Monofilament Cerclage Wiring Fixation with Locking Plates for Distal Femoral Fracture: Is it Appropriate?

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Abstract

Purpose: We aimed to determine the efficacy of cerclage wiring by comparing the clinical and radiological results between internal fixation with locking plates after distal femoral fracture reduction with or without cerclage wiring. **Materials and Methods:** One hundred and one patients who received open reduction internal fixation for distal femoral fractures of oblique, spiral, and spiral wedge type between 2007 and 2014 were reviewed retrospectively. Only locking plate fixation was performed in 46 patients, and locking plate fixation with additional cerclage wiring was performed in 55 patients (Group CW). Demographic, clinical, and radiologic factors were evaluated in both the groups. Age, gender, bone mineral density, bone graft, and the presence of concomitant fractures were measured as demographic factors. The range of motion of knee joint, Lysholm knee score, visual analog scale score, procedure time, and C-arm time were measured as clinical factors preoperatively and at the final followup. We also evaluated the duration of bone union and knee joint alignment radiologically. **Results:** There were no demographic differences between the two groups. Furthermore, there were no statistically significant differences between the two groups in terms of clinical and radiological parameters. However, the procedure time used was significantly longer in Group LP than in Group CW (108.4 vs. 95.2 min; $P = 0.027$). The C-arm time was longer in Group LP (2.8 vs. 1.2 s; $P = 0.017$). **Conclusions:** Open reduction and locking plate fixation with additional cerclage wiring is a useful method for the reduction of complicated distal femoral fractures, without increased complications such as nonunion. **Level of Evidence:** Level III, retrospective cohort design, treatment study.

Keywords: *Cerclage wiring fixation, distal femoral fracture, locking plate, open reduction*

Introduction

In cases of distal femoral fracture caused by low-energy damage in elderly patients, oblique, spiral, or supracondylar fractures are common,[1] and such fractures will be more common in the aging population. With locking plates, cerclage wires have been used to provide a more easy anatomical reduction and stable fixation of oblique, spiral, or spiral wedge fractures. However, the use of these wires is controversial.[2] It has been suggested that open techniques with locking plates and cerclage wires may interrupt blood flow in the periosteum, which may increase the incidence of nonunion and have therefore been a subject of debate.[3,4] On the other hand, previous studies on synthetic and embalmed femurs have demonstrated that using a locking plate with cerclage wires has an equivalent effect on the biomechanical strength of bone as using a locking plate alone in periprosthetic fractures.[5] However, a recent study suggested that cerclage wires used with locking plate fixation successfully treat femoral fractures of the femur with faster time to union, less complication, and fewer revisions.[6] To date, little research on live human patients has been conducted to compare the outcomes of locking plate with or without cerclage wires.

With the introduction of the concept of biological fixation, there is minimal invasive plate osteosynthesis (MIPO) techniques, when used for the treatment of distal femoral fractures, can conserve blood flow to the bone fragment and may less disturb bone union.[7-9] However, there are limitations in incorporating the MIPO technique. When performing MIPO, reduction of the distal femoral fracture is technically difficult to perform and requires an experienced surgeon.[10] In addition, because the fracture area is difficult to visualize during surgery, there are reports

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that the surgeon is exposed to more radiation during the procedure.[10,11]

Therefore, we hypothesize that when performing open reduction of distal femoral fractures, if the fracture is oblique, spiral, or spiral wedge and is difficult to reduce, cerclage wiring fixation can aid in the anatomical reduction of the bone fragments and fracture area. In this study, we aimed to determine the efficacy of cerclage wiring by comparing the clinical and radiological results between internal fixation with locking plates after distal femoral fracture reduction with or without cerclage wiring.

Materials and Methods

This study was approved by the Institutional Review Board of Wonkwang University Hospital.

Patients selection

Among the 128 patients who had open reduction and internal fixation with locking plates for distal femoral fractures from 2007 to 2014, 101 patients who were available for minimum 12 months of followup were enrolled in this study. The median age of the patients was 65 years (range 55–91 years), and there were 43 male and 68 female patients. Only locking plate fixation was performed in 46 patients from 2007 to 2010, and locking plate fixation with additional cerclage wiring was performed in 55 patients from 2011 to 2014. The patients were divided into two groups according to the fixation method used (LP Group: only locking plate fixation and CW group: locking plate fixation with additional cerclage wiring).

The inclusion criteria were as follows: (i) distal femoral fracture of oblique, spiral, and spiral wedge type with or without comminution on radiography, (ii) the use of either locking plate fixation with additional cerclage wiring or only locking plate fixation technique, (iii) availability for a minimum followup period of 12 months, (iv) no history of fractures or surgeries on the affected limb, and (v) participation in the assigned rehabilitation program. The exclusion criteria were as follows: (i) distal femoral fracture of transverse type which was not suitable to reduce with cerclage wiring, (ii) brain and/or spine injury that could potentially cause bias, (iii) concomitant proximal femoral fracture, and (iv) the time from injury to surgery was more than 2 weeks.

Surgical technique

All the surgeries were performed by a single experienced surgeon, with the patient in the supine position on a radiolucent table with the knee joint flexed at 20°–30°. A skin incision was made from the thigh to the lower knee joint, and starting from between the rectus femoris and vastus lateralis muscle, the dissection was extended to the lateral side of the knee joint, so that the knee joint surface and the fracture were exposed. Intraoperative C-arm image intensification was used at each step of reduction and plate fixation. In cases where the knee joint was affected, open anatomical reduction of the joint surface was first performed, and if cerclage wiring was applied, a Dall-Miles cable passer was used to pass a monofilament 19-gauge (1.0 mm) wire through the fractured area before fixation with locking plates [Figure 1]. After confirming the appropriate placement of the wire with a C-arm, the wire was twisted and secured while maintaining reduction of the bone fragment, and the periosteum of both lateral and posterior sides was preserved as much as possible while minimizing periosteal separation. A 19-gauge (1.0 mm) wire was used to minimize the separation between the metal plate and the bone fragment, and the knot was positioned in a frontal position to avoid interference between the metal plate fixation screws and the cerclage wire knot [Figure 2]. After achieving anatomical positioning, internal fixation was performed using a locking compression plate [distal femur (DF), Synthes®, Oberdorf, Switzerland; Figure 3]. An autogenous bone graft was performed if a bone deficit was observed even after fixation. All surgical procedures were performed by a single orthopedic surgeon.

Rehabilitation

A splint was applied for rehabilitation after surgery until the wound healed and pain and edema subsided. Active joint exercise and continuous passive joint exercise with an exercise machine were performed 1 week after surgery. Six weeks after surgery, partial-weight-bearing exercise was allowed, and complete-weight-bearing exercise was allowed about 4–5 months after surgery after performing a radiological evaluation to determine the degree of bone union.

Clinical and radiological evaluation

Outpatient clinic followup was performed 6 weeks after surgery, and followup visits were held at 1-month intervals until the bone was completely healed. After complete union, followup was performed after 3, 6, and 12 months, and radiological and clinical evaluation was performed at the last followup. It was determined that bone union was achieved if, on radiological evaluation, there was no pain on weight bearing and if callus formation was observed beyond the fracture in the anteroposterior and lateral

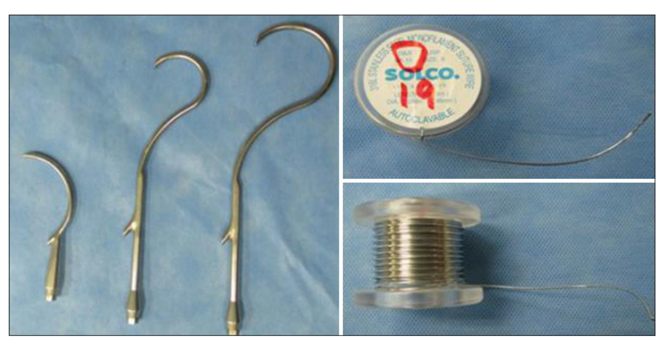

Figure 1: Images of a Dall–Miles passor and a monofilament 19-gauge (1.0 mm) wire

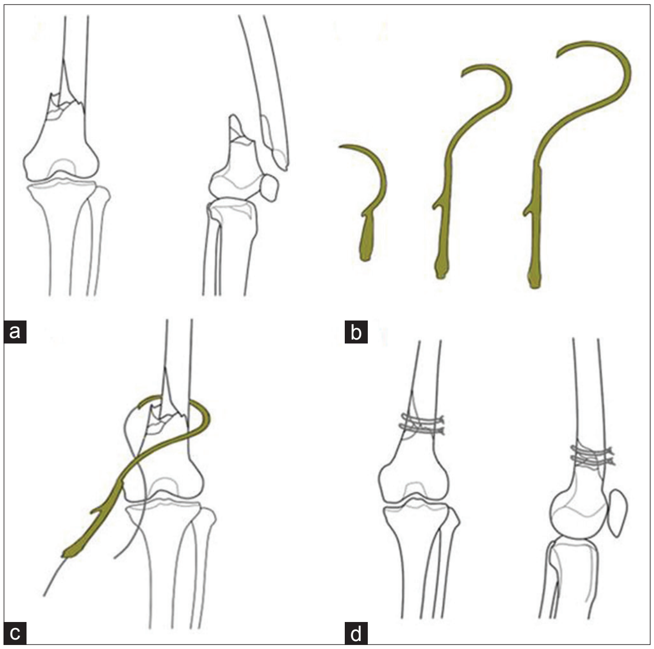

Figure 2: Schematic demonstration of reduction of distal femoral fracture using monofilament cerclage wiring fixation. (a) Anteroposterior and lateral illustration of complicated distal femoral fracture, (b) variable size and shape of wire passer, (c) cerclage wiring was done using wire passer which had appropriate size and shape to distal femur, and (d) anteroposterior and lateral illustration of reduction using cerclage wires

X-rays (the time was then noted). If bone union was not achieved by 8 months after surgery, we made a diagnosis of nonunion, and delayed union was defined as no evidence of bone union on radiographic evaluation after 6 months. A shortening deformity of >1 cm or an angular deformity of >5° was considered indicative of malunion. Age, gender, bone mineral density (BMD), time from injury to surgery, bone graft, and the presence of concomitant fractures were measured as demographic factors. The joint range of motion (ROM), visual analog scale (VAS) score, and Lysholm knee score were measured for clinical evaluation. Furthermore, procedure time and C-arm time were measured. The general Electric OEC 9900 Elite Digital Mobile C-arm (GE Healthcare, Salt Lake City, UT, USA) with the low-exposure option and an exposure time of 0.2 s per image was used. The cumulative absorbed exposure for each case was calculated by the C-arm image intensification system's software. The exposure and total image intensification time for each case were recorded.

Statistical analysis

SPSS version 14.0 (SPSS science, Chicago, IL, USA) was used for statistical analysis. The statistical significance of difference in the demographic, clinical, and radiological characteristics between the two groups was tested using Student's *t*-test and Mann–Whitney test. Significance levels for all analyses were set at $P < 0.05$. When power analysis was performed to evaluate the power of group comparison for the clinical outcomes and complications between two groups, this study achieved a power of 0.89 for the

Figure 3: (a) Pre- and postoperative X-rays of a case treated with locking plate fixation and additional cerclage wiring. (b) Pre- and postoperative X-rays of a case treated with only locking plate fixation

detection of differences with actual $\alpha = 0.05$. GPower 3.1.9.2 was used for the power analysis.

Results

Demographics

Age, gender, BMD, time from injury to surgery, bone graft, and the presence of concomitant fractures were evaluated as demographic factors. No significant differences were found in demographic characteristics between the two groups [Table 1].

Clinical and radiologic factors

On final evaluation, the mean joint ROM in Group LP was 109.3° ±14.4°, the mean Lysholm knee score was 84.6 ± 7.2, the mean VAS score was 1.7 ± 0.3, the mean postoperative mechanical axis was valgus (0.3 ± 6.4), and the mean period of bone union was 4.7 ± 3.0 months, with two cases of delayed union, one case of malunion, and one case of nonunion. In Group CW, the mean joint ROM was 102.2° ±18.5°, the mean Lysholm knee score was 82.4 ± 6.9, the mean VAS score was 1.5 ± 0.2, the mean postoperative mechanical axis was varus (1.1 ± 5.0), and the mean period of bone union was 5.1 ± 2.3 months [Figure 4], with three cases of delayed union, no cases of malunion, and two cases of nonunion. There were no statistically significant differences between the two groups in terms of clinical and radiological parameters [Table 2]. In all cases of nonunion, revision operation with autogenous bone graft was done.

The procedure time used was significantly longer in Group LP than in Group CW (108.4 vs. 95.2 min; $P = 0.027$). The C-arm time was significantly longer in Group LP (2.8 vs. 1.2 s; $P = 0.017$) [Table 2].

Figure 4: One-year postoperative X-ray of a case treated with locking plate fixation and additional cerclage wiring; bone union is observed

Table 1: Data are presented as median (range), mean±SD, or *n* (%)

Variable	Group LP (*n*=46)	Group CW (*n*=55)	*P*
Gender (male:female)	17:29	26:29	0.418
Mean age, years (range)	64 (55-86)	67 (57-91)	0.291
BMD*	-1.95±1.2	-2.14±1.5	0.324
Time from injury to surgery (days)	4 (0-14)	3 (0-14)	0.514
Concomitant Fracture	11 (31%)	11 (24.4%)	0.641
Bone graft	17 (47%)	14 (31%)	0.216

*BMD=Bone mineral density, SD=Standard deviation

Table 2: Data are presented as median (range), mean±SD, or *n* (%)

Variable	Group LP (*n*=46)	Group CW (*n*=55)	*P*
The period of bone union (month)	5.1±2.3	4.7±3.0	0.522
Lysholm knee score	84.6±7.2	82.4±6.9	0.416
Visual analogue scale	1.7±0.3	1.5±0.2	0.742
Postoperative range of motion (°)	109.3±14.4	102.6±18.5	0.068
Postoperative MA¥ (°), knee	Valgus 0.3±6.4	Varus 1.1±5.0	0.306
Procedure time (min)	108.4±10.5	95.2±9.2	0.027
C-arm time (sec)	2.8±0.4	1.2±0.5	0.017
Complication	4 (8.7%)	5 (9.0%)	0.945
Delayed union	2	3	
Nonunion	1	2	
Malunion	1	0	

¥MA=Mechanical axis, SD=Standard deviation

Discussion

The purpose of this study was to determine the efficacy of cerclage wiring by comparing the clinical and radiological results between internal fixation with locking plates with or without cerclage wiring in oblique, spiral, and spiral wedge type of distal femoral fracture. In this study, the clinical and radiologic outcomes were not different between the two groups. Especially, the time to union in the cerclage wire group (4.7 ± 3.0 months) was less, but not significant than the only plating group (5.1 ± 2.3 months).

Open fixation with locking plates is a useful surgical method in the treatment of distal femoral fractures, not only extraarticular fractures but also intraarticular fractures.[12] However, because strong muscles such as the quadriceps femoris, adductors, hamstrings, and gastrocnemius muscles act on the fractured bone segment, accurate reduction is not easy and even if achieved, it is difficult to maintain due to femoral shortening, posterior angular deformity, and posterior displacement of the distal bone segment.[13] Furthermore, the exposure of both the patient and the surgeon to radiation can be a problem.[10,14] With locking plates, cerclage wires have been used to provide an easier and more stable fixation. However, it seems that only one previous study compared the clinical outcomes of a locking plate with and without cerclage wires in the treatment of DF fractures.[6]

In this study, additional cerclage wiring before metal plate fixation was performed to facilitate the reduction of oblique or spiral fractures, and in cases of comminuted fractures, small bone fragments and multiple fragments were more easily reduced, so that bone loss was minimized. Furthermore, the procedure time and C-arm time were significantly shorter in patients who treated with cerclage wiring and plate fixation.

The normal flow of blood to the femur is from the proximal to the distal portion. Inadequate amount of blood goes if there is a fracture on this site. The effect can vary, from having harsh amount of damage to scant or absent blood supply. Upon that, having total knee or hip arthroplasty done in the past can devitalize the bone and its surrounding soft tissue by decreasing the blood flow to the femur. Unfortunately, the flow can be decreased even more because of operation itself which is done to treat the fracture. Thus, securing the blood flow to the femur is a very important condition for the healing of the fracture. Because of these problems, only few options are available for surgeons. The possibility of fixation failure, delayed union, and nonunion is high due to this.[15-17] Prior studies suggested that cerclage wiring fixation can be useful in the treatment of femoral fractures that are hard to reduce.[18,19] However, other studies suggested that cerclage wiring can impede periosteal blood flow and lead to osteonecrosis or nonunion.[3,4] Due to these conflicting results, this subject is still a point of debate. Link and Babst[20] recently reported that, of the many treatment modalities for distal femoral fracture, MIPO has major advantages compared to other modalities and must be used preferentially. Minimally invasive procedures are beneficial in that they are biological; have fewer incidences of delayed union, nonunion, and infection; and lessen the need for bone transplantation. However, there are technical difficulties associated with performing these methods, and only very experienced surgeons can perform them.[21] These issues may potentially increase the incidence of malunion, resulting in the patient experiencing fixation failure or needing additional surgery more often than if they had undergone more invasive internal fixation methods initially.[22]

There have been many reports of good results for open surgery using locking plates in the treatment of distal femoral fractures,[12] and in this study, the mean period of bone union in cases of additional cerclage wiring fixation was 4.7 months, less but not significant than the only plating group. Furthermore, there were no differences in the rates of complication such as delayed union, nonunion, and malunion between the two groups. These results can be seen as indirect evidence that cerclage wiring fixation performed in distal femoral fractures does not interfere with the bone union of distal femoral fracture. We considered the following several reasons for this less time to union in cerclage wire group. First, it has been indicated that open fixation with locking plates using cerclage wiring fixation can induce strangulation of the periosteal blood flow, which may lead to osteonecrosis and nonunion.[3,4] However, Apivatthakakul *et al*.[23] reported that, rather than cerclage wiring, extensive soft-tissue dissection and stripping to expose and reduce the fracture caused the bone necrosis and other complications. Therefore, periosteal dissection and soft-tissue injury during surgery, rather than the use of cerclage wiring itself, can be considered a more serious cause of nonunion, and not putting stress on the fractured area due to excessive reduction and minimizing unnecessary damage of the soft tissue are the most important factors that may influence postoperative outcomes. Second, Kirby and Wilson also found no evidence of cortical devascularization with any type of cerclage wire with minimal soft-tissue stripping in the femurs of six dogs.[24] As a result of their histologic and anatomical study of femoral vascularity, Nather *et al*.[25] and Pazzaglia *et al*.[26] suggested that the periosteal vascular supply is circumferential, rather than longitudinal, with multiple musculoperiosteal vessels nourishing the periosteal layer. Nather *et al*.[25] concluded that "the old taboo that applying a cerclage wire strangulates the periosteal blood supply to a bone no longer holds true." Therefore, monofilament cerclage loops should have little deleterious effect on periosteal vascularity. Our study also supports this conclusion. A 19-gauge (1.0 mm) monofilament cerclage wiring fixation is a useful surgical method in that it can actually facilitate the reduction of bone fragments, so that bone loss is minimized and through more accurate placement can reduce the distance between fragments, helping the process of fracture healing. Finally, Perren *et al*.[2] suggested that preconceived and generally accepted opinions such as "strangulation of blood supply" need to be reexamined. Furthermore, recent mechanical evaluations demonstrate that the wire application may improve the maintenance of tension and strength.[2] The improved stability through cerclage wiring might have positive effect on bone union and plate failure.[27]

The limitations of this study are that the number of cases included was small, the study was performed retrospectively, and we were unable to provide direct evidence of the circulatory status of the cortical bone after surgery. In addition, this study was not designed as a randomized trial because the two techniques were performed at different time points, with the first 46 patients undergoing only the locking plate fixation technique. However, the surgeon had more than 10 years of experience in DF fractures before beginning this study; therefore, the difference in the required surgical skills between the LP and CW Groups would not lead to a learning curve bias. Furthermore, we did not evaluate traumatic arthritis during long term followup. Further research is required to assess this method using more evaluation methods in a larger cohort and over a longer followup period.

Conclusions

Open locking plate fixation with additional cerclage wiring fixation in the treatment of distal femoral fractures showed similar time to bone union and clinical results compared to fixation without additional cerclage wiring. Furthermore, a better result was obtained in the procedure time and C-arm time. The addition of cerclage wiring fixation according to fracture type is a useful method to facilitate the reduction of complicated fractures without increasing complications such as nonunion.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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