



ORIGINAL ARTICLE

Analysis of complications and clinical outcomes in the treatment of segmental tibial fractures according to the method of internal fixation



Hoon Sang Sohn ^a, Jun Young Chung ^b, Hyung Keun Song ^{b,*}

^a Department of Orthopaedic Surgery, Yonsei University Wonju College of Medicine, South Korea

^b Department of Orthopedic Surgery, Ajou University School of Medicine, South Korea

Received 27 September 2018; received in revised form 6 November 2018; accepted 8 November 2018
Available online 22 November 2018

KEYWORDS

Complication;
Intramedullary
nailing;
MIPO;
Segmental tibial
fractures

Summary *Background/Objective:* We compared and analysed not only the clinical and radiological results of surgery but also the complications according to the definitive fixation method.

Methods: We retrospectively reviewed the medical records and radiographs of all segmental tibial fracture patients treated with either intramedullary nailing or minimally invasive plate osteosynthesis between 2010 and 2017. We enrolled 69 patients.

Results: The patients' mean age was 48.6 years (25–74). Forty-nine patients had open fractures (Type I, 20; Type II, 9; Type III, 20) and six had acute compartment syndrome. The initial stabilisation method was intramedullary nailing in 28 patients (40.6%). The time to definitive fixation was longer in the minimally invasive plate osteosynthesis group (mean, 8.8 days; range, 0–27) than that in the intramedullary nailing group (mean, 3.9 days; range, 0–35), with a statistically significant difference ($p = 0.001$). Thirteen patients developed nonunion (five with minimally invasive plate osteosynthesis and eight with intramedullary nailing, $p = 0.076$). Complications were noted in 18 patients (26.1%), including five with infection. There was no significant difference in the clinical and radiological outcomes according to the definitive fixation method. A multivariate logistic regression analysis indicated that age (odds ratio, 1.112; 95% confidence interval, 1.022–1.210; $p = 0.013$) and smoking (odds ratio, 13.976; 95% confidence interval, 1.599–122.150; $p = 0.017$) correlated with the occurrence of complications.

Conclusions: The results of our study suggest that if soft-tissue handling and restoration of bony alignment are successful, both intramedullary nailing and minimally invasive plate osteosynthesis will be effective treatment methods for segmental tibial fractures.

* Corresponding author. Department of Orthopedic Surgery, Ajou University School of Medicine, 164 World Cup-ro, Yongtong-gu, 16499 Suwon, South Korea. Fax: +82 31 219 5229.

E-mail address: ostrauma@ajou.ac.kr (H.K. Song).

1. Background

Segmental tibial fractures account for 12% of the total number of tibial shaft fractures.¹ Most are caused by high-energy damage and are characterised by a wide zone of soft-tissue damage. Fractures are often accompanied by compartment syndrome, and open fractures account for 50% of these cases. The incidence of complications such as nonunion, infection, and amputation is very high, and the treatment of open fractures both non-surgically and surgically has a poorer clinical outcome than that of simple tibial fractures.^{1,2}

Segmental tibial fractures are associated with high-energy injury, and the high incidence of complications is caused by impairment of the blood supply due to damage of the soft tissue around the tibia bone.³ No definitive treatment has been established to prevent such complications, and many treatments have been proposed, ranging from non-surgical to surgical treatment.^{1,4–7} Intramedullary nailing (IMN) is widely used because it provides biomechanical stability, can protect the surrounding soft tissues through indirect reduction, and indirectly induces bone healing.⁸

However, treating segmental tibial fractures with IMN requires skilled techniques, and various techniques, including blocking screws, additional plates, and distractors, should be used to maintain fracture reduction and avoid malalignment.⁹

Since the minimally invasive plate osteosynthesis (MIPO) technique was introduced to treat lower extremity fractures, there have been attempts to apply it to segmental tibial fractures.^{10,11} Although the authors of previous studies reported good results using the MIPO technique to treat segmental tibial fractures,^{10,11} its effectiveness compared with the IMN technique and whether it is a therapeutic alternative to IMN are still controversial.¹ However, no studies have compared IMN and MIPO in the treatment of segmental tibial fractures, compared with simple fractures of other sites.

The aim of this study was to compare the clinical and radiological results of surgery according to the methods of primary bony stabilisation and definitive fixation in the treatment of segmental tibial fractures and related factors.

2. Methods

2.1. Ethics approval and consent to participate

This study was approved by our institutional review board (IRB No. MED-MDB-15-311). Informed consent was not required due to the retrospective nature of study.

2.2. Study design and patients

We retrospectively selected data from our institution's orthopaedic trauma database that were collected

prospectively, from October 2010 to January 2017, on patients who were seen at the two level I trauma centres to which we belong. A total of 1844 patients with tibial fractures visited these trauma centres during this period.

The inclusion criteria of this research study were patients who were skeletally mature (age > 18 years); those with displaced, separate, and proximal and distal tibia shaft fractures (AO/Orthopaedic Trauma Association [OTA] C2-type fractures); those who underwent an operation with either MIPO or IMN; and those who were followed up for a minimum of 1 year. We excluded patients with a prior amputation, Gustilo-Anderson type IIIc open fracture, significant brain injury, spinal cord deficit, and pathologic fracture.

A total of 69 patients who met the above criteria were included in this research study. The patients' electronic medical records and radiographs were reviewed. We collected data including age, sex, mechanism of injury, AO/OTA fracture classification, Gustilo-Anderson open fracture grade, operation details, and complication details.

Of these 69 patients, 53 were men and 16 were women. The average age of the patients was 48.6 years (range, 25–74). Of them, 49 had open fractures (Type I, 20; Type II, 9; Type III, 20) and six were diagnosed with acute compartment syndrome.

2.3. Surgical procedures

All operations were performed by two orthopaedic surgeons who specialise in trauma care for more than five years in a Level I Trauma Centre among the authors of this study.

Injuries with a significantly damaged soft tissue that were deemed unsafe for primary definitive fixation were treated with temporary spanning external fixation. Of all patients, 49 had an open fracture. Of these, 20 had type III open fracture. During the initial surgical intervention, three patients with type IIIA underwent initial bony stabilisation with IMN and 17 with type IIIB underwent spanning external fixation. In case of external fixation, when the patient's soft tissues and whole body were judged to be stabilised, definitive internal fixation was performed. In case of open fractures, when a patient came to the emergency room, pollutants that were found with the naked eye were removed, the wound was washed with 6 L of normal saline, temporary splint fixation was performed, and the patient was moved to the operating room for debridement and saline irrigation. Afterwards, depending on the wound's state, either primary closure or negative pressure wound therapy was performed. To treat an open wound, we delayed the time of primary closure or applied a split-thickness skin graft or free flap, depending on the anatomical position, size, and stability of the open wound. Regarding antibiotic prophylaxis, first-generation cephalosporin was injected once, immediately after the

operation. In patients with an open fracture, the injection period of the first-generation cephalosporin was determined depending on the range and pollution of the wound. When the wound had severe contamination, aminoglycoside was used for additional 2 days.

In the IMN group, the conventional patella tendon split technique (knee flexed) was used in five patients and the semi-extended nail insertion technique was used in 31 (three with the medial parapatella approach, three with the lateral parapatella approach, and 25 with the suprapatella approach). In the MIPO group, a proximal lateral periarticular tibial plate was inserted in eight patients, a distal medial periarticular tibial plate was inserted in five, and a combination of proximal lateral and distal medial plates was inserted in 20. The time to surgery was defined as the time between the injury and definitive surgical treatment.

2.4. Rehabilitation protocol

Rehabilitation was initiated after definitive internal fixation. Passive and active range of motion and quadriceps strengthening exercises were applied to the knee and ankle. When a patient's whole body condition was improved and the pain was tolerable, crutch-based walking training began. Full weight bearing was allowed if callus bridging was observed in at least three out of four anteroposterior, lateral, and both oblique X-ray views. The patients were routinely followed up at 1-month intervals. Synostosis was determined when the pain of a fractured region disappeared clinically and callus bridging was found on X-ray images. Delayed union was determined in cases in which it took more than 6 months for synostosis to occur. Nonunion was determined when any additional operations such as cancellous bone grafting and revision osteosynthesis were required to obtain synostosis.

2.5. Radiographic and clinical outcomes

After clinical bony union was achieved, anteroposterior and lateral weight bearing radiographs were obtained with the knee joint in extension on a long cassette. We checked the medial proximal tibial angle, lateral distal tibial angle, and posterior proximal tibial angle. Malalignment was defined as an angulation deformity of 10° or more compared with the uninjured leg. Rotational malalignment was checked by comparing the thigh-foot angle of the injured leg and that of the uninjured leg.

A physician who was unaware of the patients' information evaluated the final clinical outcomes using the Lower Extremity Functional Scale, the scores of which ranged from 0, unable to perform any activity to 80, excellent function.¹² Complications were recorded as union- or soft-tissue related. Other complications, including infection, postoperative compartment syndrome, postoperative nerve injury, and implant failure, were also evaluated.

2.6. Statistical analysis

SPSS software version 21.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. The cohort was divided into two groups depending on the methods of definitive treatment that were used: IMN or MIPO. The Kruskal–Wallis, Mann–Whitney, Chi-square, and Fisher's exact tests, as well as regression analysis, were used to determine the relationships between the groups. A p-value of <0.05 was considered significant for all analyses.

3. Results

Table 1 shows the demographic data of the patients according to the method of primary bony stabilisation. The initial stabilisation method was IMN in 28 patients (40.6%),

Table 1 Demographic data according to the method of primary stabilisation.

	MIPO	IMN	Ex-fix	p-Value
Number	12	28	29	
Sex (Male:Female)	9:3	21:7	23:6	0.916
Age (years) ^a	42.4 ± 11.9	48.8 ± 12.3	50.9 ± 13.2	0.200
Body mass index (kg/m ²) ^a	23.4 ± 1.8	23.8 ± 2.9	24.1 ± 2.5	0.192
Current smoker (%)	5 (39.3)	11 (41.7)	8 (27.6%)	0.559
Diabetes mellitus (%)	2 (16.7)	2 (7.1)	8 (27.6)	0.126
Follow-up (months) ^a	20.8 ± 12.8	18.2 ± 2.6	18.0 ± 7.4	0.122
Compartment syndrome (%)	1 (8.3)	4 (14.3)	1 (3.4)	0.348
Open fracture (%)				
Type I	4 (33.3)	13 (46.4)	3 (10.3)	0.000
Type II	2 (16.7)	3 (10.7)	4 (13.8)	
Type III	0 (0.0)	3 (10.7)	17 (58.6)	
Injury mechanism (%)				
Motor vehicle accident	10 (83.3)	9 (32.1)	15 (51.7)	0.059
Fall from height	1 (8.3)	11 (39.3)	9 (31.0)	
Direct or crushing injury	1 (8.3)	8 (28.6)	5 (17.2)	

MIPO: minimally invasive plate osteosynthesis; IMN: intramedullary nailing; Ex-fix: external fixation.

^a Data are presented as the mean ± standard deviation.

Table 2 Comparison of parameters that were related to the operation in the MIPO and IMN groups.

	MIPO	IMN	p-Value
Initial compartment syndrome	1 (3.0%)	5 (13.9%)	0.120
Provisional external fixation	21 (63.6%)	8 (22.2%)	0.001
Open fracture	23 (69.7%)	26 (72.2%)	0.817
Time to definitive fixation (days)	8.8 ± 8.8	3.9 ± 7.7	0.018
Soft-tissue reconstruction (%)			
STSG	2 (6.1)	9 (25.0)	0.441
Free flap	11 (33.3)	2 (5.6)	

MIPO: minimally invasive plate osteosynthesis; IMN: intramedullary nailing; STSG: split-thickness skin grafting.

MIPO in 12 (17.4%), and provisional external fixation in 29 (42.0%). In the 29 patients who underwent provisional external fixation, definitive surgery was performed with either IMN in eight patients or MIPO in 21. Definitive surgery after provisional external fixation was performed at a mean of 13.3 days after the injury (range, 3–35 days).

Table 2 reveals a comparison of the factors that were related to the operation according to the method of definitive fixation. The time to definitive fixation on average was 3.9 days (0–35) in the IMN group and 8.8 days (0–27) in the MIPO group ($p = 0.018$). Soft-tissue reconstruction was performed in 24 patients (11 had split-thickness skin grafts and 13 had free flaps). All free flaps were elevated anterolateral thigh fascio-cutaneous free flaps.

It took 22.1 weeks, on average (10–59), for bony union to occur. A total of 26 and 13 patients showed delayed union and nonunion, respectively, that required additional surgery for bony union (Table 3). Bone grafting was performed in seven patients: two in the IMN group and five in the MIPO group. In two patients in the IMN group, surgery was performed at the site of the medial bone defect that was caused by valgus angulation. In three of five patients in the MIPO group, surgery was performed at the fracture gap in a displaced wedge fragment, and in the two other cases, surgery was performed

at the fracture gap of the lateral tibial side that was caused by rotational malalignment. Dynamization was performed in three patients in the IMN group. In two of these three patients, distraction between the proximal segment and mid-segment occurred during striking to insert an IM nail, causing nonunion. In the other patients, a gap due to rotational displacement of the mid-segment occurred during reaming. Exchange nailing was performed in three patients. All three patients had open fractures; in all of these patients, a nail that was thinner than the medullary canal was inserted with minimal reaming.

Complications were noted in 18 patients (11 patients in the MIPO group and seven in the IMN group): superficial infection in four patients, deep infection in one, rotational malalignment in four, axial malalignment in five, postoperative compartment syndrome in one, postoperative nerve injury in one, and implant failure in two. There was no significant difference in the incidence of complications between the two groups ($p = 0.189$). Differences in the Lower Extremity Functional Scale between each group were not statistically significant ($p = 0.985$) (Table 3).

Based the multivariate logistic regression analysis, the factors that were associated with complications for identified variables are reported in Table 4. These factors were age (odds ratio, 1.112; 95% confidence interval,

Table 3 Clinical and radiographical outcomes of patients in the MIPO and IMN groups.

	MIPO	IMN	p-Value
Time to bony union (weeks)	23.9 ± 11.4	23.8 ± 14.3	0.974
Impaired bony union (n, %)			
Delayed union	17 (51.5)	9 (25.0)	0.076
Nonunion	5 (15.2)	8 (22.2)	
LEFS	75.9 ± 3.0	75.8 ± 3.5	0.985
Complications (n, %)	11 (33.3)	7 (19.4)	0.189
Infection	4	1	
Rotational malalignment	4	0	
Axial malalignment	0	5	
Postoperative compartment syndrome	0	1	
Postoperative nerve injury	1	0	
Implant breakage	2	0	
Radiologic parameters (°)			
MPTA	87.2 ± 1.4	87.8 ± 2.6	0.245
LDTA	88.9 ± 1.5	88.6 ± 1.5	0.279
PPTA	81.3 ± 1.8	80.4 ± 2.9	0.152

MIPO: minimally invasive plate osteosynthesis; IMN: intramedullary nailing; LEFS: Lower Extremity Functional Score; MPTA: medial proximal tibial angle; LDTA: lateral distal tibial angle; PPTA: posterior proximal tibial angle.

1.022–1.210; $p = 0.013$) and smoking (odds ratio, 13.976; 95% confidence interval, 1.599–122.150; $p = 0.017$).

4. Discussion

In this study, we compared the outcomes and rate of complications for two surgical techniques commonly used to treat segmental tibial fractures, IMN and MIPO. We included in our analysis, pre-operative patient factors, the use of external fixation for primary bony stabilisation, and final clinical and radiological results. A longer time from injury to definitive fixation for the MIPO group than for the IMN group was the only factor that differed between the groups, with no between-group differences with regard to age, sex, body mass index, severity of open fractures, and other baseline characteristics.

When choosing an initial stabilisation, we first considered the patient's general condition and injury severity and then decided the surgical procedure according to wound status in the initial surgical intervention. Initial bony stabilisation with IMN that minimises soft tissue damage was performed to patients with adequate soft tissue coverage in the open fracture site. Spanning external fixation was carried out in those with poor soft tissue coverage for bony exposure, and then the time of the second operation was determined after providing adequate soft tissue coverage of the site.

The statistical difference between the two groups in the time from the injury to definitive fixation was thought to be due to the fact that plate fixation is more affected by the adjacent soft tissue than IMN is. Thus, it is considered that patients in the MIPO group took a longer time to achieve definitive fixation than did those in the IMN group because when MIPO was performed, surgery was performed after soft-tissue swelling around the incision was fully subsided. In addition, the number of patients who underwent MIPO for definitive fixation was higher than that of patients who underwent IMN for definitive fixation if the patients were treated with external fixation for primary bony stabilisation. This is because the bones were aligned to some degree when external fixation was performed; therefore, it is more convenient to perform MIPO than it is to perform external fixation in those who undergo IMN. This is also due to the

fact that an external fixator pin was inserted; thus, there was concern about the possibility of pin-site infection during IMN.

The incidence of complications in the IMN and MIPO groups was not statistically different, but the complications were different. Infection occurred in four patients in the MIPO group: superficial infection in three and deep infection in one. The MIPO technique is more advantageous in terms of infection and soft-tissue protection than open reduction and internal fixation, but it is thought that the implant is in the intramedullary canal, and because IMN has fewer exposed parts, it is less affected by the soft tissue's condition. However, Arastu et al.³ reported that intermediate fragments of segmental tibial fractures cause spinning during reaming and subsequent rotational displacement. They also found that there is a risk of damage to the soft tissue that is attached to the intermediate fragment during spinning. Regardless of the rotational displacement of the intermediate fragment, however, rotational alignment of the proximal and distal fragments is checked during the actual operation; therefore, we do not think that rotational malalignment occurred in the IMN group in this study.

Rotational malalignment was mainly observed in the MIPO group. This occurred in a patient in whom both proximal and distal medial tibial plates were used. Malalignment of the proximal and intermediate fragments developed as the intermediate and distal fragments were anatomically reduced. Rotational deformity has not been reported in other previous studies on internal fixation.^{10,11} It is known that rotational malalignment may occur depending on the anatomical location of an anatomically pre-contoured plate,¹³ and since the soft tissue of the anteromedial side of the tibia is thin, especially when a distal medial tibial plate is used, rotational malalignment is likely to occur when the plate is attached to the bone to reduce soft-tissue irritation.

In patients in the IMN group, malalignment was mainly caused by axial malalignment. This is the same as for the anterior and valgus angulations, which usually occur when treating proximal tibia fractures with IMN. To overcome this, well-known techniques such as a blocking screw, augmentation plate, pointed reduction forceps and using semi-extended position¹³ can be used. All axial

Table 4 Multivariate logistic regression analysis of the incidence of complications.

	Odds ratio	95% CI	p-Value
Sex (male)	1.025	0.160–6.568	0.980
Age (years)	1.112	1.022–1.210	0.013
BMI (kg/m ²)	1.247	0.929–1.675	0.141
Smoking (yes)	13.976	1.599–122.150	0.017
Diabetes mellitus (yes)	10.822	0.777–150.760	0.076
Open fracture (any type)	2.240	0.313–16.012	0.422
Initial compartment syndrome	8.116	0.278–236.721	0.224
Initial external fixation	5.456	0.299–99.462	0.252
Time to definitive fixation (days)	1.018	0.903–1.148	0.766
Definitive fixation device (nail versus plate)	1.202	0.179–8.047	0.850
Soft-tissue reconstruction (any)	3.212	0.418–24.670	0.262
Time to union (weeks)	1.042	0.977–1.111	0.210

Hosmer–Lemeshow test ($p = 0.925$); Nagelkerke R square (0.496). CI: confidence interval; BMI: body mass index.

malalignments in our study occurred when we used the conventional knee-flexed technique.

Each surgical method has characteristic complications. Postoperative nerve injuries occurred in patients who underwent fixation with a single proximal lateral plate. The deep peroneal nerve is close to the anterior tibial border. Applying percutaneous screws to the lateral side of the plate may injure the peroneal nerve, especially with long plates that extend below the distal half of the tibia. Postoperative compartment syndrome occurred in IMN patients; the pulse of the anterior tibial artery was weakened and capillary refill was not performed well at the time of check-up, before the end of anaesthesia after the surgery. Therefore, double-incision fasciotomy was performed, and these patients did not have any other sequelae. Implant failure occurred in two patients in the MIPO group, in whom breakage of the distal medial plate occurred. In both patients, the distal fracture was accompanied by a complex fracture of the lateral side of the tibia, and bony union was achieved by removing the broken implant and replacing it with a longer plate.

Among 69 patients included in our study, 6 had initial compartment syndrome and 1 developed compartment syndrome after surgery. Compartment syndrome is a limb-threatening condition and a surgical emergency. Since physicians are well aware of increased risk for compartment syndrome among patients with high-energy injuries such as segmented tibial fractures, close attention will enable timely diagnosis and prompt management. On the contrary, compartment syndrome occurring after surgery is easily missed, so more careful attention is required.

This study has some limitations. Although the data were collected prospectively, this study is retrospective and the sample size is limited. The selection of IMN and MIPO was not randomised, and two surgeons, not a single surgeon, participated in the study. Therefore, there was bias in the selection of IMN and MIPO. Another limitation of this study is that there were no specific criteria to determine the optimal timing for definitive surgery after the initial stabilisation. This is related with the first limitation. Before performing MIPO, we waited for the soft tissue of the plate insertion site to settle down and the wrinkle sign appears. For patients who initially exhibited poor general conditions, we took time for them to recover their systemic condition after external fixation. We decided definitive surgical time according to the availability and schedule of plastic surgeons for patients requiring soft tissue reconstruction. Time to definitive fixation did not influence the occurrence of complications ($p = 0.766$, Table 4). However, no previous studies have compared IMN and MIPO in the treatment of rare segmental tibial fractures, and this study has a strong point in that two level I trauma centres participated. Multi-centre, prospective, randomised controlled trials are needed in the future.

5. Conclusion

The results of our study suggest that if soft-tissue handling and restoration of anatomical alignment are successful in

the treatment of challenging segmental tibial fractures, both IMN and MIPO will be good treatment methods.

Competing interests

The authors declare that they have no competing interests.

Funding

No funding source.

Acknowledgements

We would like to thank Editage (www.editage.com) for English Language editing.

References

1. McMahon SE, Little ZE, Smith TO, Trompeter A, Hing CB. The management of segmental tibial shaft fractures: a systematic review. *Injury*. 2016;47:568–573.
2. Teraa M, Blokhuis TJ, Tang L, Leenen LP. Segmental tibial fractures: an infrequent but demanding injury. *Clin Orthop Relat Res*. 2013;471:2790–2796.
3. Arastu MH, Sheehan B, Paolucci EO, Buckley RE. Does it really spin? Intra-medullary nailing of segmental tibial fractures – a cadaveric study. *Injury*. 2015;46:643–648.
4. Huang CK, Chen WM, Chen TH, Lo WH. Segmental tibial fractures treated with interlocking nails. A retrospective study of 33 cases. *Acta Orthop Scand*. 1997;68:563–566.
5. Kim KC, Lee JK, Hwang DS, Yang JY, Kim YM. Tibial unreamed intramedullary nailing using Schanz screws in displaced diaphyseal segmental fractures. *Orthopedics*. 2007;30:906–908.
6. Ozturkmen Y, Karamehmetoglu M, Karadeniz H, Azboy I, Caniklioglu M. Acute treatment of segmental tibial fractures with the Ilizarov method. *Injury*. 2009;40:321–326.
7. Sarmiento A, Latta LL. Functional treatment of closed segmental fractures of the tibia. *Acta Chir Orthop Traumatol Cech*. 2008;75:325–331.
8. Wu CC, Shih CH. Segmental tibial shaft fractures treated with interlocking nailing. *J Orthop Trauma*. 1993;7:468–472.
9. Yoon RS, Bible J, Marcus MS, et al. Outcomes following combined intramedullary nail and plate fixation for complex tibia fractures: a multi-centre study. *Injury*. 2015;46:1097–1101.
10. Ma CH, Tu YK, Yeh JH, Yang SC, Wu CH. Using external and internal locking plates in a two-stage protocol for treatment of segmental tibial fractures. *J Trauma*. 2011;71:614–619.
11. Reynders P. Open acute segmental tibial fracture fixation using the Less Invasive Stabilisation System (LISS): study of 23 consecutive cases. *Injury*. 2009;40:449–454.
12. Binkley JM, Stratford PW, Lott SA, Riddle DL. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. North American Orthopaedic Rehabilitation Research Network. *Phys Ther*. 1999;79:371–383.
13. Song HK, Noh JW, Lee JH, Yang KH. Avoiding rotational mismatch of locking distal tibia plates depends on proper plate position. *J Orthop Trauma*. 2013;27:e147–e151.