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• Original Article •

Analysis of Radiological and Clinical Results in Treatment of Open Segmented Tibia Fractures: A Comparison between Intramedullary Nailing and Minimal Invasive Plate Osteosynthesis

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Purpose: The purpose of this study was to compare the data comprehensively including not only the clinical and radiographic outcomes but some parameters related to operation between the minimally invasive plate osteosynthesis (MIPO) technique and intramedullary nailing (IMN) for treatment of segmental tibia shaft fractures.

Methods: We conducted a retrospective study of 31 patients (mean age, 49.3 years, range, 27-74 years), with a mean follow-up of 14.1 months (range, 12-19 months) with acute segmental tibial fractures (AO 42-C2) who underwent either surgical treatment of MIPO or IMN. In accordance with the Gustilo-Anderson classification, 11 were type I, 5 were type II, and 15 were type III. Initial compartment syndrome was confirmed in 2 cases.

Results: There were no statistically significant differences in terms of the patient demographic data between the two groups. The time to definitive fixation was longer in the MIPO group (mean 13.7±10.9 days; range, 2-27) than in the intramedullary group (mean 5.4±9.6 days; range, 0-35) with statistically significant difference (p=0.002). Bony union was observed in most of cases but except 5 cases of nonunion were diagnosed (3 in the MIPO vs 2 in IMN, p=0.188). The average bone healing time was 27.1 weeks (10 to 56 weeks) in MIPO group and 23.2 weeks (13 to 66 weeks) in IMN group, respectively (p=0.056). Overall complications were 5 cases in MIPO group and 2 cases in the IMN group. Difference in LEFS was not statistically significant between both groups (p=0.824).

Conclusion: This study showed that segmental tibia shaft fractures treated with both MIPO and intramadullary nailing was challenging with relatively high complication rate. A well planned sequential strategy with keeping the soft tissue and personality of fracture in mind is utmost significant as much as the choice of surgical modalities. [J Trauma Inj 2016; 29: 76-81]

Key Words: Segmental tibia fracture, MIPO, Intramedullary nail

I. Introduction

The segmental tibia shaft fracture has a distinctive personality of fracture with two different level of one tibia and inevitably accompanied with moderate or severe soft tissue problem caused by high energy injury. The high potential for complications is much to do with the precarious blood supply of the intermediate segment of tibia and vulnerable soft tissue envelope.(1) High complication rates are reported for segmental tibial fractures including infection, nonunion, malunion and amputation.(2-5)

These worrisome problems are the reason there is no clinical consensus about the best way to treat

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these complicated fracture,(6) although traditionally several treatment methods have been reported to manage the segmental tibia fracture with non-operatively and surgically.(3,6-9) The intramedullary nailing (IMN) is commonly and widely used surgical modality due to its biomechanical property.(3,7,10) As widely known, however, the intramedullary nailing is a technically demanding and frequently needs additional procedure, such as a blocking screw, an additional plate and position of bone clamp so as to prevent the malalignment of entire tibia.(11) Moreover, the complications of the segmental fracture dealt with the intramedullary nailing were not within the surgeon's sphere of influence because of inherent characteristics of the segmental fracture itself.

Recently, the minimally invasive plate osteosynthesis (MIPO) technique has been applied to lower extremities and even more extended into the segmental tibia shaft fracture as well.(12,13) Although they recommended the MIPO technique for these difficult fracture with good functional outcomes, we wondered whether the MIPO technique is an alternative and as effective and safe as the outcomes of the intramedullary nailing. To our knowledge, however, there was no clinical study on comparative data with the MIPO and intramedullary nailing for the segmental tibia shaft fracture.

The purpose of this study was to compare the data comprehensively including not only the clinical and radiographic outcomes but some parameters related to operation between the MIPO technique and intramedullary nailing for treatment of segmental tibia shaft fractures. Our null hypothesis was that there were no significant differences in all comparative data between two surgical techniques.

II. Materials and Methods

During the period from October 2010 to April 2015, the authors have gone through prospectively collected orthopedic trauma databases in two hospitals (level I trauma center), and identified consecutive series of 31 adult patients with acute segmental tibial fractures (AO 42-C2) who underwent either surgical treatment of MIPO or IMN that were eligible for inclusion in our retrospective case series.

Inclusion criteria were patients who are skeletally mature (age≥18 years); those with a displaced separate proximal and distal tibial shaft fractures (each fracture is not involved into the rule of the square); those who were underwent operation with either MIPO or IMN; those who were followed up during a minimum 1-year. Exclusion criteria were as follows: prior amputation, Gustilo-Anderson type IIIc open fracture, fracture with bone loss, spinal cord deficit,

Table 1. Demographic data between MIPO and intramedullary nail groups

	MIPO	IMN	*p*-value
Number	13	18	
Sex (Male:Female)	10:3	13:5	0.552
Age (yrs)	46.5±15.1	51.3±10.4	0.470
Body Mass Index (kg/m^2)	23.3±2.4	23.3±3.7	0.674
Current Smoker (%)	3 (23.1)	6 (33.3)	0.535
Diabetes Mellitus (%)	0 (0)	3 (9.7)	0.245
Follow-up (months)	15.4±4.4	14.1±2.2	0.935
Initial Compartment Syndrome (%)	0 (0)	2 (11.1)	0.497
Open fracture (%)			0.411
Type I	3 (23.1)	8 (44.4)	
Type II	2 (15.4)	3 (16.7)	
Type III	8 (61.5)	7 (38.9)	
Injury Mechanism (%)			0.488
Motor vehicle accident	6 (46.2)	7 (38.9)	
Fall from height	4 (30.7)	6 (33.3)	
Direct blow or crushing injury	3 (23.1)	5 (27.8)	

* statistically significant difference (p<0.05).

significant brain injury, and pathologic fractures.

Total consecutive 31 patients were included in this study, which was conducted after obtaining approval from the institutional review board at our hospital. This study included 23 men (74.2%) and 8 women (25.8%), with mean age of 49.3 years (range, 27–74 years). Detailed history of enrolled patients, including smoking, diabetic status, and body mass index, were reviewed. All other demographics in regard with fractures such as fracture classification of proximal and distal site by AO/OTA classification, Gustilo–Anderson classification of open fracture, presence of initial compartment syndrome, and injury mechanism are described in Table 1.

The electronic medical records and radiographs of each patient were reviewed. Data recorded included the age, gender, mechanism of injury, fracture AO/OTA type and Gustilo–Anderson grade, treatment information, complications, and time to radiographic fracture healing. The time to surgery was defined as the time between the injury and definitive surgical treatment. Routine follow up radiographs were obtained every 4 weeks until solid continuous callus formation was observed; callus formation on 3/4 of the cortices and radiographic evidence of fracture line fading were considered signs of fracture union. Limb rotation and alignment were assessed at all follow–up visits. Malalignment (or malunion) was defined as angulation deformity of 10 degree or more, compared to the uninjured leg. Rotational malalignment was checked with thigh foot angle compared to the uninjured leg. Final clinical outcomes were evaluated using the Lower Extremity Functional Scale(14) (LEFS; 0, unable to perform any activity to 80, excellent function) by a physician who was unaware of the patients' information. Complications were recorded as union–related or soft tissue–related. SPSS version 18.0 (SPSS Inc. Chicago, IL, USA) was used for the statistical analyses.

All open fractures were managed with early, thorough debridement and irrigation, followed by additional debridement when indicated. Injuries with a significant deformity and/or soft tissues that were deemed unsafe for primary definitive fixation were treated with temporary spanning external fixation. Definitive surgical treatment was performed when the status of the soft tissue was sufficiently stabilized for soft tissue reconstruction and there was no evidence of infection. Patients were encouraged to start active and passive range of motion exercises at the knee and the ankle as soon as possible. The majority of patients were encouraged to partially weight bear at 2 or 3 weeks after surgery. Patients were allowed to fully weight bear whte there was no pain at the fracture site and radiological evidence of bone union.

III. Results

The open injury was graded as Gusilo–Anderson type I in 11 patients (35.5%), type II in 5 patients (16.1%), and type III in 15 patients (48.4%). Two patients had an impending compartment syndrome that required double incision fasciotomy. The mean follow–up period was 14.6 months (range, 12?25 months). The initial stabilization was intramedullary (IMN) nailing in 13 patients (41.9%), percutaneous plating (MIPO) in 2 patients (6.5%), and provisional external fixation in 16 patients (51.6%). In those 16 patients who had undergone provisional external fixation, definitive surgery was performed with either an IMN in 5 patients or a MIPO in 11 patients. Definitive surgery after provisional external fixation was performed at a mean of 16.2 days after injury (range, 2–35 days).

In IMN group, the conventional patella tendon split technique (knee flexed) was used in five patients and the semi–extended nail insertion technique (3 medial parapatella, 3 lateral parapatella, 7 suprapatella) was used in 13 patients. In MIPO group, proximal lateral periarticuluar tibial plate was inserted in 4 patients, distal medial periarticular tibial plate in 3 patients, and combination with proximal lateral and distal medial plate was in 6 patients. Soft tissue reconstruction was performed in 15 patients (six split thickness skin graft and nine free flap). All free flaps were elevated anterolateral thigh fasciocutaneous free flaps.

No significant differences were identified with respect to patient age (p=0.470), sex (p=0.552), body mass index (p=0.674), patient's number of smoking (p=0.535), and open fracture grade (p=0.411) between

MIPO group and IMN group (Table 1). The mean time injury to definitive fixation was 13.7 days in MIPO group and 5.4 days in IMN group, respectively (p=0.002).

Bony union was observed in most of cases but except 6 cases of nonunion were diagnosed (3 in the MIPO vs 3 in IMN, p=0.188). All nonunion were treated with autogenous bone graft (1 proximal and 2 distal in MIPO group, and 3 proximal in IMN group) (p=0.625). The average bone healing time was 27.1 weeks (range 10-56 weeks) in MIPO group and 23.2 weeks (range 13-66 weeks) in IMN group, respectively (p=0.056). Differences in LEFS were not statistically significant between each group (p=0.824) (Table 2).

Complications were noted in 7 patients (22.6%): superficial infection, 1 case; deep infection, 1 case; rotational malunion, 2 cases; angulation, 1 case; postoperatively compartment syndrome, 1 case; implant failure, 1 case and implant failure, 1 case. In the deep infection case, the fracture was healed when the infection occurred, so treatment involved surgical debridement, implant removal, and antibiotic therapy (Table 3).

IV. Discussion

This study compared clinical and radiographic results and surgery-related parameters of two different surgical techniques. Although there was no statistical difference in regards to pre- and postoperative parameters according to surgical modalities, the time to definitive surgery was statistically significantly longer in MIPO group than in IMN group. This outcome appears to be attributable to the fact that plate fixation is more affected by the

Table 2. Comparison of parameters related to operation between 2 groups

	MIPO	IMN	p value
Initial External Fixation	11 (84.6)	5 (27.8)	0.002*
Injury to definitive fixation (days)	13.7±10.9	5.4±9.6	0.002*
Soft tissue reconstruction (%)	8 (61.5)	7 (38.9)	
STSG	1 (7.7)	5 (27.8)	0.213
Free flap	7 (53.8)	2 (11.1)	
Bone graft (%)	3 (23.1)	2 (11.1)	0.625
Operation time (minutes)	86.5±10.2	79.1±8.6	0.389

* statistically significant difference (p<0.05).
STSG: split-thickness skin graft

Table 3. Clinical and radiologcal outcomes between two groups

	MIPO	IMN	p-value
Time to Union (weeks)	27.1±11.6	23.2±13.6	0.056
Impaired Bone Healing† (%)	7 (53.8)	4 (22.2)	0.188
Delayed union	4 (30.7)	2 (11.1)	
Nonunion	3 (23.1)	2 (11.1)	
LEFS	77.4±2.0	77.1±2.5	0.824
Complications	5 (38.5)	2 (11.1)	0.099
Infection	2	0	
Rotational malalignment	2	0	
Axial malalignment	0	1	
Postoperative compartment syndrome	0	1	
Postoperative nerve injury	0	0	
Implant failure	1	0	

* statistical significant difference.
† delayed union and nonunion taken together.
LEFS: lower extremity functional score

condition of adjacent soft tissues in determining the timing of surgical intervention than intramedullary nailing.

IMN is the most commonly used surgical technique. This is because that IMN has distinct mechanical and biological advantages compared to other fixation techniques.(3,7,8,10) Despite these benefits, this modality requires the surgeon's experience and skills because of challenging surgical procedures and is more prone to malalignment including valgus deformity, anterior angulation and others.(3,4) Segmental tibial fractures accompany precarious blood supply to the intermediate segment of tibia and are at risk of secondary injury due to intermediate fragment rotation when reaming.(15)

Open segmental fractures are difficult to be managed with conventional open reduction and compression due to massive soft tissue damage caused by high energy injury. Recent studies have achieved favorable results that MIPO can be used as an alternative technique to replace IMN.(12,13) MIPO is more ideal for minimizing periosteal and soft tissue injury by submuscular insertion compared to conventional open reduction and compression. Moreover, instead of intramedullary nail insertion, this technique does not damage blood supply to the intramedullary canal by preserving the intramedullary environment after reaming.

Several investigators have reported high complication rates in segmental tibia fractures, and associated complications include problems with bone union, infection, malalignment, amputation and others.(3,5,10,15-17)

In this study, complications occurred in 7 cases (22.7%), and no statistical difference was found between the two groups. Even though infection did not occur in patients with IMN, there were two cases with infection in MIPO group. This outcome was comparable to a previous study that conducted plate fixation.(12,13) McMahon et al. have addressed that malunion, one of the common complications, developed at a lower rate in the group with open plate fixation compared to the group with IMN.(6)

In the present study, malunion occurred in both groups that underwent plate osteosynthesis or IMN. Rotational deformity commonly occurred in MIPO group, while axial malalignment (valgus deformity) chiefly developed in IMN group. Rotational malalignment occurred in a patient who received MIPO using proximal lateral and distal medial plates concurrently. Malalignment of the proximal and intermediate fragments developed as intermediate and distal fragments were anatomically reduced. Rotational deformity has not been reported in other previous studies on internal fixation.(12,13) Malalignments in the proximal tibia occurred in the group with IMN, these are valgus deformity and anterior angulation that are frequently seen in proximal tibia fractures. Anterior angulation can be corrected with insertion with knee in flexion to some degree. On the contrary, valgus deformity can be overcome by the use of multiple techniques including blocking screw insertion, insertion of additional plates, intramedullary nail insertion after reduction using reduction forceps and others.

Bone graft was performed in 5 cases, 3 with plate osteosynthesis and 2 with IMN. This procedure was done to treat nonunion at the bone defect site of the medial tibia due to valgus malalignment of the proximal fragment in the group with IMN, and at the bone defect site of the lateral tibia due to rotational deformity of the distal fragment in 2 out of 3 cases in the group with MIPO. The other case had fracture gap caused by displacement of butterfly fragments at the distal fractured site and nonunion was treated with autogenous bone graft.

No statistical difference was found in age, gender, BMI, severity of open fractures and other baseline characteristics between IMN and MIPO groups. Debridement and external fixation were carried out as an initial treatment in cases of requiring damage control surgery due to severe initial or associated injuries. Since the fracture was reduced and alignment was restored to some degree through external fixation, plate osteosynthesis was primarily performed in definitive surgery while maintaining reduction with external fixation, instead of conducting IMN that requires removal of an external fixator (p=0.002). For this reason, the time to definitive surgery after the initial injury was longer in MIPO group than in IMN group (p=0.002). There was no statistical difference with respect to time to bone healing, clinical scores, and incidence of complications.

This retrospective study was limited by the relatively small sample size. In addition, the two surgical interventions, MIPO and IMN, were not randomly performed in patients. Despite these limitations, the present study was meaningful in that it compared open segmental fractures of the tibia, a rare fracture pattern, through a multicenter study. More prospective, multicenter, randomized studies with a larger sample size are warranted in the future.

V. Conclusion

This study has identified that segmental tibia shaft fractures treated with both MIPO and IMN are technically challenging and have a relatively high complication rate. Since the two surgical techniques had no statistical difference in pre- and post-operative variables, these interventions are anticipated to be appropriate to manage segmental tibial fractures. S Regardless of surgical modalities, satisfactory outcomes are expected by preserving soft tissues and achieving anatomical alignment through a well-planned sequential strategy.

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