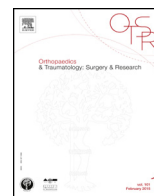




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Original article

## Successful outcome with minimally invasive plate osteosynthesis for periprosthetic tibial fracture after total knee arthroplasty



H.-J. Kim<sup>a</sup>, K.-C. Park<sup>b</sup>, J.-W. Kim<sup>a</sup>, C.-W. Oh<sup>a,\*</sup>, H.-S. Kyung<sup>a</sup>, J.-K. Oh<sup>c</sup>, K.-H. Park<sup>a</sup>, S.-D. Yoon<sup>a</sup>

<sup>a</sup> Department of Orthopedic Surgery, Kyungpook National University Hospital, 700-721 Daegu, Republic of Korea

<sup>b</sup> Department of Orthopedic Surgery, Hanyang University Guri Hospital, Guri, Republic of Korea

<sup>c</sup> Department of Orthopedic Surgery, Korea University Guro Hospital, Seoul, Republic of Korea

### ARTICLE INFO

#### Article history:

Received 20 June 2016

Accepted 3 October 2016

#### Keywords:

Total knee arthroplasty

Periprosthetic tibial fracture

Minimally invasive plate osteosynthesis

Locking plate

### ABSTRACT

**Introduction:** The incidence of periprosthetic fractures after total knee arthroplasty (TKA) is increasing, and treatment is becoming more necessary. In periprosthetic tibial fractures, the stem of the tibial component largely occupies the medullary canal of the proximal tibia, which limits the selection of implants. The purpose of this study was to evaluate the effectiveness of the minimally invasive plate osteosynthesis (MIPO) technique with locking plates for periprosthetic tibial fractures after TKA.

**Materials and methods:** Sixteen patients with periprosthetic tibial fracture after TKA were included. There were 6 type II and 10 type III fractures according to the Felix classification. Ten patients had fractures in the proximal metaphysis, and 6 in the diaphysis. MIPO using locking plates was performed on the medial side in 4 cases, the lateral side in 2 cases, and both in 10 cases. Radiographic results included time to union, alignment, and malunion. Clinical results included range of motion (ROM), functional activity data, Knee Society scores, and complications.

**Results:** Fourteen of 16 fractures achieved union at 17.1 weeks (range, 14–24) postoperatively. There were 2 failures that required a secondary procedure. Except one for 1 case with varus malunion, all had acceptable alignment. Mean ROM at the final follow-up was 108.8° (range, 15–135°), and 15 patients recovered pre-injury knee joint activity. Mean knee and function scores were 88.9 (range, 77–100) and 83.3 (range, 60–100), respectively. Knees with fewer than 8 cortices giving purchase to screws in the proximal segment showed higher failure rates ( $P=0.025$ ).

**Discussion:** MIPO with locking plates can achieve satisfactory results for periprosthetic tibial fractures after TKA. Rigid fixation of the proximal segment may be necessary for successful outcome.

**Level of evidence:** IV.

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## 1. Introduction

The incidence of total knee arthroplasty (TKA) is increasing due to enhanced survivorship in the elderly population and improvement in the quality of life. Therefore, the incidence of periprosthetic fractures after TKA is increasing, and treatment of this injury is becoming more necessary [1]. Periprosthetic femoral fractures were predominantly reported for this type of injury [2–4].

However, the prevalence of periprosthetic tibial fractures is 0.4%–1.7%, which is relatively uncommon compared to that of femoral fracture [5], with only a few studies of small series [6–10]. Because most patients requiring TKA are quite old, low bone

mineral density or poor bone stock is common. On the femoral side, the component is placed on the margin of the distal femur and it is usually possible to fix the retrograde nail or plate by using the remaining space [11]. However, the stem of the tibial component largely occupies the medullary canal of the proximal tibia, which limits the selection of implants for periprosthetic tibial fractures [12]. Intramedullary nailing is very difficult because the entry is blocked, although Haller et al. reported successful nailing in a diaphyseal fracture [6]. External fixation using thin wires may be performed; however, the wires can come into contact with the tibial component, and there is a high risk of deep infection [13]. Standard plate fixation can be performed as an alternative technique [7,8]; however, it is difficult to achieve sufficient stability.

Anatomically pre-contoured locking plates, which increase biomechanical stability, have been used instead of compression plates to fix periprosthetic femoral fractures after TKA [11].

\* Corresponding author.

E-mail address: [cwoh@knu.ac.kr](mailto:cwoh@knu.ac.kr) (C.-W. Oh).

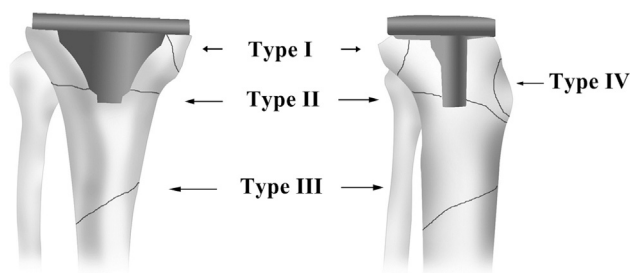


Fig. 1. Classification of periprosthetic tibial fractures described by Felix et al.

Associating locking plates to the minimally invasive plate osteosynthesis (MIPO) technique gave satisfactory fracture healing and low complication rates according to several reports [11,14–17]. However, this technique has been little applied in periprosthetic tibial fracture. To our knowledge, the present is one of the first large series reported for this injury. The study assessed the efficacy of MIPO in periprosthetic tibial fractures in terms of radiographic and clinical outcome and complications. The study hypothesis was that MIPO with locking plates is an effective and consistent treatment method for periprosthetic tibial fractures with well-fixed prostheses after TKA.

## 2. Materials and methods

The clinical and radiographic records of 16 patients with periprosthetic tibial fractures after TKA between 2004 and 2013 at 2 institutions were reviewed. The study was approved by the Institutional Review Board of our institute (IRB File No. 2015-12-006-003).

In 8 cases, the fracture was caused by traffic accidents (5 motor vehicle accidents and 3 motor vehicle-pedestrian accidents) and in 8 cases by falls. The reason for TKA was osteoarthritis in 11 patients, rheumatoid arthritis in 2 patients, osteosarcoma in 2 patients, and ankylosis caused by osteomyelitis in 1 patient. The mean age was 62.8 (range, 16–85 years); there were 13 women and 3 men. The mean interval between TKA and periprosthetic fracture was 46.6 months (range, 1–150 months).

There were 6 type II fractures (adjacent to the prosthetic stem) and 10 type III (distal to the stem) according to the Felix classification [7] (Fig. 1). Felix type I fractures and fractures with component loosening requiring revision arthroplasty (2 cases during the study period) were excluded. The tibial stem was short in 13 patients and long in 3 patients. The mean lengths of short and long stems were 35.6 mm (range, 31–40 mm) and 141.7 mm (range, 110–165 mm), respectively. Regarding fracture level, there were 10 in the proximal metaphysis and 6 in the diaphysis. All were closed fractures, except 1 with grade IIIA open fracture.

### 2.1. Operative technique

Before surgery, the appropriate length of plate was chosen for internal fixation: either pre-shaped locking compression plate – proximal lateral tibia (LCP-PLT; Synthes, Oberdorf, Switzerland), locking compression plate – medial proximal tibia (LCP-MPT; Synthes), or narrow locking compression plate (narrow LCP; Synthes). Plate length was determined so that 4 screws could be inserted on each side. Plate selection was mainly determined by the fracture level; a pre-shaped LCP was used for proximal metaphyseal fractures and a narrow LCP was used for diaphyseal fractures. The plating side (medial and/or lateral) was determined by the kind of tibial prosthesis, the level of the fracture, and the soft tissue status. If the fixation of proximal segment was weak with an insufficient number of screws, an additional plate was fixed on the other side.

In this series, double plates (Fig. 2) were used in 10 patients and a single plate (Fig. 3) in 6 patients (4 medial and 2 lateral).

The ipsilateral iliac crest and the entire lower limb were draped. A tourniquet was used if needed to reduce bleeding. Fluoroscopy was used to assess fracture reduction and plate fixation intra-operatively. Before plate fixation, closed reduction was usually achieved by manual traction. Various techniques were used for adjustment and maintenance of reduction: Schanz pin joystick, reduction screw, or temporary external fixator. The fracture site was not exposed during the reduction procedure.

Then, a linear incision of approximately 5 cm was made over the proximal (medial and/or lateral) aspect of the tibia and a 2–3 cm incision over the distal end of the plate. A medial subcutaneous or lateral submuscular tunnel was drilled on the medial and/or lateral side, and the chosen plate was inserted through the tunnel. Plate position and reduction status were evaluated by fluoroscopy in the coronal and sagittal planes, and the screws were inserted in the locking plate to avoid contact with the pre-positioned tibial component.

### 2.2. Postoperative care

Quadriceps strengthening and continuous passive motion of the knee were performed on the second postoperative day. After discharge, the patients were encouraged to perform straight leg-raising exercises and active motion of the knee. Full weight-bearing was permitted after healing of the fracture site.

### 2.3. Evaluation

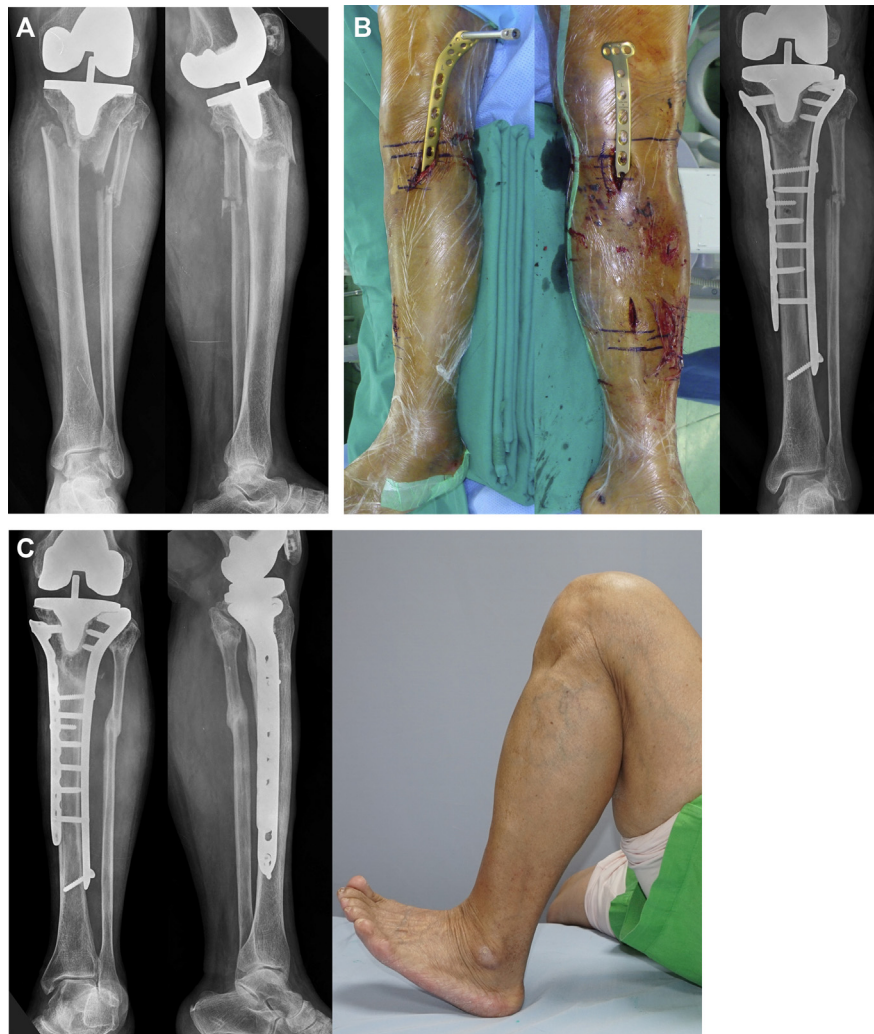
Mean follow-up was 29.7 months (range, 12–102 months). Radiographic evaluation used anteroposterior, lateral and oblique views, taken every 4 weeks until continuous callus formation. Callus formation in 3/4 cortices and fading of fracture lines on radiographs were considered signs of fracture union. A weight-bearing full-length anteroposterior lower limb radiograph was also performed to evaluate alignment. The radiographic results were assessed according to time for union and alignment, using the mechanical femorotibial angle (mFTA) on radiographs at follow-up.

Clinical outcome was evaluated on knee range of motion (ROM), functional activity data including ambulatory status (non-ambulatory, home ambulatory, or community ambulatory), and the need for assist devices (no assist, cane, walker, or wheelchair) pre-injury and at final follow-up, and the Knee Society scores.

Complications were assessed throughout the follow-up period: implant failure, non-union, malunion, and infection. Failure was defined as cases that required a secondary procedure to achieve union due to these complications. Proximal fixation stability was analyzed in cases of failure in the proximal segment. The number of cortices giving purchase to proximal screws was correlated to failure. The number of cortices giving screw purchase was defined as follows: a unicortical screw in the diaphyseal area with screw length less than two-thirds of the canal diameter in the metaphyseal area counted as 1 cortex; and a bicortical screw in the diaphyseal area with screw length more than two-thirds of the canal diameter in the metaphyseal area counted as 2 cortices.

### 2.4. Statistical analysis

Fisher's exact test was used to assess correlation between failure and risk factors: fracture type and location, number of plates, and number of cortices giving proximal screw purchase. The statistical significance threshold was set at  $P < 0.05$ . All statistical analyses were performed with SPSS software version 19.0 (IBM Co., Armonk, NY, USA).



**Fig. 2.** A. A 75-year-old woman with a Felix type II fracture in the metaphyseal area. B. Lateral submuscular plating with LCP-PLT and medial subcutaneous plating with LCP-MTP were performed using a MIPO technique. C. Fracture union at 1-year follow-up with excellent functional outcome.

### 3. Results

Fourteen of the 16 fractures achieved primary union at a mean 17.1 weeks (range, 14–24 weeks). Fifteen showed acceptable alignment (mean mFTA,  $1.4^\circ$  [range,  $-2.3^\circ$  to  $4.5^\circ$ ]), except for 1 case of varus malunion. There were no cases of secondary implant loosening.

Two failures needed a secondary procedure. One case (Felix type III, metaphyseal fracture, single plate) showed delayed union with secondary implant failure at 22 weeks, necessitating double plating and bone grafting (Fig. 4). The other case (Felix type III, diaphysis, single plate) had a superficial infection, with soft tissue irritation caused by loosened screws at the proximal side due to insufficient stability; the plate was removed before union to treat the superficial infection and secondary varus malunion ensued (Fig. 5). A third patient, with type II diabetes, experienced superficial infection during the early postoperative period; oral antibiotics successfully healed the wound, without progression to deep infection.

The mean ROM was  $108.8^\circ$  (range,  $15^\circ$ – $135^\circ$ ) at final follow-up. The patient with varus malunion had decreased activity. She was ambulatory in the house and did not need an assist device; however, she required a cane for house ambulation at the time final follow-up. Except for this patient, the other 15 had returned to their pre-injury ambulatory status at final follow-up. None needed an additional assist device. At final follow-up, mean Knee Society

knee and function scores were 88.9 (range, 77–100) and 83.3 (range, 60–100), respectively.

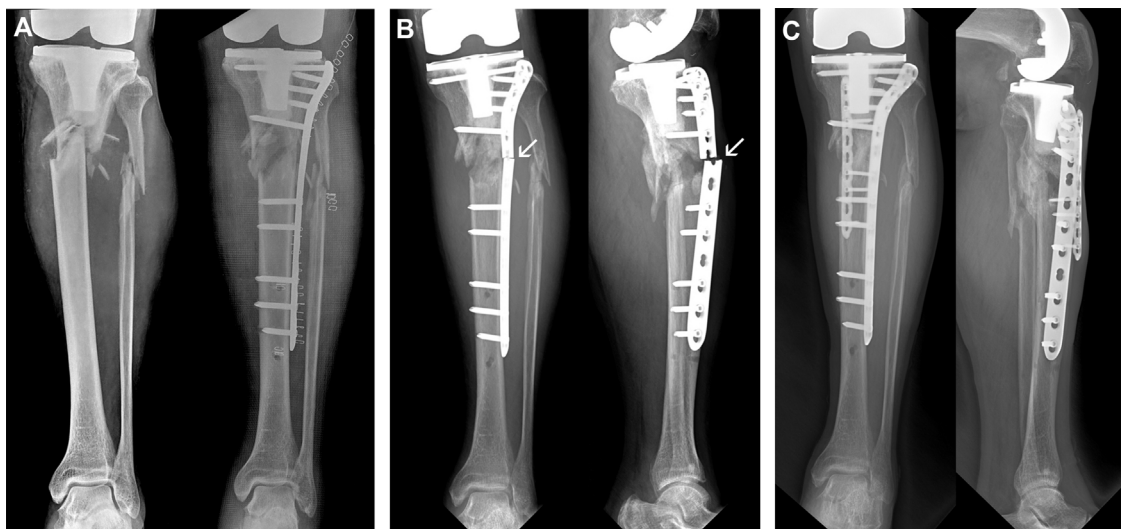
Failures were analyzed for risk factors. Regarding the number of plates used, there were 2 failures in the 6 patients in the single plate group, and none in the 10 patients in the double plate group ( $P=0.125$ , Fisher exact test). Felix type and fracture location also did not affect the final outcome or complications ( $P=0.5$ , and  $P=1.0$ , Fisher exact test). The two failures occurred in the proximal segment and the stability of proximal fixation was analyzed. Knees with fewer than 8 cortices giving purchase to screws in the proximal segment showed higher failure rates ( $P=0.025$ , Fisher exact test).

### 4. Discussion

Satisfactory radiographic and clinical results were obtained in periprosthetic tibial fracture after treatment with MIPO using locking plates, confirming the study hypothesis. Insufficient stability in the proximal segment is an important factor for fixation failure. A single locking plate usually provided good results in diaphyseal fracture, achieving a sufficient length of plate and spacing of screws. In metaphyseal fractures, double plates were needed to overcome the difficulty of screw fixation due to lack of bone stock. We also think the minimally invasive approach improved the union rate and lowered the infection rate, considering the high rate of union



**Fig. 3.** A. A 77-year-old woman with a tibial fracture distal to the long stem of the tibial component. B. Using the MIPO technique, medial plating with narrow LCP was performed. The proximal fixation construct had 4 bicortical screws with a sufficient working length from the fracture site. C. Fracture union at 1-year follow-up with excellent functional outcome.



**Fig. 4.** A. A 69-year-old man with a Felix type II fracture in the metaphyseal area fixed with a lateral locking plate (LCP-PLT). B. Non-union with secondary implant failure (arrows) after 22 weeks' FU. C. At 10 months after revision surgery (double plating and bone graft), fracture healing with satisfactory alignment.



**Fig. 5.** A. A 77-year-old woman with a Felix type III fracture in the diaphyseal area fixed by a medial locking plate (metaphyseal LCP). B. Superficial infection with redness and heat was associated with soft tissue irritation caused by loosened screws, with osteolysis (arrows) on the proximal side after 4 months. The plate was therefore removed before fracture union. C. At 3 years after plate removal, varus malunion was finally obtained.

and absence of deep infection in the series. Additionally, in contrast with the present series, revision TKA must be considered if the tibial component is unstable in periprosthetic fracture [5,7]. Thus, it is essential to assess the stability of the tibial component in periprosthetic tibial fracture.

Compared to standard plates, locking plates are an attractive option because of their improved axial and angular stability [18]. However, they may not always ensure stability in periprosthetic tibial fractures, for several reasons. As shown in the present series, most cases involved fracture in the metaphyseal area, where the pre-existing tibial component is very close to the fracture. This limited space for screw fixation in the proximal segment is the main obstacle to successful fixation in metaphyseal fractures. Because most TKA patients are elderly, with activities involving only low weights, osteoporotic bone around the prosthesis may be used for inferior screw purchase, even with locking screws. Even without a tibial prosthetic component, very high-level fracture or comminuted fracture of the proximal tibia showed failure of fixation with a single lateral locking plate [19,20]. In our early experience, we also encountered a case of failure with a single lateral locking plate. However, 9 other cases of metaphyseal fracture, fixed with lateral and medial plates, had successful healing without reduction loss or failure.

Short screw length in proximal fixation is a significant factor for fixation failure. Dougherty et al. reported that unicortical screws had less bone purchase and could lead to reduction loss in proximal tibial fracture [21]. Although the lengths of bicortical and unicortical screws were somewhat different, a long screw may be critical in the proximal segment of periprosthetic fracture. Again, double plating may be necessary to increase bone purchase in metaphyseal fracture.

In diaphyseal periprosthetic fracture, a single locking plate can achieve sufficient stability, as the space available for plate fixation is larger than in metaphyseal fracture. However, it is still important to fix a plate that is as long as possible, because biomechanical stiffness is weaker than that with an intramedullary nail [22]. Avoiding the stem of the tibial component is important in fixing the bicortical screws in the proximal segment. Therefore, careful preoperative planning is essential to successful outcome, and the remaining bone area must be analyzed preoperatively. In one case of failure involving a diaphyseal fracture in the present series, the working length

and bicortical screws of the proximal fixation construct were relatively short compared to the other cases.

Biologically, a minimally invasive approach induces fewer soft tissue complications [15,17]. Knee arthroplasty is usually performed through a midline approach. However, the previous incision may not be adequate for fixing double plates, because of the high risk of wound dehiscence. In the present study, MIPO incisions led to only 2 cases of superficial infection and none of deep infection, even in the patient with diabetes. This biological approach ensured a high rate of union, with 14 of the 16 cases achieving primary union without bone graft.

There are several limitations to the present study: retrospective design, small number of cases, and short follow-up. The study treatment was not compared with other treatment options, such as conventional open plating. We tried to analyze the association between complications rates and the number of cortices giving purchase to proximal screws on logistic regression, but there was no convergence of models due to the small number of cases; Fisher's exact test was finally used for analysis. Further large-scale comparative studies should be conducted, with longer follow-up.

## 5. Conclusion

MIPO with locking plates can provide satisfactory results in periprosthetic tibial fracture after TKA. However, the limited space for fixation around the tibial component of the prosthesis is an obstacle. Sufficient numbers of screws in double plates in metaphyseal fracture or selection of a long plate for diaphyseal fracture may be helpful options to achieve stable fixation of the proximal segment.

## Funding

This research was supported by Kyungpook National University Bokhyeon Research Fund, 2016

## Disclosure of interest

The authors declare that they have no competing interest.

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