

# Minimally Invasive Plate Osteosynthesis for Open Fractures of the Proximal Tibia

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**Background:** Relatively few studies have addressed plate osteosynthesis for open proximal tibial fractures by now. The purpose of this study was to assess the results of minimally invasive plate osteosynthesis (MIPO) for open fractures of the proximal tibia.

**Methods:** Thirty-four patients with an open proximal tibial fracture were treated by MIPO. Thirty of these, who followed for over 1 year, constituted the subject of this retrospective study. According to the AO Foundation and Orthopaedic Trauma Association (AO-OTA) classification, there were 3 patients of type 41-C, 6 of type 42-A, 8 of type 42-B, and 13 of type 42-C. In terms of the Gustilo and Anderson's open fracture grading system, 11 patients were of grade I, 6 were of grade II, and 13 were of grade III (III-A, 6; III-B, 6; III-C, 1). After thorough debridement and wound cleansing, when necessary, a soft tissue flap was placed. Primary MIPO (simultaneous plate fixation with soft tissue procedures) was performed in 18 patients, and staged MIPO (temporary external fixation followed by soft tissue procedures and subsequent conversion to plate fixation after soft tissue healing) was performed in 12 patients. Results were assessed according to the achievement and time to union, complications (including infections), and function of the knee joint using Knee Society scores. Statistical analysis was performed to identify factors influencing results.

**Results:** Primary union was achieved by 24 of the 30 study subjects. Early bone grafting was performed in 6 cases with a massive initial bone defect expected to result in non-union. No patient had malalignment greater than 10°. The mean Knee Society score was 88.7 at final follow-up visits, 23 patients achieved an excellent result, and 7 a good result. There were 3 superficial and 5 deep infections, but none required early implant removal. Functional results were similar for primary and staged MIPO ( $p = 0.113$ ). Fracture pattern ( $p = 0.089$ ) and open fracture grade ( $p = 0.079$ ) were not found to influence the results.

**Conclusions:** If soft tissue coverage is adequately performed, MIPO could be regarded as an acceptable method for the treatment of open proximal tibial fracture.

**Keywords:** *Proximal, Tibia, Open fracture, Minimally invasive surgical procedure, Plate, Osteosynthesis*

Fractures of the proximal tibia are serious injuries and present a treatment challenge. Because they result from high energy injuries, damage is usually extensive and open fractures, compartment syndromes, and vessel injuries are commonly associated.<sup>1,2)</sup> Traditional open plating presents complications, such as, infection and delayed soft tissue breakdown, despite developments over past decades. Due

to the emphasis now placed on soft tissue care, it is known that intramedullary nails and external fixators present lower infection risks and cause no more soft tissue damage than conventional compression plating techniques.<sup>3-6)</sup> Nevertheless, intramedullary nails and external fixators may be associated with higher risks of malunion or non-union.

Minimal invasive plate osteosynthesis (MIPO) using a locking plate has become alternative technique for proximal tibial fractures.<sup>7-10)</sup> The preservation of periosteal blood supply allowed by MIPO offers a clear biological advantage over traditional plating, because it reduces iatrogenic damage to surrounding soft tissues. However, little is known about the efficacy and the indications for MIPO

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in patients with an open fracture of the proximal tibia. The purpose of this study was to assess the results and the efficacy of MIPO for open fractures of the proximal tibia.

## METHODS

Between January 2005 and February 2010, thirty-four

**Table 1.** Background Information on the Patients Enrolled in the Study

Case No.	Age	Cause	AO-OTA class	Open grade	Plate location	Primary or staged	Union time	ROM	Knee Society score	Function	Alignment	Complication
1	44	TA	41-C	II	Lateral	Primary	18	0-100	84	Good	Neutral	
2	41	TA	42-B	III-A	Lateral	Staged	20	Full	95	Excellent	Neutral	
3	55	TA	42-C	I	Both	Primary	18	Full	90	Excellent	Neutral	
4	40	TA	42-A	I	Lateral	Primary	16	0-110	94	Excellent	Neutral	
5	36	F/D	42-B	I	Lateral	Staged	16	Full	90	Excellent	Neutral	
6	31	TA	41-C	II	Both	Staged	BG	Full	83	Good	6° Var	Deep inf.
7	37	TA	42-A	I	Lateral	Primary	20	Full	95	Excellent	Neutral	
8	26	TA	42-C	III-B	Lateral	Staged	20	Full	94	Excellent	Neutral	Supf. inf.
9	41	TA	42-B	III-B	Lateral	Staged	18	Full	90	Excellent	Neutral	
10	46	TA	42-B	III-B	Lateral	Primary	18	Full	94	Excellent	Neutral	
11	47	TA	42-C	II	Lateral	Primary	20	Full	90	Excellent	5° Recur	
12	53	TA	42-C	II	Both	Staged	18	Full	91	Excellent	Neutral	
13	45	TA	42-C	II	Lateral	Primary	18	Full	89	Excellent	4° Val	
14	51	TA	42-C	III-B	Lateral	Primary	BG	0-110	84	Good	4° Val	
15	33	Crushing	41-C	I	Both	Primary	20	Full	92	Excellent	Neutral	
16	47	TA	42-A	II	Lateral	Primary	18	Full	92	Excellent	Neutral	
17	43	TA	42-A	I	Lateral	Primary	18	Full	90	Excellent	Neutral	
18	56	Crushing	42-C	III-C	Lateral	Staged	BG	0-110	84	Good	3° Var	Supf. inf.
19	52	TA	42-C	III-A	Both	Staged	22	Full	83	Good	5° Val	Deep inf.
20	41	TA	42-B	I	Lateral	Primary	20	Full	90	Excellent	Neutral	
21	49	TA	42-C	I	Lateral	Primary	BG	Full	87	Excellent	4° Val	
22	48	TA	42-C	I	Both	Staged	BG	0-120	86	Excellent	3° Var	Deep inf.
23	69	Crushing	42-C	III-B	Lateral	Primary	BG	0-120	89	Excellent	Neutral	
24	26	Crushing	42-B	I	Lateral	Primary	22	Full	90	Excellent	Neutral	
25	69	TA	42-C	III-B	Lateral	Primary	20	0-110	82	Good	6° Val	Supf. inf.
26	50	TA	42-A	III-A	Lateral	Staged	16	Full	92	Excellent	5° Recur	Deep inf.
27	54	TA	42-C	III-A	Lateral	Staged	22	Full	86	Excellent	3° Var	Deep inf.
28	24	TA	42-A	I	Lateral	Primary	18	Full	94	Excellent	Neutral	
29	51	Crushing	42-B	III-A	Lateral	Staged	22	Full	95	Excellent	Neutral	
30	27	TA	42-B	III-A	Lateral	Primary	28	0-90	75	Good	3° Val	

AO-OTA: AO Foundation and Orthopaedic Trauma Association, ROM: ranges of motion, TA: traffic accident, F/D: fall down, BG: bone graft, Var: varus, Val: valgus, Recur: recurvatum, Supf.: superficial, inf.: infection.

patients with an open fracture of the proximal tibia were treated using the MIPO technique at our institution; of these 34 patients, 30 were followed for over 1 year. There were 24 men and 6 women of overall mean age 44.4 years (range, 24 to 69 years). The mechanisms of injuries were; a traffic accident in 24, a crushing injury in 5, and a fall from a substantial height in one. Eighteen of the 30 had an associated injury or fracture. The institution approved the study, which was conducted in strict adherence with established guidelines for treatment of subjects, and written informed consent was obtained from each patient.

According to the AO Foundation and Orthopaedic Trauma Association (AO-OTA) classification, 3 patients were of type 41-C, 6 were of type 42-A, 8 were of type 42-B, and 13 patients were of type 42-C. Open fractures were classified using the Gustilo-Anderson classification, and there were 11 patients with grade I, 6 patients with grade II, and 13 patients with grade III (III-A, 6; III-B, 6; III-C, 1) (Table 1).

All patients were treated initially by radical wound debridement. If necessary, early soft tissue coverage was performed using a rotational gastrocnemius or soleus muscle flap. One case with a grade III-C open fracture underwent wound irrigation and debridement followed by vascular bypass surgery to re-establish arterial flow.

Two types of anatomical pre-contoured locking plates (locking compression plate-proximal lateral tibia [LCP-PLT], Synthes, West Chester, PA, USA; Zimmer periarticular locking plate [ZPLP], Zimmer, Warsaw, IN, USA) were used. LCP-PLT, which is composed of titanium alloy, has combi-holes, which allows placing either conventional or locking screw in every hole. On the other hand, ZPLP, stainless steel construct, has separated screw holes for conventional and locking screw, and locking screws in metaphyseal region have cannula inside that they can be placed accurately through the guide pins. All locking plates were placed on the lateral side of the proximal tibia. Plate lengths were selected to obtain a minimum of three good bicortical screw purchases distal to the fracture. An additional medial locking plate was fixed using the MIPO technique, if needed. Great care was taken to handle soft tissue gently and to minimize soft tissue damage.

When the open wound did not involve the lateral side of proximal tibia or the soft tissue or flap was considered sufficient (Figs. 1 and 2), we performed simultaneous plate fixation with a soft tissue procedure, defined as primary MIPO. However, in cases with inadequate soft tissue coverage, given the need for a brief operation due to general medical condition, and the presence of a severely contaminated wound, patients were treated by staged

MIPO. Temporary external fixation was done with soft tissue procedure initially, and subsequent definitive treatment was performed with a locking plate using the MIPO technique after soft tissue reactions have subsided. During our initial experiences, a staged procedure was adopted routinely (Figs. 3 and 4), but as experience accumulated, primary MIPO was performed predominantly.

### Postoperative Care and Assessment

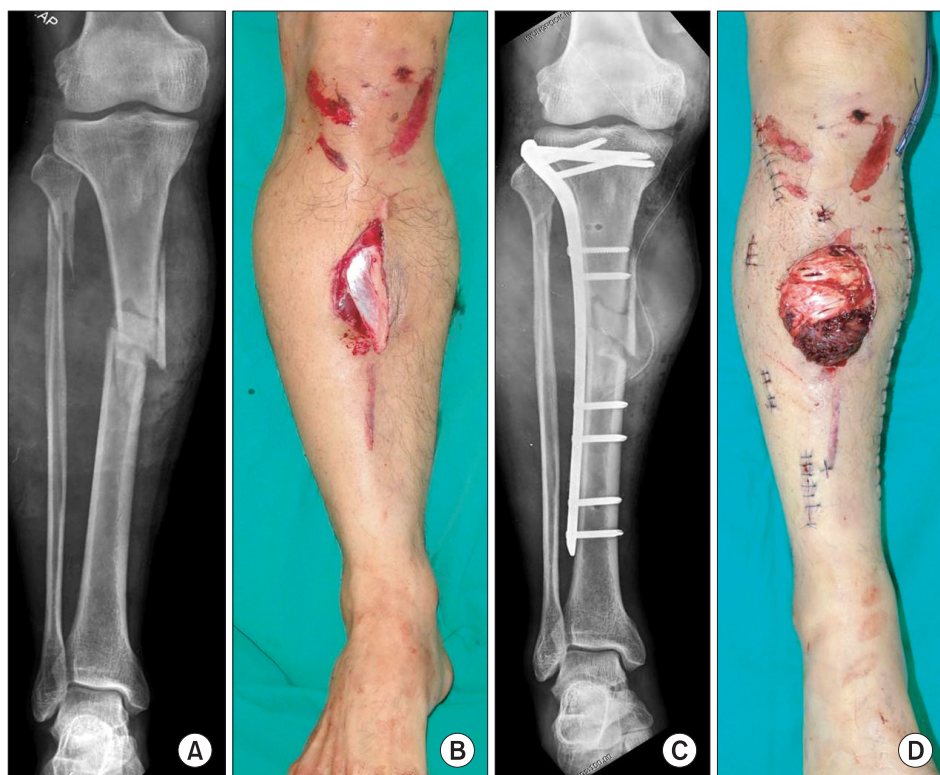
Rehabilitation was started on the second postoperative day with quadriceps setting and continuous passive motion of the knee joints. After discharge, the patients were encouraged to perform straight leg-raising exercise and active flexion of their knees and ankles, from tolerable range of motion followed by gradual increase of range similar to unaffected limb. Toe-touch weight bearing with crutches was started at approximately 4 weeks postoperatively, and limited weight bearing was allowed only after obtaining radiographic evidence of healing. Routine follow-up radiographs were obtained every 6-8 weeks until solid continuous callus formation was observed; callus formation on 3/4 cortices and radiographic evidence of fracture line fading were considered signs of fracture union. Frontal and sagittal plane angulations were assessed on anteroposterior and lateral plain radiographs obtained immediately after surgery and at final follow-up visits. Knee and ankle ranges of motion, limb rotations and alignments, and signs of implant-associated were checked at all follow-up visits. Final clinical outcomes were evaluated using Knee Society clinical rating scores,<sup>11)</sup> where excellent means 85-100; good, 70-84; fair, 60-69; and poor < 60.

Complications were recorded as union or soft tissue related, including infection. A superficial infection was defined as local cellulitis with or without serous discharge treated with oral antibiotics. Any infection that warranted operative debridement was considered a deep infection.<sup>12)</sup>

The chi-square test and regression analysis were used to determine the natures of relations between final clinical outcomes, complications, and possible influencing factors, such as fracture pattern (AO-OTA), open fracture grade (Gustilo-Anderson), operative method (primary or staged MIPO), and type of implant used. The analysis was conducted using SPSS ver. 17.0 (SPSS Inc., Chicago, IL, USA), and statistical significance was accepted for  $p$ -values < 0.05.

## RESULTS

Eighteen patients were treated by primary MIPO, and the other 12 were treated by staged MIPO. In the staged MIPO



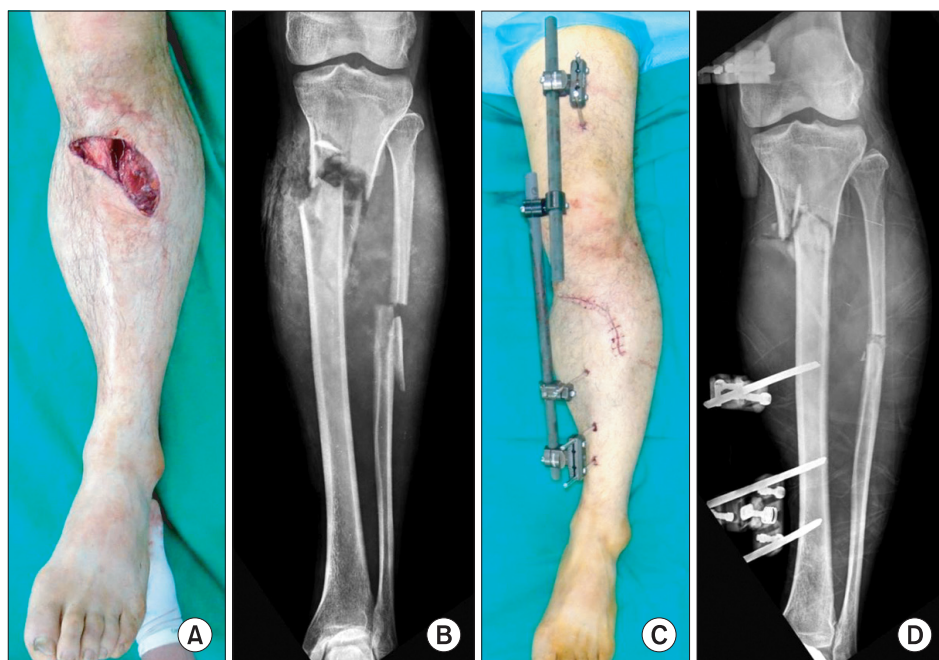
**Fig. 1.** (A, B) A 53-year-old male patient sustained type III-B open proximal tibial fracture. (C, D) Primary minimal invasive plate osteosynthesis was performed and followed by rotational gastrocnemius muscle flap.



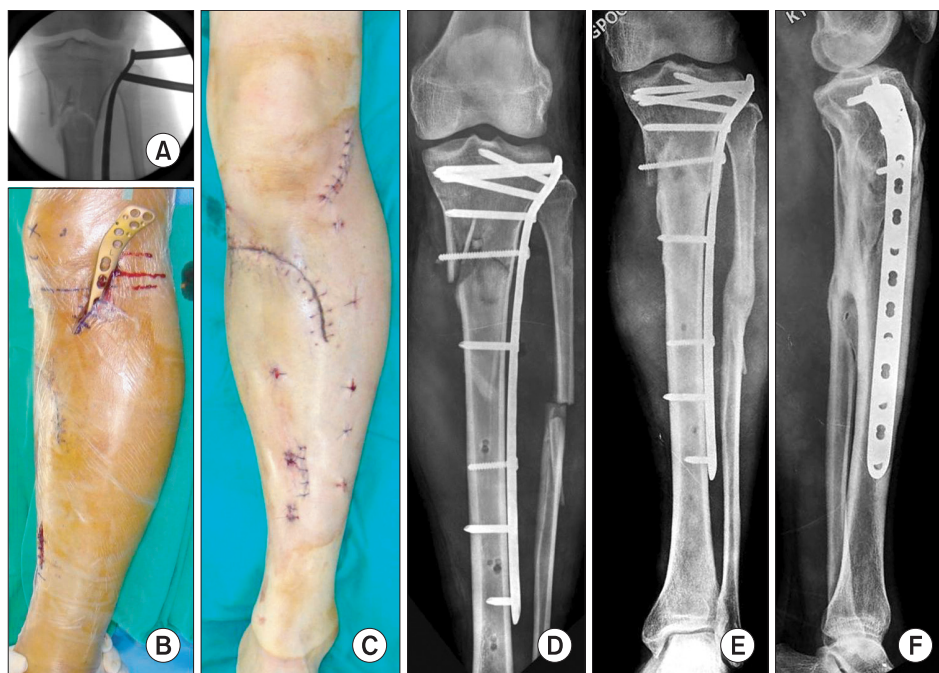
**Fig. 2.** Follow-up radiograph after 1 year shows solid union of fracture (A, B) with an excellent function (C, D).

group, conversion to definite fixation with a locking plate was performed at an average of 30 days after initial surgery (range, 8 to 61 days).

Primary bony union was achieved by 24 (80%) of 30 patients at an overall average of 19.4 weeks post-incident (range, 16 to 28 weeks). There were 6 cases of expectant



**Fig. 3.** (A, B) A 51-year-old male patient suffered from type III-A open proximal tibial fracture. (C, D) Knee bridging external fixation was performed after wound debridement and closure on that day.



**Fig. 4.** (A-C) After wound was healed at 13 days, minimal invasive plate osteosynthesis was done. (D) Satisfactory alignment was achieved. (E, F) Follow-up radiograph after 3 years shows complete union of fracture.

non-union due to large initial bone defect, requiring early bone graft; 3 in the primary MIPO group and 3 in the staged MIPO group. All six were AO-OTA type C fractures (41-C, 1; 42-C, 5), and in terms of open grade, 2 were grade I, 1 was grade II, and 3 were grade III.

No malalignment or angulation of more than 10° occurred in any planes; ten patients had a minimal angulation of -6° to 4° in the coronal plane and two patients

showed angulation of -5° in the sagittal plane. However, because these extents were negligible and did not influence knee joint function, no correction was needed. The other 18 patients showed neutral alignment.

Functional results were excellent in 23 (76.7%) patients and good in 7 (24.3%). Mean Knee Society score at final follow-up was 89 (range, 75 to 95). Functional outcome was not related to fracture pattern (linear regres-

sion test,  $p = 0.089$ ), open grade (multiple regression test,  $p = 0.079$ ), operative method (multiple regression test,  $p = 0.113$ ) or type of implant used (chi-square test,  $p = 0.242$ ).

Postoperative infection occurred in 8 (26.7%) cases; superficial infection in 3 (10%) and deep infection in 5 (16.7%). Two cases of infection occurred in open grade I, two in grade II, and 6 in grade III. Low grade open fractures (open grades I and II) showed a lower infection rate (11.8%) than high grade open fractures (open grade III, 46.2%) (chi-square test,  $p = 0.049$ ). With regard to operative method, 1 infection was occurred in group treated by primary MIPO, and 7 by staged MIPO. The primary MIPO group (5.5%) had a lower infection rate than the staged MIPO group (53.8%) (multiple logistic regression test,  $p = 0.01$ ). However, no patient required early implant removal to control infection before union.

## DISCUSSION

Fractures of the proximal tibia are the results of high-energy injuries, and because of the lack of soft tissue coverage in this region, it is vulnerable and open fractures are commonly encountered. In such cases, the treatment of damaged soft tissues is of primary concern.

During open reduction, the fracture site is not always easily approached because of the open wound and the need to avoid further damage to already injured soft tissues. Moreover, disturbance of blood supply to the fracture site cannot be avoided, and thus, non-union and infection occur with high incidence. The rate of deep infection has been reported to range from 11% to 80%, and most authors have reporting rates of 18% or more.<sup>4,13</sup>

As a result of the problems associated with open reduction and plating described above, recent studies have addressed the use of external fixators,<sup>6,14,15</sup> but although the incidence of infection is clearly better than that of plating, it is not always easy to reduce and adequately maintain fractures, especially fractures with articular involvement or comminuted proximal tibial fractures. Furthermore, mal-union, joint motion limitations, and patient inconvenience are main concerns when an external fixator is used, and pin tract infections remain problematic.

Recently, the use of intramedullary nails as a treatment for open tibial fractures was advocated.<sup>5,16,17</sup> This minimally invasive technique can be performed without further stripping of the already damaged soft tissue envelope, and provides a load sharing device with superior stiffness. However, it presents the considerable in open fractures of infection spread into the medullary canal. Whittle et al.<sup>5</sup> reported infection rates for all open tibial fractures

of from 3% to 8%, with a rate of 12% for III-A and 25% for III-B treated by the intramedullary nails. Moreover, the intramedullary nailing of proximal tibial fractures with a short proximal segment presents an additional challenge, as higher incidences of mal-reduction resulting in non-union have been reported.<sup>18-20</sup> Furthermore, nailing is contraindicated for fractures with intra-articular involvement. These characteristics may make locked plating as an attractive option for treating open fractures of the proximal tibia. Along with the development of MIPO, the popularity of locking plates for the treatment of these complex fractures has significantly increased, presumably because they do not require large incisions or soft tissue stripping, and thus, minimize subsequent failures due to infection and non-union. Furthermore, locking plates do not disturb either endosteal or periosteal blood supplies to fracture sites, and thus, reduce the risks of resultant infection and non-union. Stannard et al.<sup>21</sup> reported that the less-invasive stabilization system (LISS) is an acceptable alternative for treatment of open proximal tibial fractures with a 5.8% deep infection rate. In the present study, the deep infection rate was 16.7% but no severe complication requiring a procedure like amputation or early implant removal occurred. However, we did note that low-grade open fractures had a significantly lower infection rate.

No comparative series has been conducted to evaluate operative methods for open fractures. Nevertheless, the staged management of open fractures of the proximal tibia has been reported to provide a safe and useful strategy,<sup>22,23</sup> but it requires a secondary procedure for conversion to internal fixation. Hence, we sought to identify indications for primary MIPO. In the present study, the primary MIPO group had a significantly lower infection rate than the staged MIPO group. Although there might be some controversies, we attribute this result to more severe initial soft tissue damage in the staged group. Patients in the staged MIPO group had so serious initial soft tissue injuries that staged procedure could not be avoided. However, no significant difference was observed between operative methods (primary or staged MIPO) in terms of bony union or functional result, which demonstrates that primary and staged MIPO have equivalent outcomes. Accordingly, we are of the opinion that primary MIPO is an alternative option if adequate soft tissue reconstruction is possible. We think that additional prospective, and randomized comparative studies with large cohort size are needed to fully describe the role of this method.

In open fractures of the proximal tibia, the open wound is usually located on medial side, because the tibia is rotated externally while walking, which makes its medial

side more vulnerable due to the lack of a soft tissue envelope. However, the MIPO procedure is usually performed on the lateral side, and thus, causes no further damage to already injured medial soft tissue and periosteum. On the other hand, it is thought to be difficult to carry out primary MIPO when the open wound is on the lateral side of the tibia.

The present study is limited by a small number of patients, the inclusion of mixed open fracture types, and by its retrospective nature. Thus, we suggest that further research, including prospective study, on the efficacy of

primary MIPO for the treatment of open grade III fractures of the proximal tibia.

In conclusion, If soft tissue reconstruction can be performed adequately, MIPO may provide acceptable means of treating open fractures of the proximal tibia.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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