CLINICAL ARTICLE

Treatment of Distal Femur Nonunion Following Initial Fixation with a Lateral Locking Plate

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Objective: To report and evaluate the outcomes of patients undergoing definitive treatment for distal femur nonunion after initial treatment with a locking plate.

Methods: Fourteen patients who had undergone definitive treatment at an academic Level 1 trauma center from May 2007 to December 2013 for distal femur nonunion were identified from a fracture database. Thirteen of them were female; the average age was 65 years (range, 50–84 years). Ten patients had sustained their injuries in falls at ground level, and four in motor vehicle accidents. Twelve patients were obese (body mass index ≥ 30), 10 had diabetes, none were current smokers, and one had an open fracture classified as type IIIa according to the Gustilo–Anderson classification system for open fractures. The fractures were classified according to the AO classification system for distal femur fractures; there were three type 33-A1, six 33-A2, two 33-A3 and three 33-C3 fractures. Methods of definitive treatment involved open reduction and internal fixation (ORIF) revision, medial plating, bone grafting and the use of other biologic materials.

Results: Eight of the 14 patients (57%) achieved union during follow-up. Definitive treatment for nonunion involved ORIF revision in 11 cases. Three patients who did not undergo ORIF revision were treated with iliac crest stem cell autografts, bone graft substitutes or recombinant human-bone morphogenetic protein-2 (rh-BMP-2). Other treatments included rh-BMP-2 (12 cases), iliac crest bone autograft (five), iliac crest stem cell autograft (two), crushed cancellous bone allograft (three), CaSO_4 and tricalcium phosphate bone graft substitute (two) and demineralized bone matrix (one). The average time from definitive treatment to union was 19 weeks (range, 12–51 weeks). Two of the 11 cases who underwent ORIF revision had medial plates added to improve biomechanical stability and prevent varus collapse. This was also performed in one patient with a grade III open type 33-C3 fracture and one with a closed 33-A2 fracture. Five study patients had comminuted fractures. Two had type 33-A3 and three type 33-C3 fractures. Both patients with 33-A3 fractures and 2 two with 33-C3 fractures had persistent nonunion at the end of follow-up.

Conclusions: Definitive treatment of distal femur nonunion after initial treatment with a locking plate had a low rate of success in this study, suggesting that this procedure is ineffective as a definitive treatment for distal femur nonunion.

Key words: Distal femur fracture; Locking plate; Nonunion; Outcomes

Introduction

Fractures of the distal femur are relatively common, most often being caused by high-energy trauma in young persons and low-energy trauma in older persons. Distal femur fractures have been treated by open reduction and internal fixation (ORIF) using locking compression plates (LCPs),

dynamic condylar screws (DCSs), angled blade plates (ABPs) and intramedullary nails (IMNs). Locking plates have gained favor because they are less invasive, less disruptive to the periosteum and provide a high level of stability¹. However, they are not devoid of complications; problems include implant failure, mal-alignment, delayed union and

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nonunion². Retrospective studies have reported various rates of nonunion following treatment with LCP, these rates ranging from 0% to as high as 20%²⁻¹³.

Nonunion of the distal femur can be very challenging to treat and often has a devastating impact on patient function and quality of life. A recent review summarizing published reports regarding the methods and outcomes of definitive treatment of distal femur nonunion¹⁴ found that definitive treatment of distal femur nonunion was effective in 97% of cases. However, the vast majority of reported studies included patients who had initially been treated with condylar buttress plates (CBPs), DCSs, ABPs and IMN, definitive treatment most commonly involving fixed angle plating with cancellous autografting. Only five of the 169 patients identified had initially been treated with LCPs and only three had received LCPs as definitive treatment¹⁴.

Given that locking plates have become one of the predominant fixation methods for distal femur fractures and that they have been associated with varying rates of nonunion, further study is needed regarding the definitive treatment of nonunion when locking plates have been used for primary fixation. There is currently little published data concerning this. The purpose of the present study was to report and evaluate the outcome of surgical treatment for distal femur nonunion after initial treatment with locking plates. This is a challenging situation for which there is currently no standard treatment guideline. This study aims to share the successes and failures of surgical treatment at an academic Level 1 trauma center.

Patients and Methods

Inclusion and Exclusion Criteria

Data were collected by retrospective review of patient charts and radiographs. The criteria for inclusion were nonunion of the distal femur, initial treatment with an LCP and definitive treatment to resolve nonunion. The criteria for exclusion were nonunion of the distal femur and initial treatment other than an LCP. Nonunion was defined as the absence of clinical (pain or motion at fracture site) or radiographic evidence of union 6 months after initial fracture treatment. Union was diagnosed if radiographs demonstrated bridging callus across the fracture site and full weight bearing was tolerated without pain at the fracture site. This study was approved by the Institutional Review Board at the University of Toledo Medical Center.

Basic Patient Characteristics

A search of our Level 1 trauma center fracture database from May 2007 to December 2013 identified 69 patients who underwent LCP treatment for distal femur fractures. Nonunion had been diagnosed in 14 of these cases. Thirteen of the 14 patients were female; average age was 65 years (range, 50–84 years). Ten patients sustained fall from standing height (low energy injuries) and four from motor vehicle accidents (MVA, high energy injuries). Twelve patients were

obese (body mass index ≥ 30), 10 had diabetes, none were current smokers and one with Gustilo-Anderson type IIIa open fracture¹⁵. Fractures were classified according to the AO classification system for distal femur fractures; there were three type 33-A1, six 33-A2, two 33-A3 and three 33-C3 fractures.

Initial Treatment

Initial treatment involved ORIF with lateral placement of an LCP. Implants used included Zimmer periarticular distal femur locking plates (six, 10 or 13 hole; Zimmer, Warsaw, IN, USA), Synthes LCPs for the distal femur (nine or 11 hole) (Synthes, West Chester, PA, USA) and ITS distal femur locking plates (five, seven, nine or 13 hole) (ITS, Lassnitzhöhe, Austria). All plates were composed of titanium.

Definitive Treatment

More than one type of definitive treatment is often employed during a given surgical intervention. Methods included ORIF revision with replacement or addition of screws, ORIF with a medial plate, rh-BMP-2 (Infuse; Medtronic, Minneapolis, MN, USA), CaSO₄ and tricalcium phosphate bone graft substitute (Pro-Dense; Wright Medical Technology, Memphis, TN, USA), demineralized bone matrix (StimuBlast; Arthrex, Naples, FL, USA), iliac crest bone or stem cell autografts and crushed cancellous bone allografts. All patients had an osteo-inducing substance added, sometimes more than one type. The surgeon selected a specific product at the time of surgery.

Additional items recorded included time to the diagnosis of nonunion, time from definitive treatment to union, total follow-up time, tolerance of weight bearing and/or pain at fracture site, radiographic status, and complications. All patients had pre-operative laboratory studies to rule out infectious cause for nonunion.

Surgical Techniques

All ORIF revisions were performed with the patient placed in a supine position after induction of general anesthesia. The lower extremity and iliac crest (if bone grafting was planned) were prepared and draped in a sterile fashion. Peri-operative antibiotics were administered. A lateral approach was taken to the distal femur, splitting the iliotibial band. Meticulous dissection was performed down to the locking plate. The site of nonunion was cultured and debrided of any fibrous tissue. The initial locking plate was left *in situ* proximally; distal screws were revised and the plate repositioned, if necessary, to improve reduction. C-arm fluoroscopy was utilized to assist with reduction and implant positioning. Bone for grafting was obtained from the anterior iliac crest and packed into the nonunion site along with any other biological materials used. Gelfoam (Pfizer, New York, NY, USA) and a deep Hemovac (Zimmer) were placed into the iliac crest graft site before closure. A superficial Hemovac was placed at the distal femur and the iliotibial band and deep dermal layer closed with Vicryl sutures. The skin was

then closed with staples and a sterile dressing applied. The patient was then kept non-weight bearing on the operated-upon extremity until there was radiographic evidence of bony union.

In two cases, ORIF with a medial plate was performed with the aim of directly improving biomechanical stability and preventing varus collapse, this procedure also being performed with the patient in a supine position. These patients were also prepared and draped in a sterile fashion after induction of general anesthesia. Perioperative antibiotics were administered. An anteromedial approach to the distal femur was taken, splitting the vastus medialis muscle belly, and meticulous dissection performed down to the site of nonunion. The nonunion site was cultured and debrided of any fibrous tissue and the fracture was reduced with the assistance of C-arm fluoroscopy. A medial locking plate was placed using cancellous locking screws of appropriate length. The nonunion site was packed with bone graft and any other biologic materials used. The vastus medialis muscle, fat and subcutaneous layers were closed with Vicryl sutures and the skin with staples before a sterile dressing was applied. The patient was then required not to weight-bear on the operated-upon extremity.

Results

Definitive Treatment

Definitive treatment for nonunion addressed both fracture stability and bone healing. Stability was addressed by ORIF revision (11 cases). The three cases that did not undergo ORIF revision received iliac crest stem cell autograft, bone graft substitute, or rh-BMP-2. Healing was promoted by application of rh-BMP-2 (12 cases), iliac crest bone autograft (5), iliac crest stem cell autograft (2), crushed cancellous bone allograft (3), CaSO₄ and tricalcium phosphate bone graft substitute (2) and demineralized bone matrix (1) (Table 1).

Two patients in this study also had a medial plate placed to improve biomechanical stability and prevent varus collapse, one of these patients having a grade III open type 33-C3 fracture and 1 the other a closed 33-A2 fracture. The latter patient (Table 1, Patient 14) had union at 51 weeks; radiographs from before and after medial plate placement are shown in Fig. 1.

Fracture Types and Follow-up

Fractures were classified using the AO system; they included 33-A1 (3), 33-A2 (6), 33-A3 (2), and 33-C3 (3). Average time from fracture to diagnosis of nonunion was 7 months (range, 3–19 months) and average time from definitive treatment to union 19 weeks (range, 12–51 weeks). Average duration of follow-up was 29 months (range, 12–88 months). All nonunions were considered atrophic. Eight of the 14 patients (57%) achieved union during follow-up. Individual results are shown in Table 1.

Five patients had comminuted fractures, two type 33-A3 and three type 33-C3. Both patients with type 33-A3 fractures and two of those with type 33-C3 fractures had persistent nonunion at the end of follow-up. Figure 2 shows the radiographs of an 84 years old man (Table 1, Patient 2) who sustained a closed, type 33-C3 fracture. Radiographs showed no evidence of healing 3 months after initial treatment which was revised with ORIF with two screws at the nonunion site together with iliac crest bone autograft and crushed cancellous bone allograft. Eight months after definitive treatment, the patient still had significant pain with weight bearing and activity and radiographs showed persistent nonunion.

Complications

A number of complications arose during the care of these patients. Two patients had complications related to iliac crest bone grafting. One developed a methicillin-resistant *Staphylococcus aureus* (MRSA) infection at the iliac crest graft harvest site that required four procedures for irrigation and debridement and several months of treatment with antibiotics. Another developed severe pain at the iliac crest bone graft harvest site and ultimately underwent a femoral cutaneous nerve block procedure. Two patients developed superficial wound infections at the locking plate insertion site following initial ORIF, one with MRSA and one with *Enterobacter cloacae*; both patients underwent a single irrigation and debridement. One patient developed knee arthrofibrosis, requiring quadricepsplasty and knee arthroscopy on two occasions. Another developed post-traumatic arthritis, requiring knee arthroscopy on two occasions with meniscal repair and chondroplasty. Implants failed in two cases because of pullout of the distal locking screws; in both cases this was addressed during revision for nonunion. Two patients had pain related to their implants; in one case a medial plate was removed, whereas in the other a lateral plate was removed after union. One patient had a malunion with valgus deformity. Six patients had persistent nonunion at the end of follow-up. All cultures obtained from the nonunion site at the time of surgery were negative.

Discussion

Nonunion Following Initial Treatment with an LCP

Locking plates have become a major means of treating fractures of the distal femur. They are favored for providing a highly stable construct that requires minimal periosteal stripping¹ and for being less technically demanding and invasive than blade plates; they also eliminate less distal bone stock than DCSs². However, nonunion does occur with locking plates, rates as high as 20% having been reported^{2–12}. Nonunion following initial treatment with an LCP can be very challenging to treat and there are currently few published data regarding its definitive treatment¹⁴.

TABLE 1 Individual outcomes of patients who underwent definitive treatment for nonunion

Patient number	Age, sex	Mechanism of injury	Fracture type (AO/OTA)	Initial treatment	Definitive treatment	Additional definitive treatment(s)	Union	Time to union after definitive treatment (weeks)	Complications	Patient factors
1	66 F	Fall	Closed, R, 33-A1	ORIF with Zimmer six hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2	ORIF revision, rh-BMP-2	No (no bridging callus)			Obesity, diabetes
2	84 F	MVA	Closed, L, 33-C3	ORIF with ITS nine hole distal femur locking plate	ORIF revision, iliac crest bone autograft, crushed cancellous bone allograft		No (pain with weight bearing)			Diabetes
3	63 F	Fall	Closed, R, 33-A2	ORIF with Zimmer 10 hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2, iliac crest bone autograft		No (femur pain, no bridging callus)		Severe pain at iliac crest bone graft harvest site	Obesity, diabetes
4	63 F	Fall	Closed, L, 33-A3	ORIF with Zimmer 13 hole periparticular distal femur locking plate	Iliac crest stem cell autograft, bone graft substitute		No (femur pain, no bridging callus)			Obesity
5	63 F	Fall	Closed, L, 33-A3	ORIF with Zimmer 13 hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2		No (pain with weight bearing, no bridging callus)			Obesity, diabetes
6	50 F	Motorcycle crash	Open L, 33-C3	ORIF with Synthes nine hole LCP distal femur	ORIF with medial locking plate, iliac crest bone autograft	ORIF revision, rh-BMP-2, iliac crest bone autograft; ORIF revision, rh-BMP-2; ORIF revision, removal of medial plate, rh-BMP-2*	No (pain with weight bearing)		Infection at plate insertion site following initial ORIF (Enterobacter cloacae); L knee arthrofibrosis; symptomatic medial plate	Obesity, diabetes
7	70 F	Fall	Closed, L, 33-A1	ORIF with Zimmer 10 hole periparticular distal femur locking plate	Iliac crest stem cell autograft	ORIF revision, iliac crest bone autograft, rh-BMP-2	Yes	12		Obesity, diabetes

TABLE 1 Continued

Patient number	Age, sex	Mechanism of injury	Fracture type (AO/OTA)	Initial treatment	Definitive treatment	Additional definitive treatment(s)	Union	Time to union after definitive treatment (weeks)	Complications	Patient factors
8	73 F	Fall	Closed, L, 33-A2	ORIF with Zimmer six hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2, crushed cancellous bone allograft		Yes	12	Implant failure	Obesity, diabetes
9	69 F	MVA	Closed, L, 33-A2	ORIF with Zimmer 6 hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2		Yes	17	Post-traumatic arthritis; symptomatic implant	
10	74 F	Fall	Closed, R, 33-A2	ORIF with Zimmer 10 hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2, bone graft substitute		Yes	22		Obesity, diabetes
11	68 F	MVA	Closed, R, 33-A2	ORIF with Zimmer 10 hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2, iliac crest bone autograft		Yes	12	Implant failure; iliac crest bone graft harvest site infection (MRSA)	Obesity
12	64 F	Fall	Closed, R, 33-A1	ORIF with Synthes 11 hole LCP distal femur	rh-BMP-2		Yes	13	Infection at plate insertion site following initial ORIF (MRSA); malunion	Obesity, diabetes
13	51 F	Fall	Closed, R, 33-C3	ORIF with Zimmer 10 hole periparticular distal femur locking plate	ORIF revision, rh-BMP-2		Yes	14		Obesity, diabetes
14	56 F	Fall	Closed, L, 33-A2	ORIF with ITS nine hole distal femur locking plate	ORIF with medial ITS 5 hole locking plate, rh-BMP-2, crushed cancellous bone allograft, demineralized bone matrix		Yes	51		Obesity

L, Left; MVA, motor vehicle accidents; ORIF, open reduction and internal fixation. R, Right.

*Patient 6 underwent four separate definitive treatments over a span of 6 years.

Fig. 1 A 56-year-old woman (Table 1, Patient 14) with a closed 33-A2 fracture. (A) AP view and (B) lateral view radiographs showed nonunion after treatment with ORIF with an ITS nine hole distal femur locking plate. (C) AP view and (D) lateral view radiographs showed the patient had union at 51 weeks after medial plate and rh-BMP-2, crushed cancellous bone allograft, demineralized bone matrix placement.

Previous Definitive Treatment of Distal Femur Nonunion

Several studies have investigated definitive treatment of distal femur nonunion. Perhaps the largest case series was performed by Gardner *et al.*¹⁶. This study involved 31 patients with distal femur nonunion, all of whom were treated with fixed angle plating and either iliac crest bone autograft or demineralized bone matrix. Fixed angle plating involved removal of the initial implant and placement of an ABP, DCS or LCP. These authors did not state how many LCP's were used for definitive treatment; however, only two of their patients had been treated initially with LCPs. They reported a 97% union rate¹⁶.

Another case series by Bellabarba *et al.* examined the definitive treatment of 20 patients¹⁷, all of whom were initially treated

with CBP, DCS or ABP. Definitive treatment involved autogenous bone grafting and the use of an ABP in 13, CBP in four and LCP in three cases. They reported a union rate of 100%¹⁷.

Chapman and Finkemeier studied definitive treatment in 18 patients with bone autograft or allograft and either double plating with DCS or CBP or lateral plating with a CBP or ABP. All patients achieved union¹⁸. Wang and Weng treated 13 patients with bone autograft, removal of initial implant and placement of ABP, CBP or IMN and achieved a 100% union rate¹⁹. Prasarn *et al.* achieved 100% union in 13 patients with infected nonunion using antibiotics, initial implant removal, bone grafting and placement of an ABP, DCS or IMN²⁰. These three studies all reported excellent results; however, none of their patients had an LCP as initial or definitive treatment.

Fig. 2 A 84-year-old man (Table 1, Patient 2) with a closed, type 33-C3 fracture. (A) Preoperative antero-posterior (AP) view radiograph. (B) Preoperative lateral view radiograph. (C) AP and (D) lateral view radiographs showed ORIF with an ITS nine hole distal femur locking plate. (E) AP view and (F) lateral view radiographs showing no evidence of healing 3 months after initial treatment. (G) AP and (H) lateral views showing that the patient underwent ORIF revision with the addition of two screws into the nonunion site, iliac crest bone autograft and crushed cancellous bone allograft. Eight months after definitive treatment, the patient still had significant pain on weight bearing and activity and (I) AP view and (J) lateral view radiographs showed persistent nonunion.

Differences of Current Study

The results of the current study contrast starkly with those mentioned above. One possible explanation for this discrepancy is that in several of these studies the initial implant was removed and replaced with a new one, often of a different type. In the current study, the initial implant was left *in situ* in all cases, revision being accomplished by adding or replacing screws and sometimes repositioning the plate. These procedures were chosen because surgery is traumatic experience and it was thought that complete replacement of the surgical implants would create additional stress and damage blood supply to the nonunion site. Thus, at the time of revision, evidence of instability, such as screw loosening, were identified and corrected together with adding osteo-inducing products. However, five of the 11 patients treated by ORIF revision of the initial plate had persistent nonunion at the end of follow-up (Table 1, Patients 1–3, 5, 6). When a locking plate had already failed to facilitate union, it may have been inappropriate to leave it *in situ*. Better results may have been achieved by removing the initial plate, repeating the reduction, and adding a new locking plate; however, this procedure was not performed in the current study. The low union rate may also relate to patient factors. As mentioned earlier, locking plates have been considered one of the foremost techniques for distal femur fractures. Failure of such a typically successful method suggests that patient factors may have contributed significantly to nonunion. Many of the patients in this study were obese and diabetic, two characteristics that have been found to increase risk of distal femur nonunion with locking plates^{21,22}. These factors may have contributed to both the development of initial nonunion and the failure of definitive treatment to resolve it.

Additionally, only five of the patients in the current study received autogenous bone grafts, whereas previous studies depended heavily on this method. Autogenous bone grafting has been considered the gold standard in augmenting bone healing; it facilitates osteogenesis, osteoinduction and osteoconduction by providing the patient's own growing cells, proteins, and bony framework, respectively²³. The time to union of autogenous bone grafting is reportedly shorter than with allografts and associated with a lower rate of revision than allografts or rh-BMP-2²⁴. However, only two of the five patients who received autogenous bone grafts in the current study achieved union; additionally, two of them had complications related to procurement of iliac crest bone grafts. The most common means of promoting healing in

this study was rh-BMP-2, which was used in 12 patients, eight of whom developed union. A recent study by Takemoto *et al.* found no benefit from the use of rh-BMP-2 as a supplement to autogenous bone grafting when treating nonunion of long bone fractures²⁵. That having been said, the variations in use of bone and stem cell grafting combined with numerous biological materials makes it impossible to conclusively determine the role of any individual material in the low rate of union seen in this study.

Limitations

The current study had inherent limitations, one being the retrospective approach to data collection, which did not allow evaluation of patient functional outcomes, as the clinical notes were inconsistent and it was impossible to gather the required information for functional outcome scoring. A prospective approach using standardized methods would enable functional outcome scoring and also eliminate variability in treatments and thus facilitate better comparisons between methods. Secondly, the small number of cases of distal femur nonunion treated at this institution limited the ability to draw any statistically significant conclusions. Because this complication is uncommon, a multi-center approach would be better because it would enable an analysis of more cases. In the future, a multi-center prospective study designed to study methods for treating this type of nonunion is indicated, particularly one comparing revision of the initial LCP to replacement with either a new LCP, ABP or DCS. The long-term goal should be to develop a guideline on how best to treat this type of nonunion.

Conclusion

Definitive treatment following initial treatment with a locking plate involves stabilization of the nonunion site with ORIF revision of the initial plate or addition of a medial plate. Stimulation of healing with autogenous bone grafting and the use of various biologic materials was attempted. In this study, definitive treatment of nonunion had a low rate of success, with only eight of 14 patients achieving union during an average of 29 months follow-up (57%). Only six of 11 patients treated with ORIF revision achieved union at the end of follow-up, suggesting that revising an initial locking plate may be an ineffective definitive treatment for distal femur nonunion.

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