Reconstruction of Nonunion Tibial Fractures in War-Wounded Iraqi Civilians, 2006–2008: Better Late Than Never

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Objective: To describe medical care and surgical outcome after functional reconstructive surgery in late-presenting patients who already had at least one prior operation.

Design: Retrospective review of medical care and surgical outcome from August 2006 to December 2008 using patient records for initial data with active follow-up for the latest outcome information.

Setting: Médecins sans Frontières surgical programme in Jordan Red Crescent Hospital, Amman, Jordan.

Patients: Sixty-two civilians with nonunion tibial fractures caused by war-related trauma in Iraq; 53 completed follow-up.

Intervention: Amputation and/or reconstruction.

Main Outcome Measurements: Late surgical complications (after the patient's return to Iraq) were analyzed for infection recurrence, bone union, and functional condition (defined using the Short Musculoskeletal Functional Assessment score).

Results: Almost three fourths of patients arrived with infected injuries, 9 of whom had amputation as the initial surgery; the rest, and all uninfected patients, had reconstruction. Excluding loss to follow-up, only 4 of 53 (8%) patients who arrived with an infected injury had infection recurrence. Excluding loss to follow-up and amputation, 2 of 14 (14%) patients in the uninfected and 5 of 30 (17%) in the infected injury group did not achieve successful tibial union. Mean Dysfunctional and Bothersome Indices overall were 27.1 and 29.8, respectively, with similar results for all 3 groups (amputations, uninfected, and infected injuries).

Conclusions: Our study shows that patients with infected and uninfected injuries surgically treated in Amman achieved similar outcomes. Despite late presentation, our patients had a comparable outcome to other studies dealing with early reconstruction. Reconstruction for the infected group required longer treatment time.

Key Words: Iraq, nonunion, tibia, fracture, reconstruction

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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INTRODUCTION

In a country at war, accessing and treating patients in poorly equipped and insecure conditions are challenges for medical teams. Since the start of conflict in 2003 in Iraq, surgical teams have been confronted with a high number of war-related injuries in civilians.[1] Many of those wounded in Iraq sustained residual complications, which required reconstructive surgery.

In 2006, international medical aid organization Médecins sans Frontières (MSF; "Doctors without Borders") started a surgical program in a 49-bed ward in the Jordan Red Crescent Hospital of Amman, Jordan, to provide functional reconstructive surgery for Iraqi civilians, all of whom had had at least one previous operation in Iraq.[2] Patients have therefore experienced some delay between the time of injury and arrival in Jordan, either related to the extent or type of their injury or the number of operations undergone before their referral.

We describe the surgical treatment for war-related trauma in 62 patients from Iraq with tibial nonunions (mostly infected), who were treated in the MSF Amman surgical program between August 2006 and December 2008.

PATIENTS AND METHODS

Patient Selection

For the Amman surgical program, a network of doctors in Iraq identified patients with wounds in 3 specialty areas of functional reconstructive surgery (plastics, orthopaedics, and maxillofacial) that were difficult to treat in local settings for technical, administrative, or security reasons. The patients who could not receive complete treatment in Iraq were first seen by a general practitioner (MSF employee) and then referred to a specialist orthopaedic surgeon (non-MSF employee), who completed a referral application form. Files were then sent to

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the MSF coordination team in Amman for review and evaluation, and appropriate candidates were selected.

On each patient's arrival in Amman, a second evaluation was performed and the treatment plan was discussed. The support of surgical and infection specialists from France and the United States was solicited.

All patients included in the study had nonunions resulting from war-related compound tibial diaphysial fractures of Gustilo classification Grade II or III. Patients with involvement of the metaphysis or epiphysis were excluded.

Treatment, Discharge, and Complications

The MSF protocol for reconstruction of tibial nonunions was a two-staged approach[3] (Fig. 1). After débridement, any dead space was filled with either cement spacers (following the Masquelet technique[4]) or muscle flaps. The bone was then fixed by external fixation, internal fixation, or plaster of Paris casts. All external fixators were uniplanar external fixators. Most soft tissue surgeries involved a plastic surgeon.

All patients with positive deep bone cultures were classified as having infected injuries. These patients received intravenous antibiotics selected by sensitivity testing for 6 weeks and orally for at least 6 more weeks. After discharge to Iraq, patients were followed closely by the same network for regular clinical, radiologic, and biologic follow-up.

The time between the date of injury and the date of arrival in Amman was calculated in days. Length of stay in Amman was also calculated in days and represented the time from patient arrival in Amman to discharge to Iraq. Patients were discharged once they had: 1) no clinical or biologic symptoms or signs of infection, ie, C-reactive protein (CRP) values less than 10 mg/L;[5] 2) x-rays showing an early bridging callus; and 3) ability to perform 4 basic activities of daily living, defined as the patient being able to independently use the toilet, stand to cook, bathe, and dress.

Early surgical and medical complications, defined as those occurring during the patient's stay in Amman, were recorded for all patients. Soft tissue complications were analyzed according to the site of the diaphyseal fracture.

Outcomes

Clinical outcomes were assessed after the patient's discharge to Iraq and included:

- *Infection recurrence.* This was defined as any two of 1) signs of inflammation with or without discharging wound; 2) C-reactive protein 10 mg/L or greater; and (3) x-rays revealing sequestrum formation.
- *Bone union*. Successful tibial union required 1) radiologic evidence with bridging of the fracture by bone, callus, or trabecula, including three/four cortices); and 2) clinical evidence with absence of pain or tenderness on palpation.[6]

All nonunions were reviewed for history of systemic disease or smoking. Malunion was defined as valgus deformity of 12° or more, varus deformity of more than 6°, external rotation deformity of more than 15°, internal rotation of more than 10°, or shortening of more than 2 cm.[7]

- *Functional condition*. The Short Musculoskeletal Functional Assessment score was completed once for each patient when their union and infection conditions were assessed at the end of the follow-up period. The Dysfunctional Index and the Bothersome Index were calculated using standard formulae.[8]

Analysis

Bone union, functional condition, median delay from injury to arrival in Amman, and mean length of stay in Amman were compared for patients with infected versus uninfected injuries using Student t test with $P < 0.05$ being statistically significant. All calculations were performed using Epi-Info Version 3.5.1 (CDC, Atlanta, GA).

RESULTS

The MSF reconstructive surgery program received a total of 601 patients between August 2006 and December 2008. Orthopaedic cases represented 51% (n = 305) of all patients, of whom 83% (n = 254) had lower limb injuries. There were 62 cases of nonunion of the tibia eligible for analysis and nearly all were male (58 of 62 [94%]).

The causes of injury were car explosion (47%), bullet injury (41%), roadside bomb (6%), and mortar injury (6%). Forty-five patients (73%) had infected injuries at the time of admission. The age distribution for both infected and uninfected patients was the same ($P = 0.38$) with a median age of 31 years and a range from 5 to 63 years. Among the 45 patients with infected injuries, most (24; 53%) had draining wounds (Table 1) and infection was identified in the rest by bone culture at surgery.

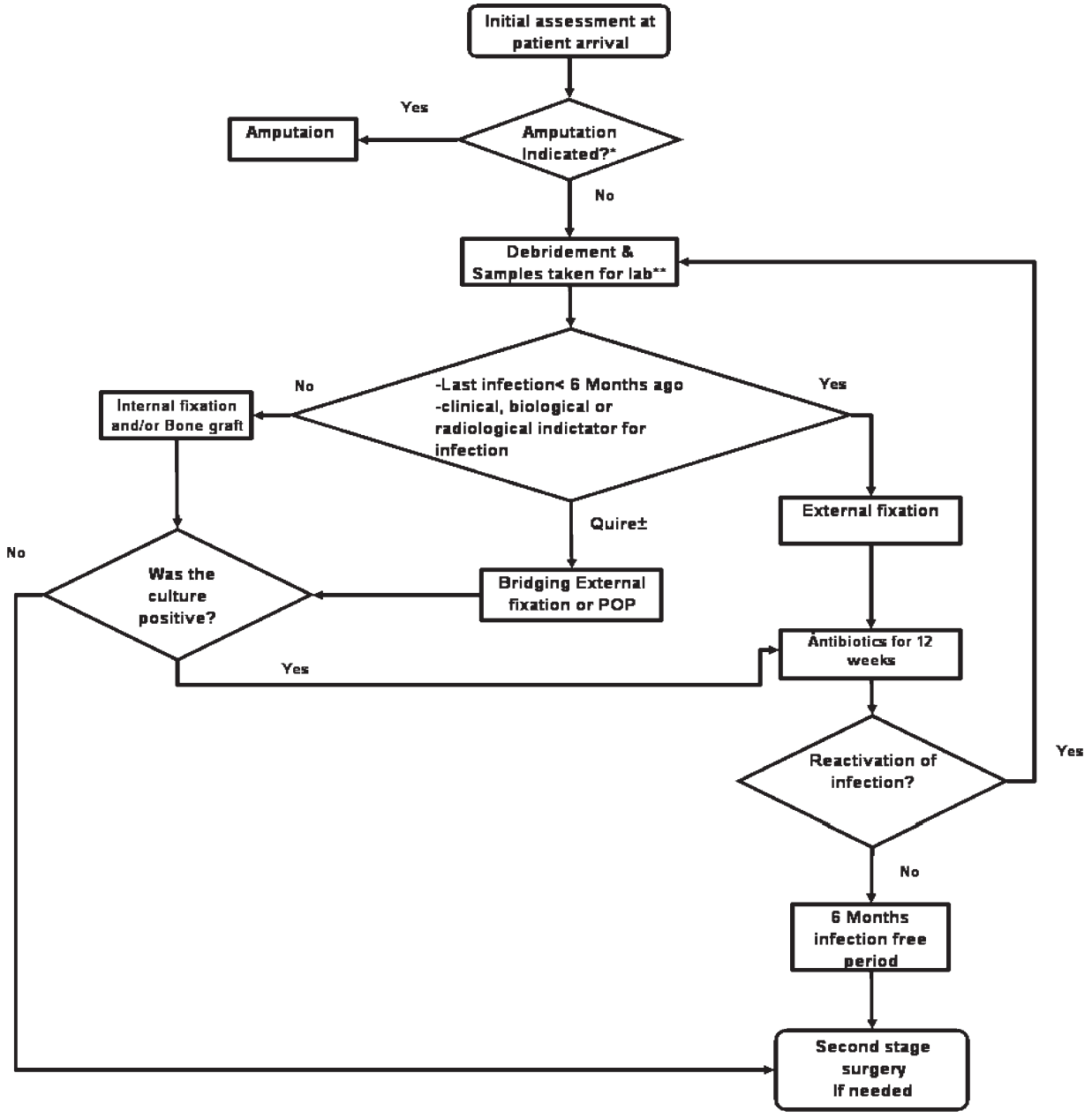
The distribution of the site of injury in the diaphysis is described in Table 2. All of the patients had been initially operated on in Iraq. The types of fixation used are described in Table 3. The mean delay from injury to arrival in Amman for all patients was 592 days with no statistically significant difference between infected and uninfected injuries (Table 2).

After the initial assessment, 9 patients, all with infected injuries, needed amputations. All amputations were performed after arrival from Iraq, ie, not as surgical sequelae for the Amman project. No amputation was needed for any patient in the uninfected group.

The 45 patients with infected injuries required more operations (Table 2). All internal fixations for this group were conducted on patients who presented with occult infection (ie, no clinical or biologic evidence of infection).

Bacteriologic data were complete for 37 of 45 (82%) patients in the infected group; 8 were excluded as a result of incomplete records. Eleven patients (30%) had one bacterium, and 26 (70%) had more than one. Bacterial species grown in culture are shown in Table 4.

A total of 268 operations were performed (on average 4 operations per patient). After débridement, dead space was filled with either cement spacers in 12 patients and muscle flaps in 39 patients. A bone graft was performed in 27 cases using nonvascularized iliac crest bone (see example of Patient 1; Fig. 2). Six patients had tibialization of the fibula (4 with additional iliac bone graft) (see example of Patient 2; Fig. 3). In 61 (23%) of the surgeries, involvement of plastic surgeons was needed. Plastic surgery procedures consisted of 13 axial flaps (mostly gastrocnemius), 6 free flaps (rectus), 2 random flaps, one cross-leg flap, one microsurgical vascular bypass,



*Indications: Infection with a defect >5cm + neurovascular injury; uncontrolled resistant bacteria.
**An excision with a good bone bleeding, three cultures for all patients, plastic surgery if needed.
± No sinus or other evidence of infection but during surgery the bone was unhealthy.

FIGURE 1. Flow chart outlining the two-staged approach used for reconstruction of tibial nonunions.

and 38 other plastic surgeries (eg, skin grafts, refashioning of flaps, wound closures).

The mean length of stay in Amman was significantly longer for infected than uninfected patients (166 vs 69 days; $P = 0.001$).

Early Surgical Complications

Of the 45 patients with infected injuries, 19 (42%) had early surgical complications, 15 of which involved soft tissue and 4 involved bone. Of the latter, 3 were reactivation of

TABLE 1. Infection Status of Patients With Infected Tibial Nonunions (N = 45)

	No.	Percent
Actively draining at admission	24	53
Prior infection and quiescent nonunion*	14	31
No prior infection and quiescent nonunion*	7	16

*Quiescent nonunions represent those fractures without clinical or biologic evidence of infection but for which bacteria were found after routine bone culture.

infection and one was a bone misalignment. All bony complications were managed immediately through further excision and antibiotic therapy until the infection was cured both clinically and biologically. For the misalignment, readjustment of the external fixation was performed.

Among the 17 patients with uninfected injuries, there were only 3 complications (18%), all involving soft tissue.

The soft tissue complications in both groups were caused by scar tissue and included marginal necrosis, minor wound dehiscence, hematoma, and seroma collection. Almost half (44%) of these occurred in the lower part of diaphysis, 39% in the middle part and 17% in the upper part.

No Deaths Occurred, and There Were Only Three Allergic Drug Reactions

Follow-Up After Discharge to Iraq and Outcomes

The mean follow-up period was 730 days. Nine of the 62 patients analyzed did not complete follow-up (contact with the patient was lost in Iraq). Hence, a total of 53 (85%) patients were included in the follow-up analysis (Table 5).

Two patients in the infected group with reconstruction had recurrence of infection (7%). One of them developed a soft tissue infection 3 months after the operation with good bone healing. The other had a plate during his surgical procedure over an occult infection; he developed reactivation of infection 9 months after surgery with good bone healing. The plate was removed and the patient has been infection-free for 6 months of follow-up. There were 2 soft tissue infection recurrences at the amputation stump (22%) (Table 5); both were treated conservatively.

There was no statistically significant difference in nonunion for patients in the infected (5 of 30 [17%]) versus the noninfected injury group (2 of 14 [14%]; $P = 0.98$). All fractures with nonunions were fixed with external fixators. Three of the 5 nonunions in the infected group had a history of systemic disease or smoking and 2 did not. One of the 2 nonunions in the uninfected group had a history of diabetes mellitus and the other had no history of systemic disease or smoking.

One patient in each of the infected and uninfected groups had malunion that required readmission for corrective osteotomy.

The mean Dysfunctional and Bothersome Indices were conducted once, at the end of the follow-up period. There were no statistically significant differences found for these indices when comparing either infected patients with reconstruction versus amputation or infected versus uninfected patients with reconstruction (Table 5).

TABLE 2. Description of Infected and Uninfected Patients

		Infected	Uninfected
Number (%)		45 (73%)	17 (27%)
Site of injury in diaphysis	Upper diaphysis	25 %	12%
	Middle diaphysis	50%	17%
	Lower diaphysis	25%	71%
Mean delay from injury to Amman (days)		568	664
Mean number of operations		5 (range, 1–19)	2 (range, 1–7)
Type of fixation in Amman (%)	External fixation	27 (60%)	12 (71%)
	Amputation	9 (20%)	0 (0%)
	Internal fixation	4 (9%)	5 (29%)
	Plaster of Paris cast	4 (9%)	0 (0%)
Mean length of stay (days)		166	69
Early surgical complications		42%	18%

TABLE 3. Fixation Used in Iraq for Tibial Nonunion Patients by Presence of Infection

	Patient Group					
	Infected		Noninfected		Total	
Type of Fixation in Iraq	No.	(%)	No.	(%)	No.	(%)
External fixation	28	62.2	11	64.7	39	62.9
Nail then external fixation	0	0.0	1	5.9	1	1.6
No Fixation	12	26.7	5	29.4	17	27.4
Removed external fixation	2	4.4	0	0.0	2	3.2
Removed nail	1	2.2	0	0.0	1	1.6
Lag screws	2	4.4	0	0.0	2	3.2
Total	45	100.0	17	100.0	62	100.0

DISCUSSION

Sixty-two patients with nonunion of the tibia were eligible for analysis in our study. These patients experienced a total of 268 operations (mean 4 per patient) and approximately 25% required a plastic surgeon. Almost three fourths of these (45) had infected injuries at admission, and these had a shorter delay to arrival at Amman, required more

TABLE 4. Proportion of Bacterial Species Grown in Culture

Species	Percent of Cultures
Staphylococcus aureus	27%
Escherichia coli	21%
Proteus	16%
Pseudomonas	12%
Enterococcus	7%
Klebsiella	5%
Acinetobacter	2%
Serratia	2%
Other	8%

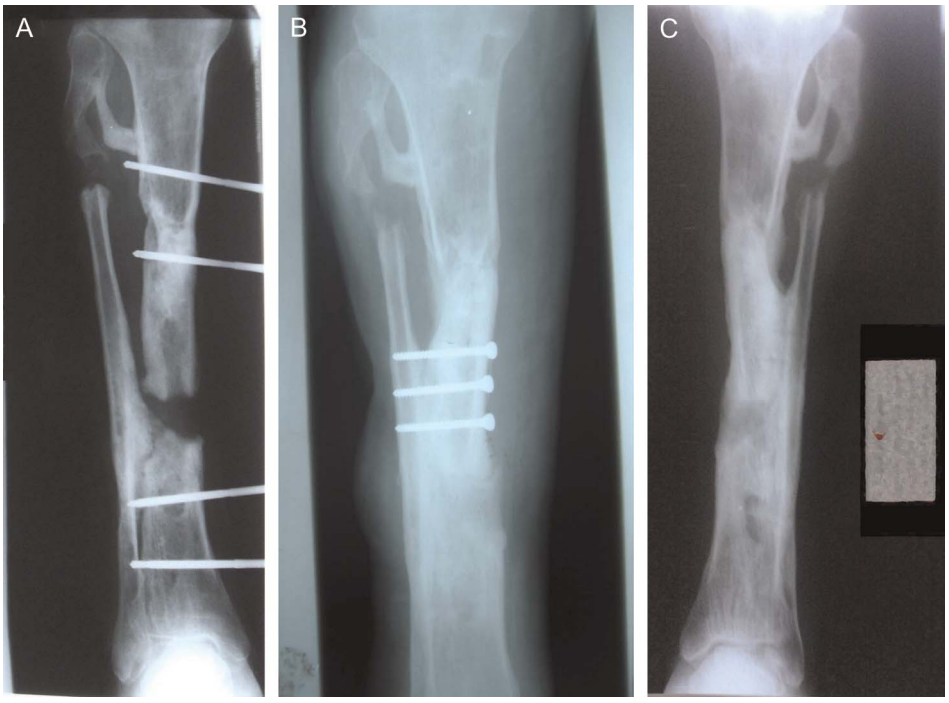


FIGURE 2A–C. Photographs of Patient 1, a 44-year-old man. (A) Bone graft 678 days after injury with hidden bone infection. (B) Second-stage tibialization of the fibula with bone graft and screw fixation. (C) Two years after tibialization, screws were removed; Short Musculoskeletal Functional Assessment with Dysfunctional Index of 24.3 and Bothersome Index of 41.7.

operations, and stayed longer in Amman. Most patients in both groups had successful tibial unions.

Civilian war injuries are a major clinical problem in conflict-affected areas of the world. Iraq has been one such area with a large number of war-related civilian deaths and injuries,[9] posing a substantial need for reconstructive surgery programs.

The patients in our study were mainly young men. This complies with the findings of Behbehani et al in a plastic surgery unit during the 1991 Gulf War.[10] Because the effect on society of the functional loss of the young male population is highly significant (related to the "large number of years lived with disability"[11]), reconstruction is important, ultimately providing support for the whole society affected by the conflict.

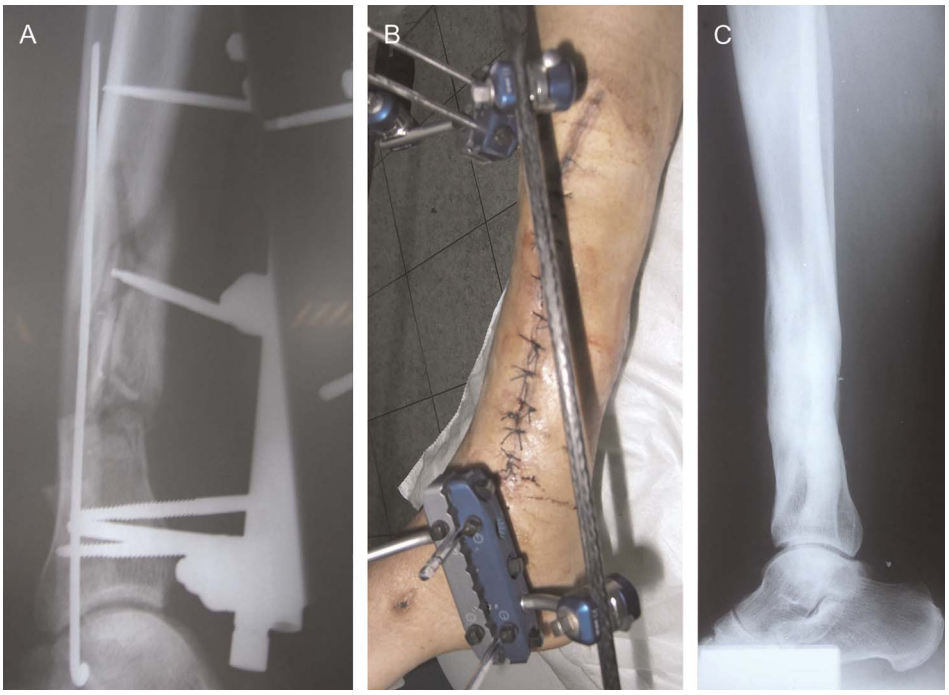


FIGURE 3A–C. Photographs of Patient 2 (29-year-old man). (A) Infected delayed union of tibia 69 days after injury. (B) Débridement and external fixation completed. (C) Two and a half years after second-stage bone graft; Short Musculoskeletal Functional Assessment with Dysfunctional Index of 7.1 and Bothersome Index of 2.1; no reactivation of infection.

TABLE 5. Follow-Up After Discharge From Amman

Patient Category	Infected Nonunion + Reconstruction	Infected Nonunion + Amputation	P_1*	Uninfected Nonunion + Reconstruction	P_2*
Completed follow-up	30	9		14	
Lost to follow-up	6	0		3	
Infection recurrence	2 (7%)	2 (22%)		0 (0%)	
Status of bone union					
United (%)	24 (80%)	—		11 (79%)	
Malunion (%)	1 (3%)			1 (7%)	
Nonunion (%)	5 (17%)	—		2 (14%)	
SMFA					
Dysfunctional Index	27.2	28.9	0.2	25.4	0.6
Bothersome Index	32.2	29.8	0.9	27.3	0.4

*P_1 = P value for SMFA comparison for patients with infected nonunion and reconstruction vs amputation; P_2 = P value for SMFA comparison for patients with reconstruction and infected vs uninfected nonunions.
SMFA, The Short Musculoskeletal Functional Assessment score.

Lower-limb injuries are the most common during these conflicts, up to 75% according to some estimates.[12,13] There are few publications focusing on tibial nonunions after civilian war injuries. Previous studies on reconstruction describe surgical reconstructions a few days or weeks after injury.[14,15] Our study is unique in its description of outcomes for patients with tibial nonunions after a delay in starting reconstructive surgery.

Lower limb war injury carries a high incidence of infections.[16–19] We found that 73% of tibial nonunions arrived from Iraq infected, but it is not clear whether this was the result of the original injury or was related to complications from previous surgeries in Iraq. Approximately 15% of infections were occult, only discovered after bone culture performed routinely in the first operation. There is no publication, as far as we are aware, addressing occult infections after civilian war injuries with which we could compare our results.

Our results showed a higher proportion (70%) of patients with infected injuries with more than one bacterium isolated than reported from other studies (27%[20] and 37%[21]). This may be a result of the severity of the war-related extremity injury, delay in presentation, or either lack or inadequacy of facilities during initial care in Iraq.

After more than 1 year of follow-up, our results for infection recurrence in the infected injuries group (in 2 of 39, or 5% of patients) are in keeping with other studies (no recurrence of infection after wide resections[22]; 8% infection recurrence for a follow-up period of 49 months[3] for nonwar-related osteomyelitis; a 5–9% chance of recurrence after 1 disease-free year[20,23]).

The two-staged surgery method has proven a successful approach for treating infected nonunions.[3] Dissection of scarred and damaged tissue requires special technical care.[21] A previous study using this type of excision showed 100% infection-free survival in a 4-year follow-up of chronic osteomyelitis.[22]

The main limitation of a retrospective record review is that the quality of the study is dependent on the quality of the records being reviewed. In addition, our study of tibial nonunions included patients with a range of injuries, both infected and noninfected, with varying lengths of delay from initial injury to treatment, and we assessed more than one outcome. Furthermore, different factors (such as age, size of the bone gap, vascularity, and infection control) determined the type of approach used for each patient; hence, there was neither a single type of injury nor was a single approach used for treatment. The inherent heterogeneity in both injury and treatment approach was a limitation in our study; however, this highlights the reality of operational research. Our work involves a look back at current practice in a "real" field situation, with results that will be of immediate value for other surgical programs, both within MSF and beyond.

The presence of 16% of occult infections with poor soft tissue cover made us reluctant to perform internal fixations unless certain criteria were fulfilled (Fig. 1).[24] All amputations were performed soon after arrival in Amman; no amputation was conducted as a result of our project's treatment failure. It has been recommended that a decision to amputate should be made immediately after injury.[25,26] We would support this, because we encountered significant challenges in obtaining agreement for amputation in patients who had undergone multiple surgeries (only one patient preferred amputation to multistage, long-term surgery). Psychologists were of great help in preparing patients for these procedures.

In the infected patient group, early surgical complications involved soft-tissue problems (79%) or bony complications (21%). The high incidence of soft-tissue infection could be explained by the level of scarring and the presence of multiple foreign bodies secondary to the traumatic injury. The majority of these complications occurred in the lower and middle part of the diaphysis of the tibia rather than the upper part. This is possibly the result of the nature of the blood supply to these parts.[27]

Follow-up was completed for 3 major outcomes: recurrence of infection, bone union, and functional ability. Although comparable studies dealing with patients in similar settings are lacking, our study showed that the late reconstruction of infected tibial nonunions can give acceptable results. The fact that the Dysfunctional and Bothersome Indices showed no significant difference between those treated

with amputations and those with reconstruction (of either infected or uninfected nonunions) raises the question about which approach is the best. Some studies performed on both military populations and nonwar injuries have indicated that amputations are superior to reconstruction.[28,29] These studies, however, describe the results of early reconstruction or amputations. In contrast, our study patients were treated late, whether for amputation or reconstruction, and were all civilian. Furthermore, our patients were from a society with different physical requirements (such as kneeling to pray, using an Eastern or squat WC, and sitting on the ground). Despite these differences, however, the Dysfunctional and Bothersome Indices after 730 days of follow-up remained comparable to the other studies.

Even if performed late, we show that outcomes may not be so different from those of war-injured soldiers treated from the beginning of their injuries in excellent settings.[14,15,30] Following the general principles of two-stage surgery, with a multidisciplinary surgical team, trustworthy laboratory results, and proper antibiotic management, patient populations surgically treated in Amman benefit from similar outcomes as those receiving treatment in better-resourced contexts.

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