

# Functional Treatment of Closed Segmental Fractures of the Tibia

## Funkční léčba zavřených segmentálních zlomenin tibie

A. SARMIENTO, L. L. LATTA

Investigation conducted at the University of Miami and University of Southern California, USA

### ABSTRACT

#### PURPOSE OF THE STUDY

Segmental tibial fractures are commonly believed to be more difficult to manage, requiring surgical treatment. Our experience with forty-eight segmental tibial fractures suggests that these fractures, if closed and with shortening of an acceptable initial degree and a corrected deformity, may be successfully treated with functional braces.

#### MATERIAL AND METHODS

Forty-eight closed segmental fractures of the tibia that had initial shortening  $\geq 12$  mm and angular deformity manually corrected to  $\geq 7$  degrees were stabilized in an above-the-knee cast for a median time of 33 days and a mode of 15 days. They were subsequently stabilized in a functional brace that allowed unencumbered motion of all joints. All other segmental fractures outside the established parameters were managed by other methods.

#### RESULTS

All fractures healed at a median time of 15.3 weeks. The final shortening was 4.7 millimeters with a mode of 12 millimeters. The maximum shortening was 14 millimeters. Fractures healed with a medial-lateral (M.L) angular deformities ranging zero to 19 degrees, a median of 5.9 degrees and a mode of 3.4 degrees.

#### CONCLUSION

The relatively early introduction of weight bearing and the freedom of motion of all joints that the brace permits seem to result in motion at the fracture site, which in turn enhances osteogenesis. As we have previously documented, the initial shortening that closed tibial fractures experience does not increase with the physiological use of the extremity. The final shortening and angulation observed in most of the fractures should not be considered complications, simply inconsequential deviations from the normal. The same should apply to closed segmental fractures.

**Key words:** segmental tibial fractures, functional bracing, conservative treatment.

### INTRODUCTION

Segmental tibial fractures are usually considered more difficult to manage, as they are frequently the result of high-energy injuries. Many of them are open fractures, which increase the risk of complications, such as infection. However, there is no reliable scientific data to suggest that the presence of fractures at two different levels of the tibial diaphysis necessarily compromises osteogenesis. The mechanism of healing of the two fractures is independent from each other. When the fractures are treated by means of rigid fixation with a plate or external fixator the medullary blood supply is rapidly restored, but peripheral callus does not form (24, 25). Under this circumstance, the activity of the periosteum as an osteogenic contributor, is likely to be minimal, and the rigid immobilization of the bone produces cortical atrophy and a resulting weaker callus (18, 24, 25).

Since it is clear that the initial shortening experienced by axially unstable tibial fractures (oblique, spiral, comminuted) associated with a fibular fracture, experience at the time of the injury the final shortening, fractures meeting this criterion, whether simple or segmental, should heal without additional shortening. Angular deformity, if only of a few degrees, should not increase further, because the hydraulic environment created by the snugly fitting brace, prevents its further progression.

The fractures healed at a median time of 15.3 weeks. Nonunion was not encountered. The final median shortening was 4.7 millimeters with a mode of twelve millimeters. The maximum shortening was fourteen millimeters. Fractures healed with a medial-lateral (M.L) angular deformities ranging from zero to 19 degrees, a median of six degrees and a mode of 3.4 degrees. Long-term follow-up was not available.

## MATERIAL AND METHODS

We reviewed a series of 47 closed segmental tibial fractures treated with a below-the-knee functional brace and report on time to union, final shortening and angulation. Weight bearing was allowed from the outset of treatment as dictated by symptoms.

The criteria for inclusion for this treatment method were closed fractures that had initial shortening <12 mm, and angular deformity corrected to <7degrees.

The study was conducted consecutively at two different institutions: the first 17 (35.3%) patients were treated at Jackson Memorial Hospital, the main teaching hospital for the University of Miami, (U.M.) and the remaining 31 (64.5%) patients at the Los Angeles County Medical Center, the main teaching hospital for the University of Southern California (USC).

The data recorded at the time of every outpatient visit was the same at both institutions. However, specific information regarding some data such as gender, age and mechanism of injury in the U.M. group was not available since the original raw data had been lost. Therefore, it became necessary for us to use the data we had used for an earlier publications, which did not separately indicated the age, gender and mechanism of injury for the various levels of the fractures (19). This is noted throughout the text and in the appropriate tables.

The group of patients treated at the University of Miami consisted of 733 closed diaphyseal tibial fractures, from which seventeen were segmental fractures. One hundred and thirty-eight were lost to follow-up. The University of Southern California group was made of 2300 closed diaphyseal tibial fractures from which only 950 fractures were available to complete follow-up to either healing or to the appearance of a nonunion. From this group come the thirty-one segmental fractures.

All forty-eight fractures in the study were initially stabilized in an above-the-knee cast, which was replaced with a functional brace at a median time of 33 days and a mode of 15 days). No information is available concerning the number of times that the above-the-knee cast was reapplied in order to obtain the most desirable alignment. The fractures were stabilized under anaesthesia if manipulation was anticipated for the attainment of improved alignment; otherwise it was done under sedation when forceful manipulation was not needed. Attempts to regain length were not made, as we had already demonstrated that the initial shortening of axially unstable closed tibial fractures, associated with a fibula fracture do not experience additional shortening. Also, that in this instance recurrence of shortening to the initial level occurs during weight bearing ambulation (10, 13, 18, 22, 26, 27). Graduated weight bearing ambulation was encouraged and dictated by the patients according to the severity of symptoms. Patients were followed in a special outpatient clinic usually at one month intervals according to a long-established protocol (28).

Seventy-four percent of patients were male and 25.8% were female (USC). The right leg was fractured in 51%

Table 1. Patients and injuries in each study

Parameters		Univ. of Miami patients	Univ. S. Carolina patients	Total
Number of patients		17	31	48
Gender	Male		23 (74 %)	
	Female		8 (26 %)	
Age	Median		39 years	
	Range		16 – 72 years	
Mechanism of injury	MCA		9 (29 %)	
	PVA		16 (52 %)	
	MVA		4 (13 %)	
	Fall		8 (26 %)	
	DB		1 (3 %)	
Fibula fracture	Yes	15 (88 %)	26 (84 %)	41 (85 %)
	No	2 (12 %)	5 (16 %)	7 (15 %)
Days to brace	Median		33	
	Mode		15	

patients, and the left leg in 48.3% patients (USC). The median age was 39 years, ranging from 16 to 72 years; the mode was 43 years (USC). The mechanism of injury consisted of motorcycle accidents (MCA) in 29% patients; pedestrians struck by motor vehicles (PVA) 51% patients; passengers in motor vehicles (MVA) 12.9% patients; falls from a height (F) 2.5% patients; and direct blow (DV) 3.2%. 85.4% patients (USC) had an associated fracture of the fibula, while the remaining 14.6% had an intact fibula (USC) (Table 1).

## RESULTS

The fractures were considered healed when radiological evidence of bridging callus was observed and the patient was able to walk without the brace and without pain. All fractures healed. The radiographs were read by orthopaedic residents attending the Fracture Brace Clinic at every visit. However, a senior resident assigned to prepare a formal presentation of results, reviewed the films and made whatever corrections he/she deemed appropriate and then prepared a manuscript for publication. The healing occurred at a median of 15.2 weeks (Fig. 1). The longest healing time was 30 weeks. The median final shortening was 4.7 millimeters with a mode of 12 millimeters (Figs. 2 and 3). The maximum shortening was 14 millimeters. Fractures healed with medial-lateral (M.L) angular deformities ranging zero to 19 degrees, with a median of 5.9 degrees and a mode of 3.4 degrees (Fig. 4). In the antero-posterior (A.P) plane, fractures healed with a median deformity of 1.5 degrees; a mode of 4 degrees and a maximum of 10 degrees (Figs.5 and 6), (Table 2). Angular alignment was assessed from the knee line to ankle line on the anteroposterior radiograph and in relation to the center of the diaphysis on the lateral radiograph.

No attempt was made to obtain data concerning long-term function, because previous experiences had indicated that in our teaching/charity hospitals once fractu-

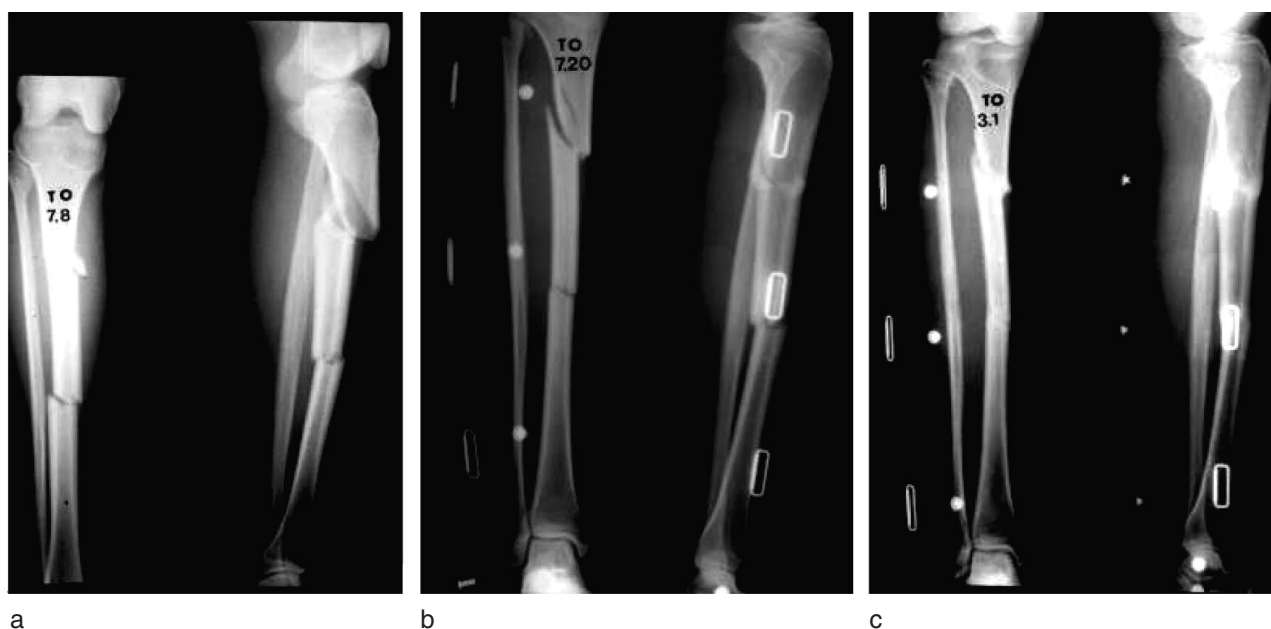
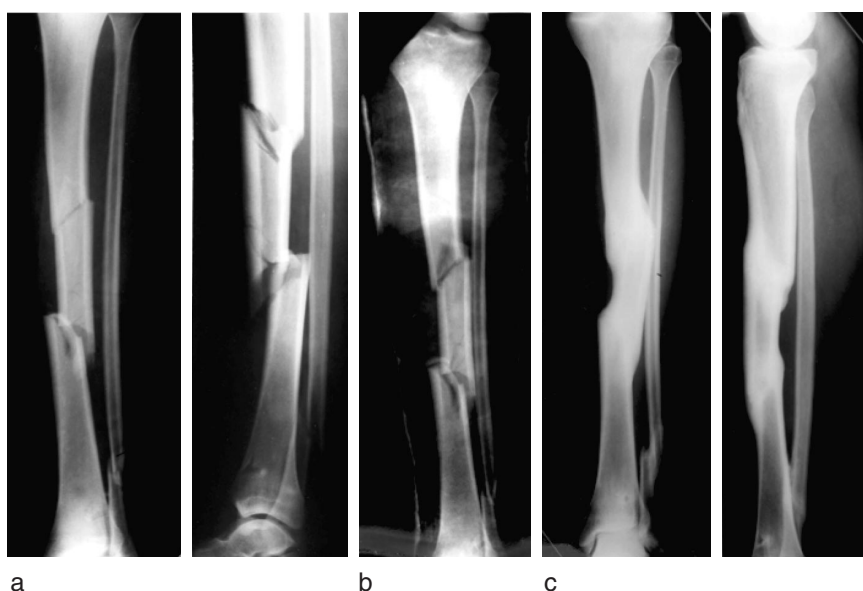


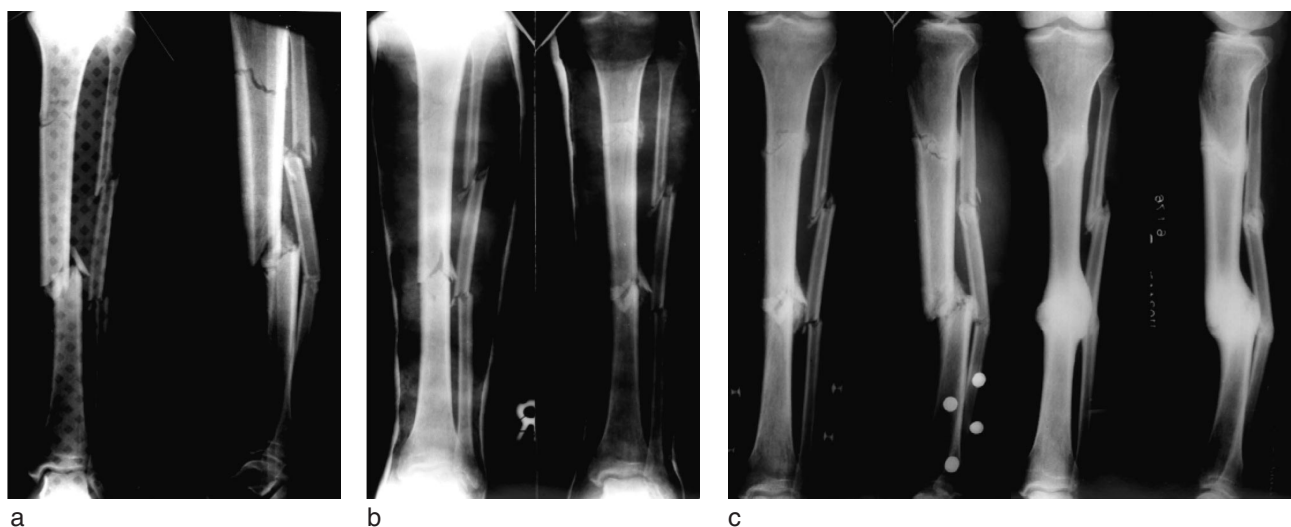
Fig. 1a-c. a) Antero-posterior and lateral radiographs of closed segmental fracture illustrating the acceptable initial shortening. b) Radiographs obtained in a functional brace after manual realignment of the fragments. c) Radiographs taken eight months after the initial insult. The fracture had been healed for some time.



Fig. 2a-b. a) Composite picture of radiographs of double segmental closed fracture of the tibia. Notice the acceptable original shortening. No attempt was made to regain length. The fracture healed with the same initial shortening and with good alignment. b) Clinical photographs of the patient's legs.



*Fig. 3a-c. a) Radiograph of closed segmental fracture of the tibia illustrating the acceptable initial shortening and the correctable angular deformity. b) Radiograph taken after the manual alignment of the fragments and the application of the above-the-knee cast. c) Radiograph obtained long after the fracture healed. The initial shortening remained essentially unchanged.*



*Fig. 4a-c. a) Radiograph of closed segmental tibia fracture illustrating the acceptable initial shortening and posterior angulation at the distal fracture. b) Radiograph taken after manual reduction of the fracture and the application of the above-the-knee cast. c) Radiograph taken long after healing had taken place illustrating the inconsequential residual recurvatum deformity.*

res are healed most patients never return for long-term further evaluation. This is due to the fact that our patients at both institutions were members of the lowest strata of society, with poor education and lacking the financial means to return to outpatient clinics. They reasoned that once the injured leg becomes painless and they were able to ambulate without external support additional medical care was not necessary. The range of motion of the knee and ankle was not reported since previous experiences had demonstrated that the short period of immobilization in the above-the-knee cast does not produce long-term limitation of motion.

## DISCUSSION

Functional bracing of closed segmental fractures that demonstrate an initially acceptable degree of shortening ( $\leq 12$  millimeters) and angular deformities appropriately corrected manually do  $\leq 7$  degrees appears to be a valuable therapeutic modality. As in the case of non-segmental closed tibial fractures, the initial shortening does not increase with the use of the extremity (12, 14, 17, 20, 24, 25, 26, 28). Patients whose tibial fractures heal with less than 12 millimeters of shortening and less with  $\leq 7$  degrees of angulation can be considered to be



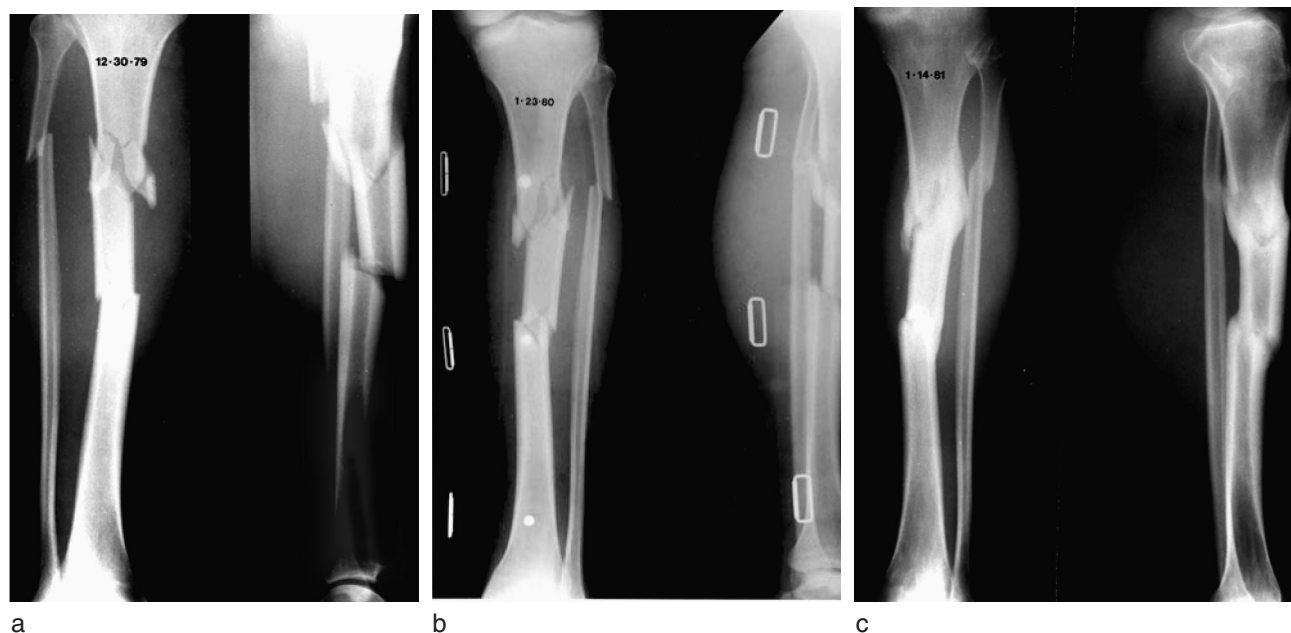


Fig. 5a-c. a) Radiograph of closed segmental tibia fracture demonstrating acceptable initial shortening. b) Radiographs obtained after the application of the brace. No attempt was made to regain length. c) Radiographs obtained after completion of healing. Notice that the initial shortening remained essentially unchanged.

Table 2. Outcomes

Parameters			Univ. of Miami patients	Univ. S. Carolina patients	Total, both series
Number of patients			17	31	48
Healing time: wks.	mean	Closed	13.5	17.2	16.0
Final shortening, in mm	mean		3.7	5.4	4.8
	mode			10.0	
Final angulation in the ML plane, number of patients (% of group)		$\geq 5^\circ$	11 (64.7 %)	23 (74.2 %)	34 (70.8 %)
	Varus	$6^\circ-8^\circ$	3 (17.6 %)	3 (9.7 %)	6 (12.5 %)
		$>8^\circ$	0 (0 %)	1 (3.2 %)	1 (2.1 %)
	Valgus	$6^\circ-8^\circ$	3 (17.6 %)	2 (6.5 %)	5 (10.4 %)
		$8^\circ$	0 (0 %)	2 (6.5 %)	2 (4.2 %)
Final angulation in the AP plane, number of patients (% of group)		$\geq 5^\circ$		25 (80.6 %)	
	Anterior	$6^\circ-8^\circ$		0 (0 %)	
		$>8^\circ$		0 (0 %)	
	Bow	$6^\circ-8^\circ$		4 (12.9 %)	
		$>8^\circ$		2 (6.5 %)	

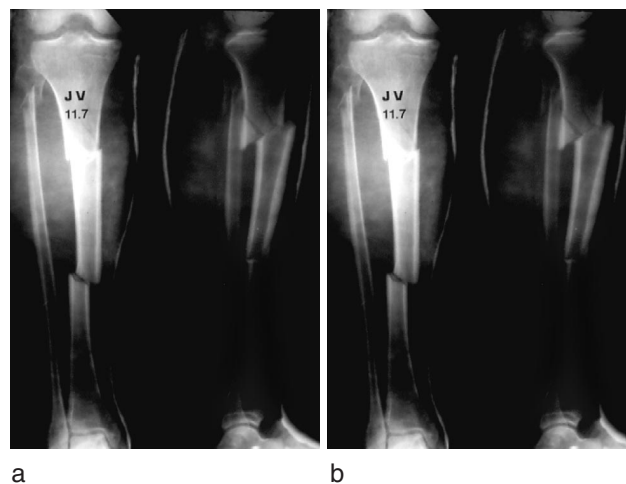


Fig. 6a-b. a) Radiograph of closed segmental fracture showing acceptable initial shortening. b) Radiograph obtained seven months after the initial injury. The shortening and angular deformity are acceptable.

clinically and cosmetically good results, since such deviations from the normal are not complications. They are aesthetically difficult to recognize with the naked eye, do not produce a limp, or are likely to produce late osteoarthritic changes 16.

When the fractures are treated by means of rigid fixation with a plate or external fixator the medullary blood supply is rapidly restored, but peripheral callus does not form (12, 13, 18, 19, 20, 22, 23, 24, 25, 31). Under this circumstance, the activity of the periosteum as an osteogenic contributor is likely to be minimal, and the rigid immobilization of the bone produces cortical atrophy

and a resulting weaker callus. The early introduction of weight bearing and the freedom of motion of all joints that the brace permits result in motion at the fracture site, which in turn enhances osteogenesis (9, 18, 20, 21, 22, 23, 24, 25, 30).

Several reports in current orthopaedic literature have recommended intramedullary nailing of tibial fractures with varying degrees of success (1, 3, 5, 6, 7, 11, 15, 32, 33, 34). This method of fracture fixation, however, is not free of complications, among which chronic knee pain remains the most elusive one. Court-Brown et al reported an incidence of knee pain in 56.2% of patients, most

of them significantly younger. There was considerable functional impairment with 91.7% of patients experiencing pain on kneeling and 33.7% having pain even at rest. They stated that 24.4% patients required removal of the nail (2). Orfany et reported the need for nail removal because of knee pain in 80% of 61 patients, and after 16 months the pain had not resolved in 22 (36%) of these patients (17). Toivanen et al reported knee pain in 86% of patients who had a transtendinous approach, and 81% in patients who had a paratendinous approach. They stated that 69% of their patients had anterior knee pain at an average of 1.5 years after nail removal (30). In a recent and most comprehensive review of the literature Katsulos et al., documented the high incidence of complications associated with intramedullary nailing of tibial fractures (8).

The final shortening recorded in our patients with diaphyseal fractures at all levels of the tibia seems to be comparable to those reported by others using different treatment modalities (1,5,7,15,33). In our study the mean shortening was 5.1 mm. At our institution, intramedullary nailing was the preferred method of treatment for axially unstable fractures with initial shortening greater than 15 mm. We do not have information as to the number of fractures treated surgically during the same period of time. The high rate of union in our study supports the biological fact that closed diaphyseal fractures if allowed to experience physiological motion at the fracture site usually heal uneventfully. Others have reported on the incidence of nonunion following intramedullary nailing, though not limited to segmental fractures. Gregory and Sanders reported 8% nonunion in 38 closed fractures (5). Wiss and Stetson reported a nonunion rate of 2% (32). Court-Brown et al. reported a nonunion rate of 1.6% (3). Kakar and Tornetta reported an average healing time for closed segmental fractures treated with intramedullary nails of 19.7 weeks. They allowed full weight bearing within three months and did not encounter nonunions. They also reported chronic knee pain in 27% patients. Their reported healing time for their closed segmental fractures averaged 4.5 months. Their average shortening was 3mm 9 range 0-15, but did not separate the closed from the open fractures (7). With the functional bracing method we used, weight bearing was encouraged from the outset to a degree dictated by symptoms, according to our long-standing protocol (28).

Since in our study surgery was not performed, no infections were encountered. Others have reported other complications, such as cortical necrosis and compartment syndromes (4, 10, 14). The satisfactory results we report do not mean that the nonsurgical functional treatment is the best or only method of treatment. Quite the contrary, functional bracing has relatively few indications, but when those indications are properly recognize the results can be satisfactory. We have rarely used the functional bracing method in the care of open fractures because these fracture usually experience unacceptable degrees of shortening and oftentimes show unacceptable angular deformities. These fractures are best treated with external fixators or internal fixation.

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Prof. Augusto Sarmiento, M. D.,  
Department of Orthopaedic and  
Rehabilitation University of Miami  
School of Medicine D-27  
P.O.Box 016960 Miami, Fl. 33101  
USA

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