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Retrospective comparison of postoperative infection and bone union between late and immediate intramedullary nailing of Gustilo grades I, II, and IIIA open tibial shaft fractures

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ABSTRACT

Background The optimal method of skeletal stabilization is still controversial. Therefore, we examined the clinical outcomes associated with late (L) versus immediate intramedullary nailing (IMN).

Methods This was a retrospective comparative study of trauma registry data from an emergency medical care center (university hospital). We examined 85 open tibial shaft fractures (85 patients) treated with L or immediate (I) IMN from January 2004 to December 2010. The L and I groups comprised 37 (33 men, 4 women) and 48 (44 men, 4 women) patients, respectively. The postoperative infection rate, time to bone union, and delayed union/non-union were evaluated.

Results The mean ages at the time of trauma in the L and I groups were 41.8 (18–79) and 42.0 (18–71) years, respectively; the mean follow-up periods were 15.0 (6–39) and 18.3 (8–36) months, respectively. A higher rate of postoperative infection was found in the L group than in the I group (p=0.004). Superficial/deep infection developed at a higher rate in the L group than in the I group (p=0.042 and 0.045, respectively). Among patients with Gustilo grade IIIA fractures, postoperative infection occurred at a higher rate in the L group than in the I group (p=0.008). However, the delayed union rate, non-union rate, and time to bone union were not significantly different between the groups.

Conclusions Gustilo grade IIIA fractures had a high infection rate, which is likely due to various factors, including pin-site infection after external fixation. We think that I IMN is safer than L IMN, and it should be the treatment of choice.

Level of evidence Retrospective comparative study, level III.

INTRODUCTION

Open tibial shaft fractures are usually the result of high-energy trauma such as a traffic crash and falls. Among all cases of open fractures, 63% occur in the tibia alone.[1] These fractures are often associated with severe soft-tissue damage and wound contamination, and their prognosis is largely dependent on the degree of initial fracture displacement, comminution, and soft-tissue injury.[2] In open tibial fractures, Gustilo grades I, II, and IIIA injuries can be covered with soft tissue; therefore, displaced bone can be safely and absolutely fixed immediately.[3] However, some countries without a trauma center still perform late internal fixation (intramedullary nailing (IMN), plating, and Ender nailing after external fixation).[4 5] High rates of pin-tract infections, pin loosening, poor patient compliance, and malunion rates of ≥20% have limited the use of external fixators as a definitive form of fixation.[4 6 7] Despite initial encouraging results, plate fixation of open tibial fractures has been associated with implant failures, non-unions, and deep infection rates as high as 35%.[8] Therefore, IMN has become the standard treatment for open tibial fractures, as axial ligament, early weight bearing, and immediate knee and ankle motion are possible.[9] However, the optimal method of skeletal stabilization is still controversial.

The purpose of the present study was to examine the clinical outcomes associated with late (performed after external fixation, splints, or skeletal traction) versus immediate IMN of open tibial shaft fractures. We hypothesized that immediate IMN is a safer initial treatment than late IMN for low-grade open tibial shaft fractures.

METHODS

Among 93 consecutive patients with Gustilo grades I, II, or IIIA open tibial shaft fractures treated at our hospital from January 2004 to December 2010, 85 patients (77 men and 8 women; follow-up rate: 91%) who could be followed for 12 months or longer were examined. From 2004 to 2006, late IMN was performed after external fixation, splints, or skeletal traction (L group), whereas from 2007 to 2010, immediate IMN was performed early after trauma (within 8 hours, I group). The L and I groups comprised 37 (33 men and 4 women) and 48 patients (44 men and 4 women), respectively. Patients with bilateral injury and high-risk patients with additional chest and/or head injuries that required temporary external fixation such as damage control orthopedic surgery were excluded from this study.[10] This retrospective comparative study was approved by the Institutional Review Board for Clinical Research of Tokai University.

In the L group, irrigation with at least 5 L of saline was performed after sufficient debridement during the initial treatment, followed by external fixation (Hoffmann; Stryker, Kalamazoo, Michigan, USA) (12 patients), skeletal traction (10), or splint placement (15) with 8 hour intravenous injections of second-generation cephem antibiotics. After the absence of symptoms of infection was confirmed, IMN (reamed nailing in 15 patients and unreamed nailing in 22) was performed secondarily (average waiting period: 16 days) after considering the patient's performance status, wound condition (eg, fever, wound exudate, blister formation, etc), and laboratory findings (white cell count ≤10 000/μL and C reactive protein level ≤0.1 mg/dL). If there is no symptom of infection, second-generation cephem antibiotics were intravenously injected twice per day for 1 week. Similarly, in the I group, second-generation cephem antibiotics were injected after sufficient irrigation and debridement were performed, and unreamed IMN was performed within 8 hours after trauma (average waiting period: 4.2-hour). For nailing, an identical type of intramedullary nail was used (TriGen Knee Nail; Smith & Nephew, Memphis, Tennessee, USA), with at least two proximal and two distal screws in both groups. In addition, in the case of a third bone fragment, closed reduction with cortical bone contact within 1 cm was performed to avoid nailing.

In both groups, the thigh and foot of the affected side were fixed with a splint and maintained in resting position for 1 week postoperatively. During the second week, rehabilitation for the knee/foot range of motion was started. Partial weight bearing started at 6–8 weeks postoperatively, whereas full weight bearing started at 10 weeks postoperatively or later after confirming the status of bone union. The affected part was subjected to outpatient radiographic examination of the frontal and lateral planes every 4–8 weeks after discharge until bone union was confirmed. Bone union was confirmed in the presence of a bridging callus in at least three of four parts of the tibia (anterior, upper, internal, and external) on plain radiographs. Delayed union was defined as cases in which bone union took longer than 9 months.

The following parameters were evaluated: the rate of postoperative infection (superficial: requiring superficial wound debridement; deep: leading to osteomyelitis), time to bone union (the appearance of a bridging callus on plain radiographs in the frontal and lateral planes), and delayed union (incomplete bone union at 6 months postoperatively or later) or non-union (incomplete bone union at 1 year postoperatively or later).

Data were analyzed by using SPSS for Windows (V.19.0; SPSS, Chicago, Illinois, USA). The t-test or Wilcoxon signed-rank test was used to make intergroup comparisons.

RESULTS

The causes of trauma included traffic crashes in 69 patients, falls in 12, and clamping accidents in 4. Patients' mean ages at the time of trauma in the L and I groups were 41.8 (range, 18–79) and 42.0 (range, 18–71) years, respectively. There were 10/17/10 and 12/19/17 patients with Gustilo grades I/II/IIIA fractures in the L and I groups, respectively. The types of fracture according to the AO/OTA classification (L group/I group) included type A in 6/17 patients, B in 9/17 patients, and C in 9/3. The mean follow-up periods in the L and I groups were 15.0 (range, 6–39) and 18.3 (range, 8–36) months, respectively (table 1).

Superficial/deep postoperative infection developed in 5 (13.5%)/3 (8.1%) patients and 1/0 (2.1%) patients in the L and I groups, respectively, which shows that the L group had a higher infection rate than the I group (p=0.042 and 0.045, respectively). In addition, the numbers of patients who developed surface or deep infections were 8 (21.6%) and 1 (2.1%) in the L and I groups, respectively, which also indicates that the L group had a higher rate of infection than the I group (p=0.004) (table 2). In this study, 3 patients had *Staphylococcus aureus*, 2 had methicillin-resistant *Staphylococcus aureus* (MRSA), and 1 had *Serratia* species in 6 superficial infections. Therefore, 2 patients with deep infection had MRSA, and of those, 1 had *Pseudomonas aeruginosa*.

No significant difference was seen in the postoperative infection rate of patients with Gustilo grades I/II fractures between the two groups. However, among 10 patients with Gustilo grade IIIA fractures in the L group, 5 (50%) developed postoperative infection (2 patients (20%) with superficial infection and 3 (30%) with deep infection). Thus, infection was seen at a high rate for Gustilo grade IIIA fractures. All three patients with deep infection developed the infection after external fixation. Among 17 patients with Gustilo grade IIIA fractures in the I group, only 1 patient (6.9%) developed superficial infection, and no patients developed deep infection. A significant difference was seen in the rate of deep infection between the L and I groups (p=0.017); however, no significant difference was found for the rate of superficial infection (p=0.26). The overall infection rate was higher in the L group than in the I group (p=0.008; table 3).

Delayed union/non-union was found in 3 (8.1%)/2 (5.4%) patients and 2 (4.2%)/1 (2.1%) patients in the L and I groups, respectively, with no significant difference between the groups (p=0.444 and 0.411, respectively). The mean time to bone union of all patients, excluding six with deep infection and non-union, was 15.0 (range, 10–20) and 16.5 (range, 9–19) weeks in the L and I groups, respectively, with no significant difference between the groups (p=0.524; table 4).

DISCUSSION

There have been numerous reports on secondary IMN (late IMN) after external fixation for open tibial shaft fractures. However, the reported rates of deep postoperative infection vary between 7.2% and 44%.[11–14] This is likely due to the substantial effect of the difference in the method of treatment and/or management of external fixation among the facilities.

Table 1 Characteristics of patients who received late and immediate intramedullary nailing for open fractures of the tibial shaft

	No. of cases	Men/Women	Age (years)	GA grade (I/II/IIIA)	AO type (A/B/C)	Follow-up period (months)
L	37	33/4	41.8 (18–79)	10/17/10	12/17/8	15.0 (6–39)
I	48	44/4	42.0 (18–71)	12/19/17	14/24/10	18.3 (8–36)
Total	85	77/8		22/36/27	26/41/18	

GA, Gustilo-Anderson; I, immediate intramedullary nailing; L, late intramedullary nailing; no., number.

Table 2 Comparison of postoperative infection rates between late and immediate intramedullary nailing for open fractures of the tibial shaft

	No. of cases	Type of infection: Superficial	Type of infection: Deep	Total
L	37	5 (13.5%)	3 (8.1%)	8 (21.6%)
I	48	1 (2.1%)	0	1 (2.1%)
p Value		0.042*	0.045*	0.004*

p, late versus immediate.
*Statistically significant.
I, immediate intramedullary nailing; L, late intramedullary nailing; no., number.

Table 3 Comparison of deep and superficial infection rates between late and immediate intramedullary nailing for open fractures of the tibial shaft

	GA grade I	No. of infections	GA grade II	No. of infections	GA grade IIIA	Type of infection		
	n	Total	n	Total	n	Superficial	Deep	Total
L	10	1	17	2	10	2 (20%)	3 (30%)	5 (50%)
I	12	0	19	0	17	1 (6.9%)	0	1 (6.9%)
p Value		0.26		0.12		0.26	0.017*	0.008*

p: late versus immediate.
*Statistically significant.
GA, Gustilo-Anderson; I, immediate intramedullary nailing; L, late intramedullary nailing; no., number.

Yokoyama *et al*[11] reported the following as important factors for preventing infection in case of early unreamed IMN: (1) early flap coverage with well-vascularized tissue within 1 week after trauma, (2) a short duration of external fixation (within 2 weeks), (3) early unreamed IMN, (4) debridement of the screw hole at the pin site, (5) a slightly prolonged interval between the removal of the external fixator and IMN until complete healing of the pin site, (6) complete healing of the pin site and (7) debridement of the screw in cases of conversion (elective) surgery from external fixation to intramedullary nailing. Bhandari *et al*[15] performed a meta-analysis of the infection risk of the conversion method for tibial fractures. They reported that a lack of pin-track infection was the most important factor for preventing infections and, compared to longer durations (>28 days) of external fixator use, shorter durations resulted in an 83% decrease in the risk of infection of use. However, in our late IMN cases, superficial infection occurred in 5 patients (13.5%), and deep infection occurred in 3 patients (8.1%). The three patients who developed deep infection had undergone conversion (from external fixation to IMN) for Gustilo grade IIIA fractures. None of the patients satisfied all the aforementioned factors for preventing infection. Therefore, it is likely that the patients subsequently developed infection because of the lack of pin-site treatment and/or the absence of a waiting period (table 5). When examining the infection rate by the Gustilo grade, the infection rate in cases of grade IIIA fractures in the L group was as high as 50%. In contrast, there was no clear difference between Gustilo grades I and II. In particular, the deep infection rate was significantly higher in the L group than in the I group. Therefore, IMN after external fixation is likely to require extensive medical care (table 3). However, on the basis of our result that no patient who underwent conversion developed postoperative deep infection, conversion surgery to IMN after splint or skeletal traction without external fixation for Gustilo grades I and II fractures is likely a safe method of treatment, although three cases of superficial infection were seen. In recent years, half pins with antimicrobial agents have been developed for external fixation, offering the possibility of decreasing pin-track infection.[16 17] The future use of these pins may enable surgeons to perform conversion surgery from external fixation safely. Thus, these pins are highly likely to be available for use as implants in the future.

Our study's results indicate that compared to late IMN, immediate IMN for Gustilo grades I, II, and IIIA fractures is a safe surgical method, and it is associated with fewer postoperative infections (superficial/deep) (p=0.004) and no significant difference in the time to bone union (p=0.524). Sanders *et al*[18] reported that no infection was seen in patients with Gustilo grades I, II, and IIIA fractures; however, infection was seen in 13% of patients with Gustilo grades IIIB fracture after immediate IMN. Kakar and Tornetta[3] reported an infection rate as low as 3% (superficial infection: one patient, deep infection: four patients) after immediate IMN among 161 patients with Gustilo grades I, II, IIIA, and IIIB open tibial fractures, indicating the safety and efficacy of the treatment. In addition, Roussignol *et al*[19] reported that the operative duration and Gustilo grade correlated with the postoperative infection rate in secondary IMN after external fixation in 55 patients with Gustilo grades I, II, IIIA, IIIB, and IIIC fractures, suggesting that IMN should be performed early, before pin-site infection occurs due to external fixation. Thus, consistent with our results, these reports indicate that IMN should be performed early in the case of Gustilo grades I, II, and IIIA tibial shaft fractures that have less soft-tissue injury. In this study, a significant difference in the infection rate was seen between the L and I groups only for Gustilo grade IIIA open tibial shaft fractures (p=0.017).

Table 4 Comparison of the delayed union rate, non-union rate, and time to bone union between late and immediate intramedullary nailing for open fractures of the tibial shaft

	No. of cases	Delayed union (no. of cases)	Non-union (no. of cases)	Time to bone union* (weeks)
L	37	3 (8.1%)	2 (5.4%)	15.0 (10–20)
I	48	2 (4.2%)	1 (2.1%)	16.5 (9–19)
p Value		0.444	0.411	0.524

p: late versus immediate.
*Excludes deep infection and cases of non-union.
I, immediate intramedullary nailing; L, late intramedullary nailing; no., number.

Table 5 Important key factors for preventing deep infection in cases converted from external fixation to intramedullary nailing

Deep infection (patient no.)	Gustilo-Anderson grade	Important key factors for preventing deep infection					
		1	2	3	4	5	6
1	IIIA	Yes	10 days	**Reamed nail**	**No**	**No**	Yes
2	IIIA	Yes	**21 days**	**Reamed nail**	**No**	**No**	**No**
3	IIIA	Yes	**18 days**	Unreamed nail	**No**	**No**	Yes

1: early flap coverage by well-vascularized tissue within 1 week after trauma, 2: short duration of external fixation, 3: early unreamed intramedullary nailing, 4: debridement of the screw hole at the pin site, 5: slightly prolonged interval between removal of the external fixator and intramedullary nailing until complete healing of the pin site, 6: complete healing of the pin site, bold font: did not meet the criteria. no., number.

Therefore, early definitive (immediate) IMN may decrease the infection rates for grade IIIA open tibial shaft fractures.

Wiss and Stetson[20] reported a 24% infection rate for grades I and II open fractures, and they suggested that reamed IMN may be contraindicated in the management of open fractures. This high infection rate was considered to be due to the decrease in cortical bone blood flow caused by the development of local bony necrosis after reaming[21 22] and/or damage to the nutrient artery.[23 24] Proponents of tibial nail insertion without reaming argue that this technique results in lower infection rates owing to less disruption of the endosteal blood supply.[25] Therefore, we performed unreamed IMN in the I group, and no deep infections occurred.

We previously reported that decreasing the hospital stay or frequency of operation can decrease medical expenses by 30% on the basis of our cost-effectiveness comparison between late and immediate IMN.[26] In addition, early post-traumatic IMN should be considered to prevent deep vein thrombosis, because rehabilitation can be started early, avoiding long-term recumbency. Since a decrease in the frequency of operation lessens the physical and economic burdens on the patient, we think that immediate IMN should be used as the therapeutic approach in the future. However, since hospitals where post-traumatic IMN can be performed early are limited, we think that emphasis should be placed on a timely transfer to a trauma center.

Our study has some limitations. First, this was a consecutive cohort study on delayed timing rather than a randomized, prospective study. Second, no unified method was used for the initial treatment in the L group. Future prospective clinical studies at large multicenters are needed to overcome these limitations.

Immediate IMN resulted in a lower postoperative infection rate than late IMN. Conversion surgery from external fixation to IMN requires intensive medical care, because the surgery leads to a high postoperative infection rate; thus, a treatment that considers various factors is required. Conversion surgery after splint/skeletal traction in the case of Gustilo grades I and II fractures can be performed safely. However, on the basis of our results, we think that immediate IMN should be the treatment of choice rather than late IMN from the standpoint of both patients and surgeons.

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