ lateral plate was removed, with placement of a new lateral locking plate.

**Table 1.** Demographics, medical history, and ambulatory status of patients with distal femoral nonunion after lateral plating.

| Patient | Nonunion | Sex | Age* (years) | Nonunion duration (months) | Number of prior surgeries | Weightbearing ability* | Assistive device* | Medical history/comorbidities |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Female | 49 | 21.7 | 2 | Partial | Cane | Obesity |
| 2 | 2 | Female | 58 | 14.5 | 3 | None | Wheelchair | Hypertension, osteoarthritis, mood disorder |
| 3 | 3 | Female | 35 | 27.3 | 1 | None | Wheelchair | Infected fracture site; asthma, mood disorder |
| 4 | 4 | Female | 44 | 8.5 | 2 | None | Crutches | Asthma |
| 5 | 5 | Female | 51 | 3.6 | 3 | None | Wheelchair | Obesity, osteoarthritis, mood disorder |
| 6 | 6 | Female | 83 | 9.6 | 1 | Partial | Walker | Hypertension |
| 7 | 7 | Female | 48 | 26.7 | 7 | None | Wheelchair | Mood disorder |
| 8 | 8 | Female | 77 | 8.4 | 1 | None | Wheelchair | Hypertension |
| 9 | 9 | Male | 42 | 21.5 | 2 | Partial | Crutches | None |
| 10 | 10 | Female | 71 | 5.6 | 1 | None | Walker | Hypertension |
| 11 | 11 | Female | 44 | 3.2 | 3 | None | Crutches | Asthma, mood disorder |
| 12 | 12 | Male | 37 | 15.9 | 1 | Partial | Crutches | None |
| 13 | 13 | Male | 45 | 12.2 | 4 | None | Wheelchair | Obesity, type 2 diabetes, osteoarthritis, mood disorder |
| 14 | 14 | Female | 57 | 7.7 | 2 | None | Crutches | Hypertension |
| 15 | 15 | Female | 70 | 24.5 | 2 | None | Walker | Hypertension, osteoarthritis |
| 16 | 16 | Male | 73 | 7.9 | 3 | None | Walker | Infected fracture site; type 2 diabetes, Hypertension, CVD |
| 17 | 17 | Male | 44 | 61.1 | 4 | Partial | Crutches | Osteoarthritis |
| 18 | 18 | Female | 75 | 6.8 | 2 | None | Wheelchair | Hypertension, CVD, mood disorder |
| 19 | 19 | Female | 63 | 8.7 | 1 | None | Walker | Obesity, Hypertension, CVD |
| 20 | 20 | Male | 69 | 13.7 | 1 | Partial | Walker | Hypertension |
| 21 | 21 | Female | 63 | 7.7 | 2 | None | Wheelchair | Hypertension, CVD, multiple myeloma, asthma |
| 22[†] | 22 | Female | 79 | 23.3 | 2 | None | Wheelchair | Obesity, stroke, COPD |
| 22[†] | 23 | Female | 79 | 23.3 | 2 | None | Wheelchair | Obesity, stroke, COPD |

*Age, weightbearing status, and use of assistive device at presentation to our office; CVD = cardiovascular disease. COPD = chronic obstructive pulmonary disease; [†]Patient 22 had bilateral distal femoral nonunions.

After the soft tissues recovered, if progression to bony healing was slower than desired, the second stage consisted of medial plating and bone grafting.

A single-stage procedure was performed in 15 patients (16 femurs) who had no clinical or laboratory signs of infection, an apparently well-fixed and stable lateral locking plate, and a satisfactory soft tissue envelope (Table 2). This single stage involved careful dissection and elevation of the medial soft tissues with a medial parapatellar approach, packing the nonunion site with bone graft or bone graft substitute, and fixation with a large-fragment medial locking plate (4.5 mm Broad or 4.5 mm Narrow Locking Compression Plate [LCP®], Synthes, West Chester, PA, USA). The plate was intentionally not contoured to sit flush on the bone but rather was contoured to act as a wave plate so bone graft could be packed between the nonunion site and the undersurface of the plate (Fig. 2).

Eleven of these single-stage reconstructions received autogenous bone graft obtained from the posterior iliac crest, three received autogenous bone graft obtained from the contralateral femur using the Reamer-Irrigator-Aspirator (RIA) System (Synthes), one received bone graft obtained from both tibias using the RIA, one received demineralized bone matrix (Trinity™; Osiris Therapeutics, Baltimore, MD, USA), three early in the series (before 2009) received BMP-7 (OP-1™; Stryker Biotech, Hopkinton, MA, USA), and two received BMP-2 (Infuse®; Medtronic, Minneapolis, MN, USA) (Table 2). RIA was used rather than autogenous posterior iliac crest bone graft with patients who were morbidly obese (BMI > 35 kg/m²).

Seven patients (seven femurs) underwent treatment in two stages owing to fatigue failure of the lateral plate. In the first stage, all previous hardware was removed, the wound was thoroughly irrigated and débrided (the

**Fig. 2A–D** The presenting (**A**) AP and (**B**) lateral radiographs from an 83-year-old woman (Patient 6) who was referred with a distal femoral nonunion and no signs of progression to healing 9.6 months after lateral plating of a periprosthetic fracture sustained in a fall are shown. The patient's final (**C**) AP and (**D**) lateral radiographs 22 months after medial plating show solid bony union. The plate was intentionally not contoured to sit flush on the bone but rather was contoured to act as a wave plate so bone graft could be packed between the nonunion site and the undersurface of the plate.

nonunion site was not débrided) and a lateral locking plate (4.5 mm Broad or 4.5 mm Narrow LCP® (Synthes) was implanted. After adequate time was given for soft tissue healing and recovery from this first stage, and if bony healing progression was slower than desired (as was the case with all patients included in the current series), the patient underwent a second-stage procedure comprising implantation of a large-fragment medial locking plate as described above. These patients underwent the second procedure a median of 91 days (range, 60–394 days) after the first procedure. Four of these two-stage reconstructions received posterior iliac crest autograft, one received BMP-7 (OP-1™), one received posterior iliac crest and contralateral femoral autograft (RIA), one received contralateral femur RIA, and one received demineralized bone matrix (Trinity™) (Table 2).

One patient (Patient 9) had a deep culture specimen obtained during the first stage of surgical treatment (hardware removal and lateral locking plate) that was positive for *Staphylococcus epidermis,* and was treated postoperatively with a course of oral antibiotics. The deep culture specimen obtained from another patient (Patient 13) during our single-stage surgical treatment (medial locking plate) was positive for *Pseudomonas aeruginosa,* which was treated postoperatively with intravenous antibiotics by the infectious disease service. Neither patient had any

additional signs or symptoms of infection during or after our treatment. Two other patients (Patients 3 and 16) had been diagnosed with infections after their initial injuries and had been treated successfully before being referred to our center. These patients had no signs of infection during or after our treatment.

Statistical Analysis, Study Size

Radiographic union was determined by evidence of bridging bone on three of four cortices [12] with absence of a radiolucent line at the injury site, or more than 25% cross-sectional area of bridging bone via CT [3]. Fifteen of the 20 patients who completed followup had a CT scan, while the remaining five patients did not have a CT scan since their plain radiographs clearly showed signs of osseous union. Radiographic healing was determined independently of the treating surgeon (MRB) by one of two musculoskeletal radiologists (JCL and GVG). Clinical healing was determined by minimal or no pain and ability to bear weight on the affected lower limb. Descriptive statistics were used to summarize demographic and clinical variables.

## Results

Nineteen of the 20 patients (20 of the 21 nonunions), available for followup had attained radiographic signs of osseous union within 12 months after the medial locking plate surgery (Table 2). At the most recent followup, all 19 patients (with 20 nonunions) who had radiographic signs of osseous union were able to bear partial or full body weight on the injured extremity. Thirteen of the patients were able to ambulate without the use of any assistive devices, whereas five required a cane or walker. Two of these five patients required a wheelchair for longer distances. One patient (Patient 21) remained a wheelchair ambulator owing to multiple myeloma affecting her spine, unrelated to her distal femur injury.

Six patients experienced complications postoperatively (Table 2). One patient (Patient 11) with a persistent nonunion did not wish to have additional surgery but later presented with a broken lateral plate at 24 months after her dual-plating surgery. Four patients underwent removal of symptomatic hardware (two of the medial plate, two of the medial and lateral plates). One of these patients also had irrigation and débridement of a nonhealing eschar of the surgical incision (culture negative) and also underwent a quadricepsplasty to treat arthrofibrosis and improve knee ROM. One patient experienced breakdown of her posterior iliac crest harvest site while at a nursing facility and was

**Table 2.** Treatment, healing, and functional status of dual plating for distal femoral nonunion.

| Patient | Nonunion | Single- or dual-stage treatment | Bone graft* | Union in 12 months | Followup (months) | Final weightbearing ability | Final assistive device | Complications |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Dual | PICBG, BMP-7 | Yes | 40.8 | Full | None | |
| 2 | 2 | Single | RIA, BMP-2 | NA | NA | NA | NA | Lost to followup |
| 3 | 3 | Single | PICBG | Yes | 12.0 | Full | None | |
| 4 | 4 | Single | PICBG, BMP-7 | Yes | 93.6 | Full | None | Nonhealing surgical incision; knee arthrofibrosis; symptomatic medial and lateral plates |
| 5 | 5 | Single | RIA | Yes | 25.2 | Full | None | Symptomatic medial and lateral plates |
| 6 | 6 | Single | PICBG | Yes | 29.7 | Full | Walker (wheelchair for long distances) | |
| 7 | 7 | Single | PICBG | NA | NA | NA | NA | Lost to followup |
| 8 | 8 | Single | PICBG, BMP-2 | Yes | 59.9 | Full | Walker | Breakdown of PICBG harvest site |
| 9 | 9 | Dual | PICBG, RIA | Yes | 18.0 | Full | None | |
| 10 | 10 | Single | PICBG | Yes | 16.8 | Full | Cane | |
| 11 | 11 | Dual | PICBG | No | 23.8 | – | --- | Persistent nonunion, broken lateral plate |
| 12 | 12 | Single | RIA, BMP-7 | Yes | 34.8 | Full | None | |
| 13 | 13 | Dual | RIA | Yes | 31.2 | Full | None | |
| 14 | 14 | Single | PICBG | Yes | 88.8 | Full | None | Symptomatic medial plate |
| 15 | 15 | Single | PICBG | Yes | 12.0 | Full | None | |
| 16 | 16 | Dual | PICBG | Yes | 19.2 | Full | Cane | |
| 17 | 17 | Single | PICBG | Yes | 15.6 | Full | None | Symptomatic medial plate |
| 18 | 18 | Single | PICBG | Yes | 6.0 | Full | Walker | |
| 19 | 19 | Single | PICBG, BMP-7 | Yes | 9.6 | Full | None | |
| 20 | 20 | Dual | PICBG | Yes | 26.6 | Full | None | |
| 21 | 21 | Dual | DMB | Yes | 18.0 | Full | Wheelchair | |
| 22[†] | 22 | Single | RIA | Yes | 18.0 | Full | None (wheelchair for long distances) | |
| 22[†] | 23 | Single | DMB | Yes | 18.0 | Full | None (wheelchair for long distances) | |

* PICBG = autogenous posterior iliac crest bone graft. RIA = autogenous reamer-irrigator-aspirator bone graft; BMP-7 = bone morphogenetic protein-7; BMP-2 = bone morphogenetic protein-2; DMB = demineralized bone matrix; [†]Patient 22 had bilateral distal femoral nonunions; NA = not available.

treated successfully to closure with a wound vacuum device.

## Discussion

Nonunion of the distal femur is a severe problem that is associated with loss of ROM, pain, and decreased quality of life. These injuries frequently show bone loss and extensive soft tissue scarring [5]. Many treatment options have been described in the literature including external fixation, arthroplasty, retrograde intramedullary nailing, and ORIF with lateral fixed angle plating [2, 4, 8, 10, 11, 15, 16, 21]. We initiated the use of medial stabilization plating, grafting, and revision of lateral plating as needed in 2007 because we frequently observed motion at distal

femoral nonunion sites with varus/valgus stress (using fluoroscopy and direct observation at the nonunion site). Whereas lateral plating of the distal femur is an excellent treatment option for acute fractures, we believe many distal femoral nonunions require the added stability from dual plating to achieve successful union. We found that this approach reliably resulted in osseous union, although as one might expect in a series of complex, multiply operated patients, complications did arise in some patients treated according to this algorithm.

Our study is a retrospective case series of patients with distal femoral nonunion after fracture treatment with a lateral locking plate. All patients were treated by the same surgeon with a subspecialty practice in orthopaedic trauma and reconstructive surgery, so the results may not generalize to all surgeons. However, given that one surgeon (MRB) performed all of the surgical procedures and followups, we were able to obtain complete records and patient data to perform our analysis. Six patients received BMP in addition to autogenous bone graft with the medial locking plate, but it is unclear if this had any effect on the results. Our lack of functional outcomes is another limitation of the study, although all patients who achieved healing were able to bear full or partial weight on the affected limb and improved their ambulation status (except for one who was wheelchair bound owing to a chronic neurologic disease). Because many patients did not attend followups precisely as they were scheduled, and some missed interval followups, we are unable to calculate a specific time to fracture healing for our cohort.

Some studies regarding distal femoral nonunions have concentrated on ORIF with a fixed-angle device with or without autogenous bone grafting. Bellabarba et al. [2] reported that 20 of 20 patients achieved union after treatment with indirect reduction techniques, a fixed-angle device, and bone grafting in nine of the patients. Similarly, Gardner et al. [11] reported 97% of 31 patients achieved union when treated with a fixed-angle device, lag screw fixation, and bone graft augmentation. These clinical series highlight the excellent results achieved with fixed-angle plating and bone grafting. However, four patients in our study who previously had undergone revision ORIF with a fixed-angle device to treat their nonunion presented to us with a persistent nonunion. Each patient presented with hardware failure of the lateral plate and a persistent nonunion. They were treated with a two-stage ORIF with replacement of the lateral locking plate followed by medial locked plating with bone grafting; all four patients went on to achieve bony union. The addition of a medial locking plate to a lateral locking plate provides a reliable solution to the difficult problem of recalcitrant distal femoral nonunion when standard techniques have failed.

Other options exist for treatment of nonunion of the distal femur. Ilizarov external fixation to treat a distal femoral nonunion has certain advantages including minimal soft tissue disruption, the ability to gradually compress, stable fixation, and early weightbearing. The Ilizarov technique is particularly effective in patients with infection, deformity, or limb shortening. However, the Ilizarov method has a steep learning curve and requires strict patient compliance with frequent followups [4, 17]. Several case series using arthroplasty to reconstruct distal femoral nonunion have shown a high proportion of patients achieve good pain relief and return to ambulation, suggesting this technique may be appropriate as a salvage procedure in elderly patients [8, 10, 16]. Results of retrograde nailing for distal femoral nonunion historically have been poor. Koval et al. [15] reported only four of 16 patients with distal femoral nonunions achieved union after retrograde nailing, although Wu and Shih [21] reported that 22 of 24 patients with supracondylar nonunions treated with dynamically locked retrograde nails and cancellous bone grafting attained union at an average of 4.2 months.

In a systematic review of 19 published studies, Ebraheim et al. [9] reported that only 3% of patients who had a distal femoral nonunion initially had been treated with locking plates and autogenous bone graft. This contrasts with data from Hoffman et al. [14], who reported that 18% of 111 distal femur fractures treated with lateral locking plates without concomitant bone grafting achieved union, indicating that bone grafting with lateral locking plate fixation may be associated with a higher likelihood of fracture union. Although some studies [7, 18] have evaluated elements of the internal fixation construct, such as plate length and numbers of screws, these topics remain areas of ongoing study.

Although a high proportion of our patients attained radiographic signs of osseous union, six had complications, including one with persistent nonunion, four with symptomatic hardware, and one with superficial wound breakdown. Of the four patients with symptomatic hardware, two underwent removal of the medial plate and two underwent removal of medial and lateral plates. The soft tissue envelope over the medial aspect of the femur may predispose patients to experience hardware prominence in this area.

We found that a high proportion of patients with a distal femoral nonunion achieved union after addition of a medial locking plate to an in situ lateral locking plate and believe this technique adds to the armamentarium of surgeons treating these challenging injuries. We believe that the addition of a medial locking plate with bone graft is an effective way to consistently achieve union in this patient population. Future studies might identify patient characteristics related to high probability of benefit from addition

of a medial locking plate with bone graft for the treatment of distal femoral nonunion, such as advanced age, osteoporosis, diabetes mellitus, smoking, and highly comminuted fracture pattern.

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