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Segmental Tibial Fractures: An Infrequent but Demanding Injury

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Abstract

Background Segmental tibial fractures are considered to be a special injury type associated with high complication rates. However, it is unclear whether healing of these fractures truly differs from that of nonsegmental fractures.

Questions/purposes We therefore asked (1) does the time to union in segmental tibial fractures differ from that of nonsegmental fractures; and (2) does the complication rate of segmental fractures differ from that of nonsegmental fractures?

Methods We retrospectively studied 30 patients with segmental tibial fractures treated at a Level I trauma center from January 2000 to December 2008 and compared healing and complications with a matched control group of 30 nonsegmental tibial fractures. In followup we determined time to union, delayed and nonunion, and overall complication rates. Patients were followed at least until union was attained. The minimum followup was 5 months (median, 15 months; range, 5–54 months).

Results Median time to union was 34 weeks (range, 12–122 weeks). Segmental fractures took longer to heal than nonsegmental fractures (median, 34 weeks; range, 12–122 weeks and median, 24 weeks; range, 11–39 weeks, respectively). The overall rate of complications was higher in segmental fractures as was the necessity for reoperation to attain healing.

Conclusions Healing of segmental tibial fractures is characterized by substantially more complications and longer healing times than nonsegmental fractures and should be considered as a special type of injury. We believe these should be treated in specialized trauma centers.

Level of Evidence Level III, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

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Introduction

Segmental tibial fractures feature a unique fracture type characterized by a completely isolated intercalary osseous fragment separated by at least two distinct fracture lines [2, 12, 15, 19] (Fig. 1). These fractures are usually the result of high-energy trauma and are, therefore, often accompanied by substantial damage of the surrounding soft tissue envelope [20]. Reports specifically addressing segmental tibial fractures typically include relatively few cases, often mixed with nonsegmental fractures likely as a result of the relatively low incidence of these fractures. Reported incidences of tibial fractures being truly segmental have varied between 3% and 12% [2, 4, 16, 21].

Fig. 1A–D (**A**) This radiograph shows a 5-day postoperative, Grade I, open, segmental fracture of the left tibia treated with unreamed interlocked IMN and preventive fasciotomy. (**B**) Six months later, after removal of the IMN, an external fixator was applied and sequestrectomy was performed because of osteomyelitis. (**C**) Another 3 weeks later, after removal of the external fixator, reaming was performed of the intramedullary canal and a 13-mm diameter cannulated tibia nail was inserted without distal locking. (**D**) Ultimately, 56 weeks and nine operations after the initial trauma, union of both fracture lines occurred.

Almost invariably, high complication rates are reported for segmental tibial fractures [4, 15, 19, 20]. Proposed causes are the precarious blood supply of the intermediate fragment and the often severely damaged surrounding soft tissue [15, 19] causing impaired fracture healing (up to 50%), compartment syndrome (up to 50%), and septic complications (up to 35%) [1, 4, 15, 19]. Reports often state that segmental tibial fractures are accompanied by substantial healing problems such as delayed union and nonunion as compared with nonsegmental fractures [4, 19, 20]; however, these conclusions are based on comparisons with literature controls and not based on direct comparisons.

Therefore, we formulated the following questions: (1) does time to union in segmental tibial fractures differ from that of nonsegmental fractures; and (2) is the overall complication rate of segmental fractures different compared with nonsegmental fractures?

Patients and Methods

We retrospectively reviewed all 37 patients with acute open or closed segmental tibial fractures treated at our Level I trauma center from January 2000 to December 2008. Segmental fractures were defined as fractures featuring at least two distinct fracture lines that created a completely separate cylindrical intermediate segment. During the study time we treated a total of 432 patients with fractures of the tibial diaphysis. All fractures were classified according to the Association for the Study of Internal Fixation (AO) classification system [13] and the Gustilo and Anderson classification in case the fracture was open [6, 7]. According to the AO system, segmental tibial fractures were classified as AO Type 42C2. Other criteria for inclusion were (1) age 16 years or older at admission; and (2) that the initial treatment was applied at our institution. We excluded seven patients with (1) an earlier fracture or retained hardware at the affected side; (2) a fracture resulting from primary malignancy or metastatic disease of the bone; (3) known disorders of bone metabolism; and (4) death or amputation before fixation was performed. These exclusions left 30 patients: 22 male and eight female patients (Table 1). The median age was 47 years (range, 16–79 years). Causes of segmental tibial fractures were car crashes (n = 9), accidents including both motorcycles and cars (n = 12), falls from heights (n = 5), and accidents involving pedestrians and cars (n = 3); there was one industrial accident. Altogether, 24 of the 30 fractures were the result of traffic accidents. Serious additional injuries were present in 21 patients, especially of the musculoskeletal type (Table 2). Thirteen fractures were closed, and 17 fractures were open (nine were Grade I, two were Grade II, and six were Grade III open fractures). Patients were at least followed until union was attained. The minimum followup was 5 months (median, 16 months; range, 5–54 months).

Table 1. Patient, fracture, and major fracture healing characteristics

Demographics and fracture characteristics	Segmental fractures	Nonsegmental fractures	p value
Age (years)	47 (16–79)	40 (19–82)	0.589
Sex (male/female)	22/8	24/6	0.542
Presence of diabetes	1/30	0/30	0.313
AO class fracture	42C2 (n = 30)	42A1 (n = 8) 42A2 (n = 6) 42A3 (n = 7) 42B1 (n = 3) 42B2 (n = 4) 42B3 (n = 2)	< 0.001
Number open/closed fractures	17/30	16/30	0.795
Gustilo and Anderson Grade II/III	8/30	8/30	1.000
Additional injuries	21/30	20/30	0.781
Time to initial surgery (hours)	4 (1–48)	6 (1–48)	0.975
Duration of initial surgery (minutes)	98 (40–400)	165 (40–430)	0.979
Type of initial fixation			0.776
Unreamed IMN	18	20	
Reamed IMN	4	4	
Plate osteosynthesis	3	1	
External fixation	5	5	
Length of initial hospital stay (days)	23 (3–78)	20 (2–96)	0.802
Delayed union	21/29	9/30	0.001
Nonunion	4/29	0/30	0.035
Amputation	1/30	0/30	0.313
Time to union (weeks)	34 (12–122)	24 (11–39)	< 0.001
Proximal fracture (weeks)	28 (12–122)	NA	NA
Distal fracture (weeks)	32 (12–122)	NA	NA
Need for unplanned reoperation	17/29	9/30	0.027
Duration of followup (months)	16 (5–54)	15 (8–30)	0.827

Data are medians and ranges or absolute numbers; IMN = intramedullary nailing; NA = not applicable.

The control group was composed of 30 patients with nonsegmental tibial shaft fractures (AO Type 42A or 42B) treated at our institution from January 2007 to December 2008. Control subjects were matched for age, sex, additional injuries, and frequency and type of open fractures. The same inclusion and exclusion criteria as applied to the patients with segmental fractures were used. Patients were followed at least until union was achieved. The control group of 30 cases with nonsegmental tibial fractures did not differ from the segmental fracture group in characteristics such as sex, age, additional injuries, the amount and types of open fractures, and presence of diabetes, which potentially affects fracture healing negatively. The time to initial surgery, duration of initial surgery, type of initial fixation, and length of initial hospital stay did also not differ between the two groups (Table 1).

Table 2. Additional injuries

Type of injury*	Number
Craniofacial	6/30
Chest	10/30
Abdominal	6/30
Musculoskeletal	15/30
Any additional injury	21/30

* Superficial wounds excluded.

At our Level I trauma center, treatment of fractures largely follows the AO principles [13]. Antibiotics were applied according to validated protocols. Cases with Grade II or IIIA injuries received 2 g cefazolin immediately after presentation at the emergency department, and cases with Grade IIIB or IIIC fractures received additionally 1 g gentamicin. Patients with fractures classified as Gustilo Grades I to IIIA received 2 g cefazolin perioperatively, and patients with fractures classified as Grades IIIB or IIIC received additionally 160 mg gentamicin. For Grade IIIB and IIIC fractures, 1 g cefazolin every 6 hours and 2.5 mg/kg gentamicin every 12 hours were continued for 3 days postoperatively.

Open fractures were classified as surgical emergencies, and wound débridement and extensive lavage were performed as soon as possible followed by fracture stabilization and skin and soft tissue reconstruction, if necessary. The method used to achieve skeletal stabilization depended on fracture characteristics, the condition of the surrounding soft tissue, and the patient as a whole. In general intramedullary nailing (IMN) was preferred only when the patient was unstable or the soft tissue was too damaged; external fixation was performed and plating was performed in cases when IMN failed. In both the segmental as well as the nonsegmental group, the majority of fractures were treated with unreamed IMN, whereas a minority in both groups were treated using gently reamed nailing, LISS® plating (Synthes, Inc, West Chester, PA, USA), or initial fixation with an external fixator that was replaced by internal fixation in a second operation (Table 1). Two patients in the group of segmental and one patient in the group of nonsegmental fractures ultimately developed signs of an acute compartment syndrome necessitating fasciotomies in early stages. One case of segmental fracture required amputation in an early phase (< 2 weeks) as a result of the extensiveness of the injury and concomitant infection.

Postoperative mobilization depended on the type of fixation used and the appearance of the fracture on postoperative radiographs. After definitive fixation, postoperative rehabilitation generally consisted of supported mobilization with crutches, initially with partial weight-bearing. Full weightbearing was allowed as soon as there was evidence of a bridging callus on both the AP and lateral projections at, most often, 6 weeks postoperatively.

Patients were followed at the outpatient clinic at intervals ranging from 4 to 6 weeks in the first 6 months after hospital discharge and 4 to 12 weeks thereafter. Clinical data were obtained retrospectively from the hospital databases and all radiographs were rereviewed at the time this study was performed. Clinical evaluation comprised assessment of pain or tenderness at the fracture location, pain during walking and weightbearing, and stability and potential deformity at the fracture location. Deep wound infection was defined as the presence of local inflammatory symptoms such as redness, erythema, or swelling; presence of purulent discharge; and positive bacterial cultures (wound or blood). The presence of a superficial wound infection was defined as signs of local inflammation without systemic signs or purulent discharge. These inflammatory problems were defined as fracture side-related complications together with the occurrence of compartment syndrome, amputation, bone healing problems (delayed union and nonunion), and malunion. Reoperations were also considered; however, we only assessed reoperations to attain union, which were defined as refixation, bone grafting, or sequestrectomy. Surgical interventions such as washing or flaps were not considered as operations needed to attain union.

Two of us (MT and LT, neither a treating surgeon) evaluated fracture union based on serial radiographs taken at orthogonal planes. Union was defined as the presence of mature, bridging callus of the four cortices on both AP and lateral directions and painless, full weightbearing. In case of disagreement, assessment of union was based on a consensus decision of both observers. Time to union was counted from the initial trauma irrespective of intermittent surgery. Delayed union was defined as not achieving union within 6 months from the initial trauma, whereas nonunion was defined as persistence of the fracture at 9 months from the initial trauma without any tendency to progressive union in the previous 3 months [4, 17]. We defined malunion as a retrocurvatum/antecurvatum or a varus/valgus deformity of more than 5°.

We determined differences in time to union between segmental and nonsegmental fractures using the Mann-Whitney U test, because the data did not fulfill the requirements for parametric testing. We compared differences between union times for the proximal and distal fracture in segmental fractures using the Wilcoxon rank-sum test. Differences in complication rates such as delayed union, nonunion, and reoperation between patients with a segmental and nonsegmental fracture were determined using the chi-square test. Relative risks to experience complications in case of segmental fractures compared with nonsegmental fractures were obtained by crosstabulation statistics. With respect to the most essential data such as occurrence of complications and radiographic assessments, there were no missing data, whereas for some baseline variables, some missing data were present; however, except for smoking behavior, less than 10% of the data was missing per variable. In case of missing data, complete case analysis was performed. Statistical analyses were conducted using SPSS® statistical software, Version 15.0 (SPSS® Inc, IBM®, Armonk, NY, USA).

Results

Median time to union was longer ($p < 0.001$) for segmental tibial fractures compared with nonsegmental tibial fractures: 34 weeks (range, 12–122 weeks) versus 24 weeks (range, 11–39 weeks), respectively. In case of segmental fractures, the median time required for union of the proximal and distal fracture lines was similar ($p = 0.154$): 28.0 weeks and 32.0 weeks, respectively. The union time for segmental fractures, in which both fracture lines were located at the distal one-third of the diaphysis, did not differ ($p = 0.125$) from fractures located elsewhere (median, 45 weeks; range, 28–94 weeks versus median, 32 weeks; range, 12–122 weeks). Segmental fractures initially treated with IMN united faster ($p = 0.040$) (median, 31 weeks; range, 12–67 weeks) than fractures treated otherwise (median, 48 weeks; range, 28–122 weeks), whereas segmental fractures treated with gently reamed IMN united faster ($p = 0.031$) than fractures treated with unreamed IMN (median, 19 weeks; range, 18–31 weeks versus median, 36 weeks; range, 12–67 weeks). No such differences were observed for the nonsegmental fractures, time to union was not different ($p = 0.980$) in cases treated with IMN than otherwise treated fractures (median, 24 weeks; range 11–39 weeks versus median, 22 weeks; range, 15–36 weeks, respectively), and in addition, union time for nonsegmental fractures treated with reaming was similar ($p = 0.431$) compared with those treated with unreamed IMN (median, 21 weeks; range 11–30 weeks versus median, 24 weeks; range, 12–39 weeks, respectively).

Overall the rate of fracture site-related complications was higher ($p = 0.010$) in segmental fractures compared with nonsegmental fractures. Delayed union occurred more frequently ($p = 0.001$) in segmental fractures compared with nonsegmental fractures (21 of 29 and nine of 30 cases, respectively). This was also the case for nonunions, which were not observed in the control group of nonsegmental fractures ($p = 0.035$: four of 29 and zero of 30 cases, respectively). The nonunions occurred exclusively in the open segmental fractures. No deep infections were observed in the nonsegmental fractures (zero of 30 cases) compared with 10 cases in the segmental group (10 of 29

Table 3. Relative risks experiencing healing problems and reoperation, segmental fractures compared with nonsegmental fractures

Event	Relative risk	95% CI	p value
Bone healing problem*	2.4	1.3–4.4	0.0035
Nonunion	9.3	0.5–165	0.129
Delayed union	2.0	1.0–3.7	0.036
Malunion	1.7	0.5–6.6	0.425
Deep infection	22	1–354	0.031
Compartment syndrome	2.1	0.2–22.3	0.524
Reoperation†	2.0	1.0–3.7	0.036
Complicated healing‡	1.7	1.1–2.6	0.015

* Delayed union and nonunion taken together; †need for reoperation to attain union; ‡at least experiencing one fracture side-related complication; CI = confidence interval.

cases) ($p < 0.001$). The necessity for reoperation to attain union was higher ($p = 0.027$) in cases with segmental fractures (17 of 29 cases) than in nonsegmental tibial fractures (nine of 30 cases). Relative risks of experiencing delayed union; nonunion; deep infection; any fracture side-related complication; and the need for reoperation to attain union were higher in the group with segmental fractures (Table 3).

Discussion

It is often suggested that segmental tibial fractures are characterized by a problematic healing process with prolonged time to union and hence increased rates of delayed and nonunion. These statements are based on comparisons with historical data available in the literature. The aim of this study was to confirm whether the healing process of segmental tibial fractures indeed differs from that of nonsegmental fractures by comparing a group of segmental tibial fractures with a matched group of nonsegmental tibial fractures treated at the same trauma center according to the same protocols. We therefore asked (1) does time to union in segmental tibial fractures differ from that of nonsegmental fractures; and (2) is the overall complication rate of segmental fractures different compared with nonsegmental fractures?

This study has some important limitations, of which some are introduced by the retrospective character of the study. First relates to the assessment of union time. To properly assess union time, (1) serial radiographs; (2) clear criteria for healing; (3) multiple blinded observers; and (4) interobserver variability statistics are required. Assessment of fracture union based on radiographs is often considered to have considerable intra- and interobserver variability; however, the literature reports relatively good intra- and interobserver statistics for assessment of union when clear criteria are formulated [3, 18]. In the current study no serial radiographs at predefined intervals were available, because the study was not prospectively designed; however, our hospital treatment protocol guarantees clinical and radiographic followup every 4 to 6 weeks until 6 months after hospital discharge; thereafter, these intervals are sometimes longer. We did not blindly assess the radiographs because this is not easily performed for segmental fractures; in contrast, we assessed the radiographs with two observers separately. In case of disagreement, decisions on time to union were based on consensus. Furthermore, all radiographs in both patient groups were evaluated by the same observers using the same criteria. Second, we lacked data on potentially important confounding factors such as smoking history and extent of soft tissue injury in closed fractures; clearly such factors could have influenced the healing process. Third, inherent to studying segmental tibial fractures are small study populations, which could have resulted in some data not being significant, whereas in a larger population, the findings might have been significant (for example, differences in time to union of the proximal and distal fracture line). However, this can only be circumvented when combining results of multiple large trauma centers.

Our observations emphasize the relatively long time required for union to occur in cases of segmental tibial fractures as suggested in the available literature [2, 4, 9, 11, 15, 19]. This seems to result from the segmental fracture per se and not the associated damage, because the time to union of segmental fractures differed from that of a matched group of nonsegmental fractures. Median time to union of the segmental fractures in our series was 34 weeks, which is consistent with union times of segmental tibial fractures reported in the literature ranging from 15 to 43 weeks (Table 4) [2, 4, 5, 8, 9, 11, 12, 14–16, 19–21]. This widespread variance can possibly be explained by how union was defined in the separate studies. Some studies did not report any definition [12, 19], and others used less stringent definitions [9, 14] than we applied in the current study. Differences in patient characteristics in these small patient populations are another potential explanation. Giannoudis et al. [4] reported on a population requiring a relatively long time to heal, but their study included a large proportion of open fractures [4], whereas Sarmiento and Latta reported a short time to union but reported exclusively on closed segmental tibial fractures [16]. Because open fractures show a general tendency to unite more slowly than closed fractures [4, 9, 14], this could at least partially explain the observed differences in healing times. Notably, we observed shorter union times for segmental fractures treated with gently reamed IMN compared with unreamed IMN, which could indicate that reamed IMN is potentially superior in the treatment of segmental tibial fractures as is reported for nonsegmental tibial fractures [10].

Table 4. Overview of studies reporting treatment and outcomes of segmental tibial fractures

Study	Mean age (years)	Number of cases	Sex	AO type	Open/closed	Initial fixation	Union time (weeks)	Malunion	Delayed union	Nonunion	Followup (months)
Zucman and Maurer, 1969 [21]	53	36	NA	NA	19/17	36 U IMN	20	0/36	NA	3/36	NA
Langard and Bo, 1976 [11]	NA	54	NA	NA	28/26	33 Surg fix 21 NO	NA	NA	11/54	1/54	UC
Melis et al., 1981 [12]	NA	36	NA	NA	16/22	36 R IMN	21 (17–30)* 23 (17–30)	1/36	NA	1/36	20
Rommens et al., 1989 [15]	37	40	37/3	42C2	26/15	23 Plate 18 Fix ex	34	2/37	1/37	8/37	UC
Woll and Duwelius, 1992 [19]	39	31	28/3	42C2	26/5	20 Fix ex 7 U IMN 2 NO 1 Plate	21	11/31	4/31	11/31	10 (2–19)
Wu and Shih, 1993 [20]	32 (18–54)	38	35/7	42C2	32/10	38 R IMN	20 ± 7	0/38	NA	1/38	32
Huang et al., 1997 [8]	56 (18–79)	33	29/4	42C2	9/24	33 R IMN	17 (12–20)* 20 (12–34)	1/33	3/33	0/33	48 (12–84)
Bonnevialle et al., 2003 [2]	41	49	34/15	42C2	30/15	32 R IMN 7 U IMN 10 Fix ex	43 ± 20† 40 ± 13 41 ± 11	NA	NA	12/49	
Giannoudis et al., 2003 [4]	39 (22–67)	27	25/2	42C2	19/8	14 U IMN 2 R IMN 8 Fix ex 2 Plate 1 NO	39 (10–78)* 41 (12–65)	1/27	20/27	1/27	12–60
Kakar and Tornetta, 2007 [9]	44 (16–90)	62	42/20	42C2	36/26	62 U IMN	22	3/51	11/51	0/51	18 (6–48)
Sarmiento and Latta, 2008 [16]	39 (16–72)	48	23/8	42C2	0/48	48 NO	15	NA	NA	0/48	UC
Ozturkmen et al., 2009 [14]	38 (22–66)	24	19/5	42C2	17/7	24 Fix ex	36 (10–78)* 40 (12–80)	2/24	NA	2/24	28 (12–70)
Giotakis et al., 2010 [5]	47 (25–79)	20	15/5	42C	7/13	20 Fix ex	22 (13–31)	3/20	NA	2/20	71 (22–107)
Current study	47 (16–79)	30	22/8	42C2	17/13	18 U IMN 4 R IMN 3 Plate 5 Fix ex	34 (12–122)	5/29	21/29	4/29	16 (5–54)

Data represent absolute numbers, means with or without SD, or medians with ranges. Delayed and nonunion were defined variably in each study, if defined at all, as was the case for how union was defined; * union time for proximal and distal fracture; † union time reported separately for each treatment method; NA = not available; U IMN = unreamed intramedullary nailing; Surg fix = surgical fixation without specification; NO = nonoperative; R IMN = reamed intramedullary nailing; Fix ex = external fixation; UC = until consolidation, no specification of followup time.

We also observed a higher incidence of complications during the healing process. The amount of delayed and nonunion was higher in the group of segmental tibial fractures. Our series of segmental tibial fractures contained four cases of nonunions (four of 29 cases), all in patients with open fractures. Reported rates of nonunions in segmental tibial fractures differ substantially. Rates of 3% were reported for interlocked nailing [20], whereas others [15, 19] reported nonunion rates in up to one-third of the patients treated with variable techniques. Comparability of these studies is hampered by differences in the definitions of nonunion. Our rate of nonunion, however, does not substantially differ from that reported by other authors using similar definitions [1, 2, 4, 9]. The same accounts for delayed union, which is classified quite variable in studies reporting on this outcome [1, 4, 19]. Some studies did not specifically address delayed union [2, 5, 12, 14, 16, 20, 21], whereas Giannoudis et al. [4] used a comparable definition to ours reporting similar rates of delayed union (20 of 27 and 21 of 29, respectively). Furthermore, we observed a larger need for reoperations in the segmental fracture group compared with the nonsegmental fractures, which is likely related to the increased occurrence of problems regarding bone healing and the higher incidence of septic complications in the segmental fractures. The elevated incidence of septic complications could be a result of the relatively large amount of preventive fasciotomies performed in the group with segmental fractures, because six of the 10 deep infections observed in segmental fractures were related to cases in which preventive fasciotomy was performed.

Our observations confirm, by direct comparison with a matched control group of nonsegmental fractures, the problematic healing of segmental tibial fractures suggested in the literature. Our data further underline the unique and challenging character of segmental tibial fractures and the need for specialized treatment by an experienced orthopaedic or trauma surgeon in a specialized trauma center. We advocate treating these fractures using IMNs and, in addition, believe it is mandatory to properly inform patients beforehand about the often problematic healing in segmental fractures.

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