Reconstruction of Segmental Bone Defects Due to Chronic Osteomyelitis with Use of an External Fixator and an Intramedullary Nail. Surgical Technique

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Reconstruction of Segmental Bone Defects Due to Chronic Osteomyelitis with Use of an External Fixator and an Intramedullary Nail

Surgical Technique

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ABSTRACT FROM THE ORIGINAL ARTICLE

BACKGROUND: Callus distraction over an intramedullary nail is a rarely used technique for the reconstruction of intercalary defects of the femur and tibia after radical débridement of chronic osteomyelitic foci. The aim of this study was to summarize our experience with distraction osteogenesis performed with an external fixator combined with an intramedullary nail for the treatment of bone defects and limb-shortening resulting from radical débridement of chronic osteomyelitis.

METHODS: Thirteen patients who ranged in age from eighteen to sixty-three years underwent radical débridement to treat a nonunion associated with chronic osteomyelitis of the tibia (seven patients) and femur (six patients). The lesions were classified, according to the Cierny-Mader classification system, as type IVA (nine) and type IVB (four). The resulting segmental defects and any limb-length discrepancy were then reconstructed with use of distraction osteogenesis over an intramedullary nail. Two patients required a local gastrocnemius flap. Free nonvascularized fibular grafts were added to the distraction site for augmentation of a femoral defect at the time of external fixator removal and locking of the nail in two patients. At the time of the latest follow-up, functional and radiographic results were evaluated with use of the criteria of Paley et al.

RESULTS: The mean size of the defect was 10 cm (range, 6 to 13 cm) in the femur and 7 cm (range, 5 to 10 cm) in the tibia. The mean external fixator index was 13.5 days/cm, the consolidation index was 31.7 days/cm, and the mean time to union at the docking site was nine months (range, five to sixteen months). At a mean follow-up of 47.3 months, eleven of the thirteen patients had an excellent result in terms of both bone and functional assessment. There were two recurrences of infection necessitating nail removal. These patients underwent revision with an Ilizarov fixator. Subsequently, the infection was controlled and the nonunions healed.

CONCLUSIONS: This combined method may prove to be an improvement on the classic techniques for the treatment of a nonunion of a long bone associated with chronic osteomyelitis, in terms of external fixation period and consolidation index. The earlier removal of the external fixator is associated with increased patient comfort, a decreased complication rate, and a convenient and rapid rehabilitation.

LEVEL OF EVIDENCE: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

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INTRODUCTION

Musculoskeletal infections remain a common problem. Because of better staging systems, more refined surgical techniques, antibiotics, and adjuvant treatment modalities such as hyperbaric oxygen, the treatment strategy for chronic osteomyelitis has changed greatly over the past twenty years[1].

Callus distraction over an intramedullary nail is a rarely used technique for the reconstruction of intercalary defects of the femur and tibia after radical débridement of chronic osteomyelitic foci. The combined technique reduces the external fixation time and consolidation index compared with the classic techniques for the treatment of long-bone nonunions associated with chronic osteomyelitis. Earlier removal of the external fixator is associated with increased patient comfort, a decreased complication rate, and a convenient and rapid rehabilitation.

TABLE I Cierny-Mader Classification System for Long-Bone Osteomyelitis[9]

Anatomic type	
	Type I (medullary osteomyelitis)
	Type II (superficial osteomyelitis)
	Type III (localized osteomyelitis)
	Type IV (diffuse osteomyelitis)
Physiologic class	
	A Host (normal)
	B Host
	B^S (systemic compromise)
	B^L (local compromise)
	B^{LS} (local and systemic compromise)
	C Host (treatment worse than disease)

FIG. 1-A

Figs. 1-A through 1-G A forty-seven-year-old man with Cierny-Mader type-IVB chronic osteomyelitis of the left tibia. **Fig. 1-A** Clinical photograph of the affected leg.

SURGICAL TECHNIQUE

Stage I

Preoperatively, plain anteroposterior and lateral radiographs, magnetic resonance imaging, and indium-labeled leukocyte radionuclide scans are used to examine the entire long bone and identify any foci of distant or skipped infection or dead bone. These studies thus assist in determining resection levels. Hardware removal and radical resection of

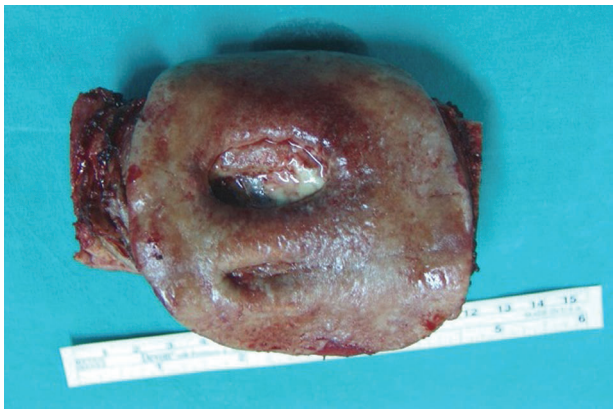

FIG. 1-B

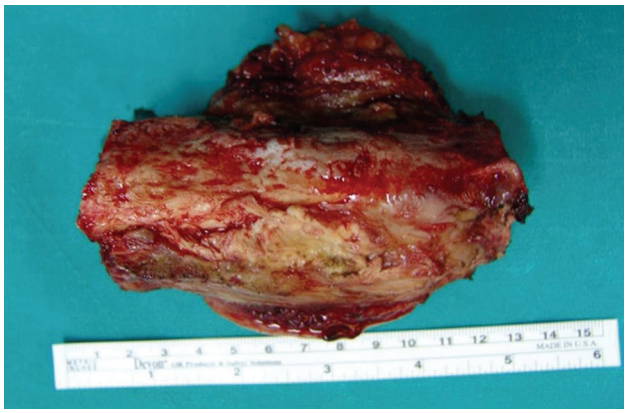

FIG. 1-C

Figs. 1-B and 1-C The widely resected specimens.

dead bone with débridement of the infected scarred soft tissue are then performed, and representative tissue cultures, including the sinus tract for all dead bone, are obtained (Figs. 1-A through 1-G). Cortical bleeding, defined as punctate bleeding from the cortical bone and described as the so-called paprika sign, is accepted as an indication of vital tissue (Figs. 2-A and 2-B)[2]. The dead space is filled with custom-made antibiotic-impregnated polymethylmethacrylate beads (a combination of 2.4 g of teicoplanin or 2 g of vancomycin and 40 g of polymethylmethacrylate powder). Patients who have an intramedullary implant are managed by implant removal and insertion of an antibiotic-impregnated polymethylmethacrylate cement rod in place of the nail and immobilization of the limb in a custom-made brace (Figs. 3-A through 3-D)[3]. In all other patients, stabilization is achieved with a temporary external fixator (Fig. 4). In our series, small soft-tissue defects resulting from débridement of infected soft

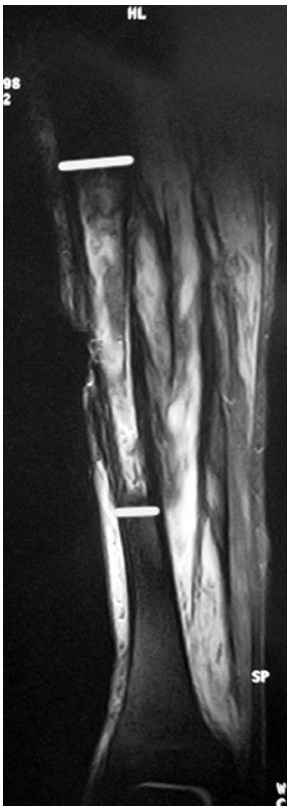

FIG. 1-D FIG. 1-E

Fig. 1-D Margins of resection (black lines) as determined on lateral radiograph.
Fig. 1-E Margins of resection (white lines) as determined on T2-weighted magnetic resonance image.

tissues and fistulae and ranging from 2 cm to 3 cm in size were closed during acute shortening in three patients (Figs. 5-A, 5-B, and 5-C)[4].

Stage II (Intramedullary Nail Insertion, Application of External Fixator, and Osteotomy)

After a period of six weeks, or when normal C-reactive protein levels and erythrocyte sedimentation rates are attained, patients undergo removal of the antibiotic beads or cement rods. A biopsy specimen, obtained from the bone gap as a percutaneous procedure before the second operation, is sent for Gram-staining and frozen-section analysis. The absence of microorganisms on Gram-staining and the presence of <5 polymorphonuclear leukocytes per high-power field indicate resolution of infection. Antegrade nailing is used only for patients with a segmental defect but without a limb-length discrepancy. Retrograde nailing is

TABLE II Systemic and Local Factors That Affect Immune Competence, Metabolism, and Local Vascularity

Systemic Compromise (B^S)	Local Compromise (B^L)
Malnutrition	Chronic lymphedema
Renal and/or hepatic failure	Venous stasis
Diabetes mellitus	Major vessel compromise
Chronic hypoxia	Arteritis
Immune disease	Extensive scarring
Malignancy	Radiation fibrosis
Extremes of age	Small-vessel disease
Immunosuppression or immune deficiency	Neuropathy
Asplenic patients	
HIV/AIDS	
Ethanol and/or tobacco abuse	

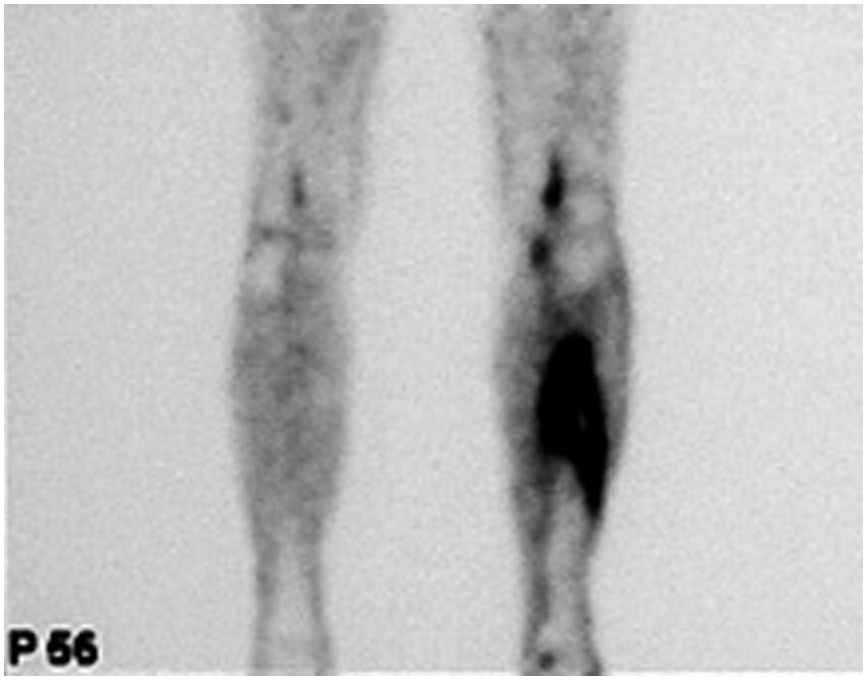

FIG. 1-F

FIG. 1-G

Fig. 1-F A technetium-99 bone scan assists in determining the level of resection. **Fig. 1-G** Radiograph showing the resected bone specimen.

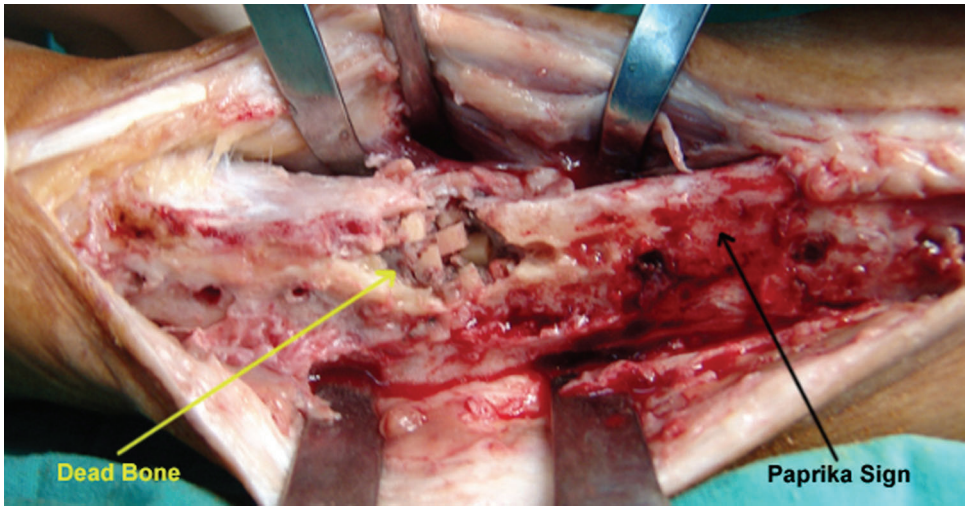

FIG. 2-A

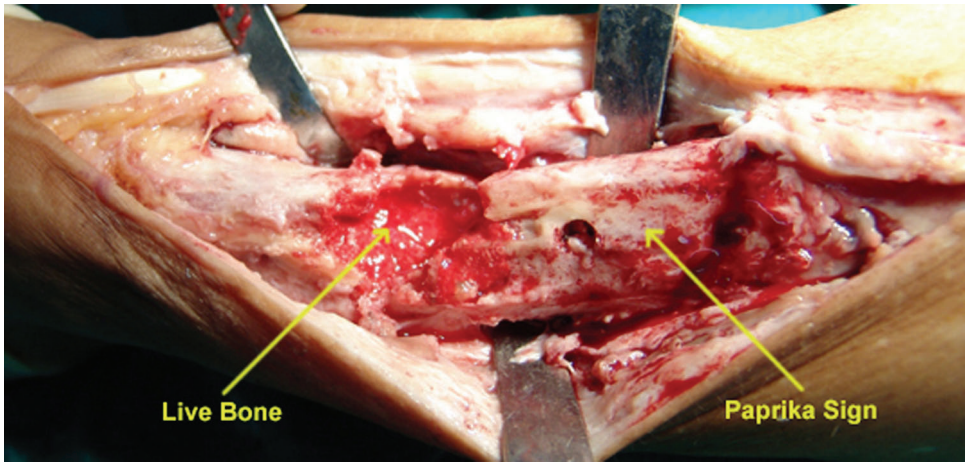

FIG. 2-B

Figs. 2-A and 2-B During débridement, live bone demonstrates the so-called paprika sign.

used for the treatment of shortening combined with a segmental defect. With retrograde nailing, the nail is locked distally and the excess length of nail is left in the soft tissues proximally as a template for future lengthening. With distraction, the nail glides distally until the correct length is achieved; the nail is then locked at the completion of lengthening. For patients undergoing segmental transport to treat a bone defect without a length discrepancy, antegrade nailing is performed. Additional holes are predrilled at the planned site of locking of the segment at the completion of bone transport to prevent recoil of the segment. The level of the extra holes is determined with use of intramedullary nail templates on standing orthoradiographs, both of which have the same scale of magnification (Figs. 6-A, 6-B, and 6-C).

Treatment of Femoral Defects

The patient is placed supine on a radiolucent table with the limbs in a scissors position and with a bolster below the pelvis on the involved side. Through a standard approach (through the piriformis fossa for antegrade

FIG. 3-A

FIG. 3-B

FIG. 3-C

FIG. 3-D

Figs. 3-A through 3-D Insertion of antibiotic-impregnated, custom-made polymethylmethacrylate rods and beads. **Fig. 3-A** The intramedullary rod has been inserted. **Fig. 3-B** The prepared antibiotic-impregnated polymethylmethacrylate beads. **Fig. 3-C** The beads are packed about the intramedullary rod. **Fig. 3-D** Lateral radiograph shows rod and beads in place.

FIG. 4

Fig. 4 Radiograph showing temporary external fixation following resection of dead bone and insertion of antibiotic-impregnated beads. **Figs. 5-A, 5-B, and 5-C** Treatment of a patient with chronic osteomyelitis of the distal part of the tibia. **Fig. 5-A** Planning the operation. **Fig. 5-B** The dead bone has been resected and antibiotic-impregnated beads have been inserted. **Fig. 5-C** Soft-tissue closure following acute shortening.

FIG. 5-A

FIG. 5-B

FIG. 5-C

FIG. 6-A

FIG. 6-B

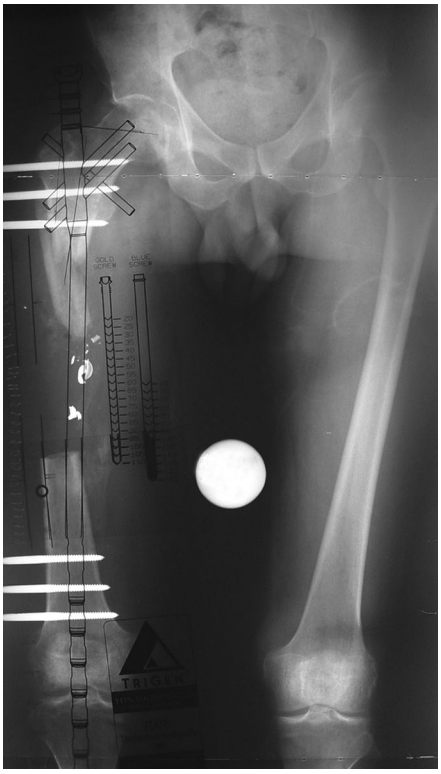

FIG. 6-C

Figs. 6-A, 6-B, and 6-C A radiographic template is used to determine the levels at which the extra locking holes should be predrilled. **Fig. 6-A** Anteroposterior radiograph showing a template over a tibia. **Fig. 6-B** Lateral radiograph showing a template over a tibia. **Fig. 6-C** Anteroposterior radiograph showing a template over a femur.

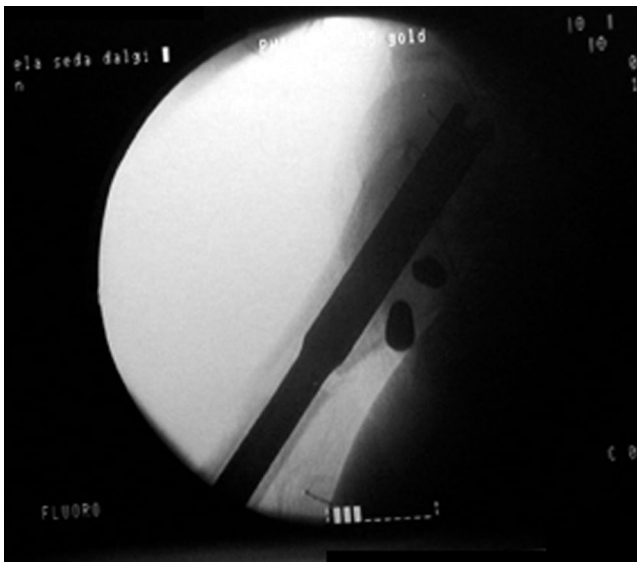

FIG. 7-A

FIG. 7-B

Figs. 7-A and 7-B Lateral image-intensifier view, depicting a clear space between the Schanz screws and the nail in the proximal part (Fig. 7-A) and distal part (Fig. 7-B) of the femur.

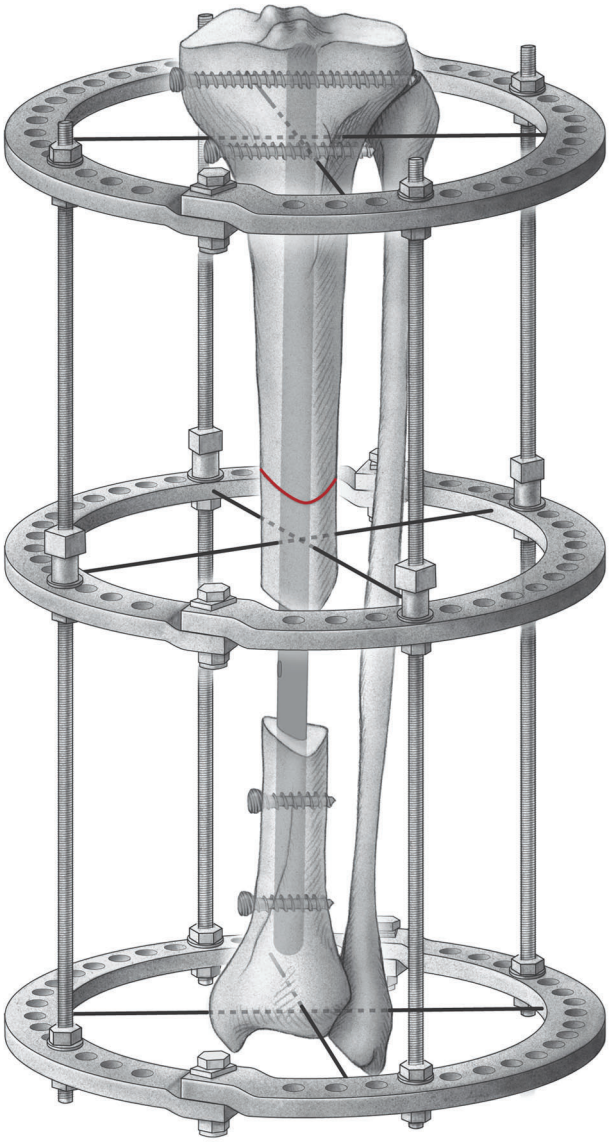

FIG. 8-A

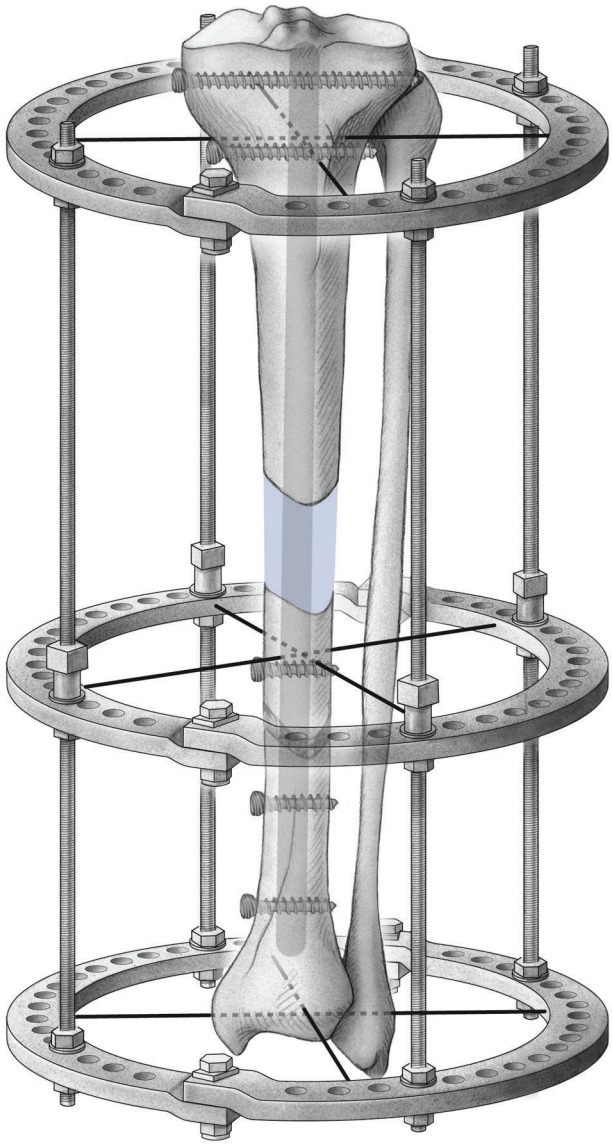

FIG. 8-B

Figs. 8-A, 8-B, and 8-C A segmental defect of the tibia. **Fig. 8-A** Initial position of the segment after osteotomy. **Fig. 8-B** Position of the segment at the end of segmentary transfer (and lengthening).

nailing and through a parapatellar incision for retrograde nailing) the medullary canal is reamed over a guidewire to a diameter 1.5 mm larger than that of the intramedullary nail that will be used. With lengthening procedures, the goal is to provide sufficient nail length on both sides of the regenerated bone at the completion of distraction. This necessitates the use of an intramedullary nail that is longer than the length of the femur; retrograde nailing allows the excess nail length to protrude into the buttock until distraction is completed, by which time the nail will have glided gradually to its correct position. The proximal part of the femur is overreamed because the proximal part of the nail is of a larger diameter than the rest of the nail. An appropriately placed corticotomy is then done percutaneously with an osteotome.

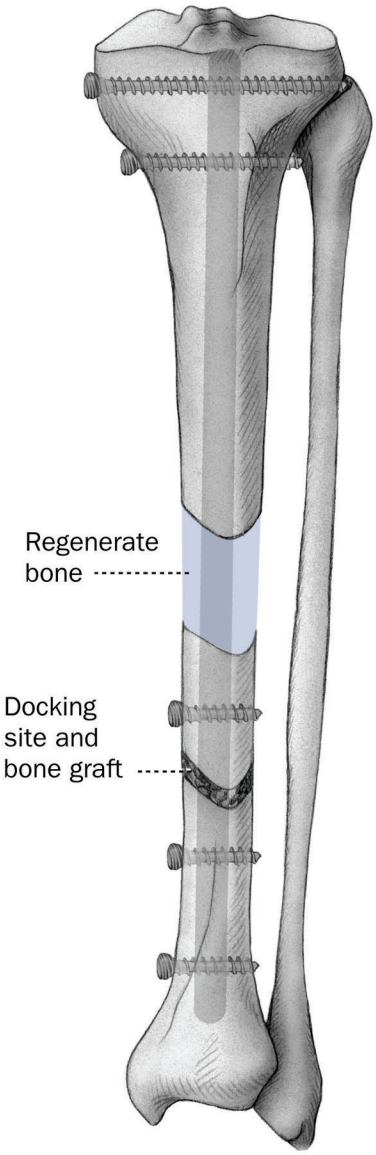

FIG. 8-C

Position of the segment after removal of the external fixator.

Finally, an intramedullary nail (TriGen; Smith and Nephew, Memphis, Tennessee) of appropriate size is inserted and locked proximally, distally, or on both sides, according to the planned distraction.

Two to three Schanz screws are inserted proximal and distal to the level of the osteotomy site, taking care that they do not come into contact with the intramedullary nail[5]. At least 1 mm of free space should exist between the Schanz screws and the intramedullary nail to prevent medullary infection triggered by a pin-site infection[6]. To insert half-pins without contact with the nail, the cannulated drill-bit technique described by Paley et al. is utilized[7]. A Kirschner wire is inserted on the lateral cortex of the femur, perpendicular to the nail, at the level of the Schanz screw. The location of the wire is confirmed with the image intensifier. A hole is reamed over the Kirschner wire with a 4.8-mm cannulated drill bit. The half-pin can then be inserted, and clearance between the pin and the rod is confirmed with the image intensifier (Figs. 7-A and 7-B).

Treatment of Tibial Defects (Figs. 8-A, 8-B, and 8-C)

After the medullary canal is reamed 1.5 mm larger than the planned size of the nail, the nail is inserted and a three-ring circular external fixator is applied. Each end of the external fixator is fixed with one Kirsch-

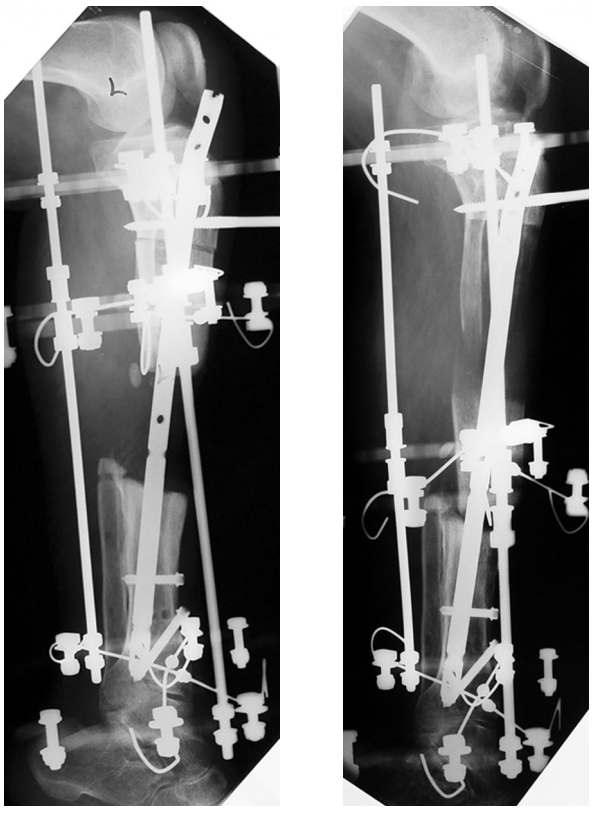

FIG. 9-A **FIG. 9-B**

Figs. 9-A and 9-B Simultaneous lengthening and segment transfer of the tibia. **Fig. 9-A** At the start of lengthening, with the intramedullary nail left proud. **Fig. 9-B** At the end of lengthening, with the nail inside the bone.

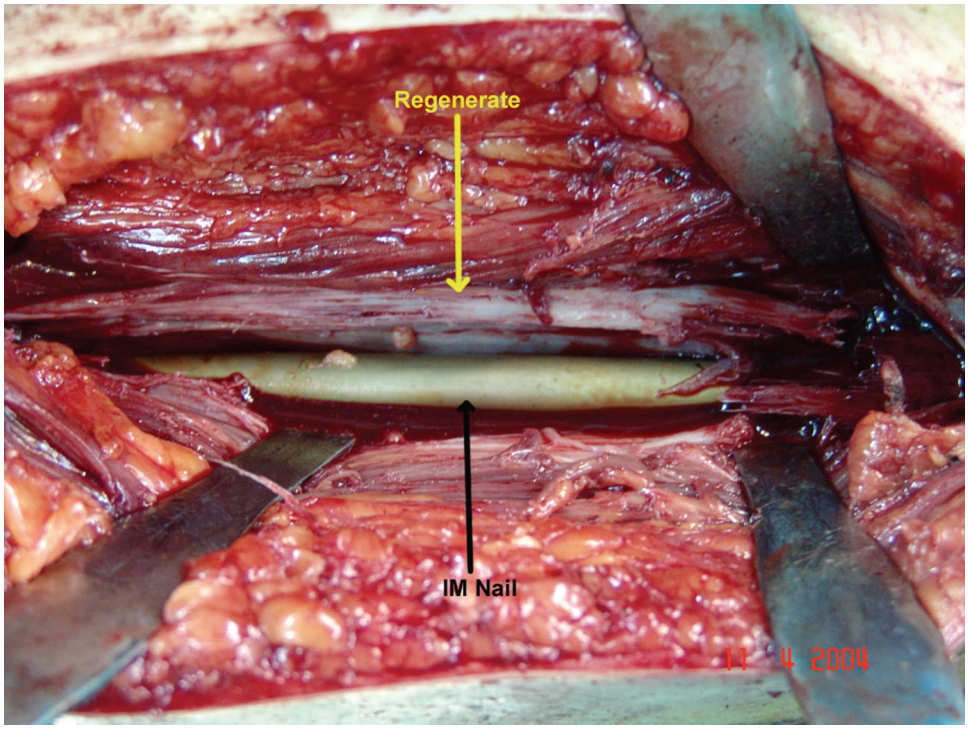

FIG. 10-A

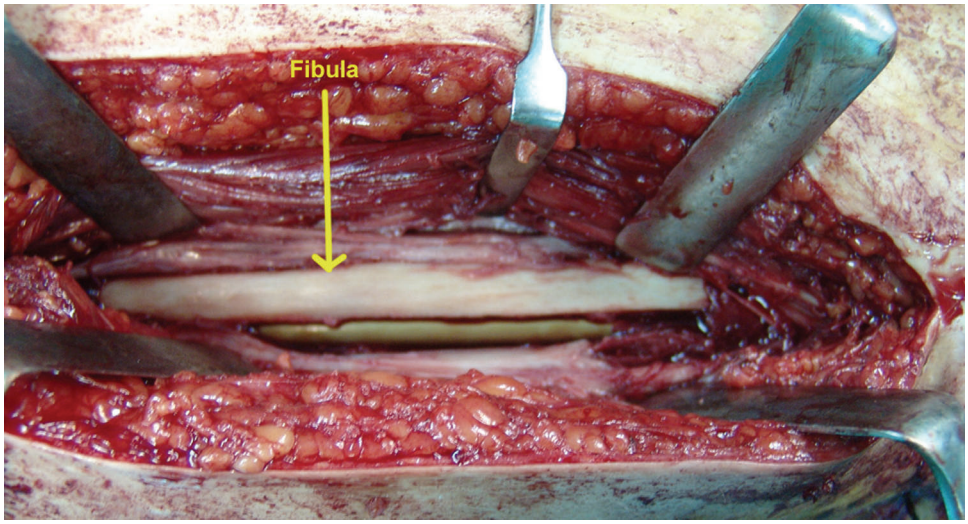

FIG. 10-B

Figs. 10-A and 10-B Before (Fig. 10-A) and after (Fig. 10-B) insertion of nonvascularized fibular strut into the regenerate in the posteromedial aspect of the proximal part of the femur. IM = intramedullary.

ner wire and one half-pin. The fibula should be fixed to the tibia by means of a fibulotibial transfixion wire at each end. None of the pins and wires should come into contact with the nail. A corticotomy is done at the appropriate level. For a patient with shortening and a segmental defect, an intramedullary nail of the eventual desired length of the tibia is inserted and left proud

proximally so that it can slide distally during treatment (Figs. 9-A and 9-B).

POSTOPERATIVE CARE

Distraction is started on the seventh postoperative day[8]. The rate of the distraction is 1 mm per day, divided into four equal increments. An epidural catheter is placed for postoperative pain management, and range-of-motion exercises of the hip and knee are initiated as soon as the patient is comfortable enough to tolerate them. In patients with a long tibial intramedullary nail, knee exercises are postponed until the nail comes to lie inside the bone during lengthening. Full weight-bearing with two crutches is started as soon as possible.

Stage III (Removal of the External Fixator and Static Locking of the Nail)

After the distraction is completed, the nail is statically locked and the external fixators removed. Autogenous cancellous bone graft is added at the docking site. In patients with a proximal femoral osteotomy, a nonvascularized fibular graft is inserted into the posteromedial distraction site to provide additional support and decrease the force transmitted through the nail until total consolidation occurs (Figs. 10-A and 10-B).

CRITICAL CONCEPTS

INDICATIONS:

- Cierny-Mader Type IVA or IVB chronic osteomyelitis of the femoral and tibial metaphysis and diaphysis[9]

CONTRAINDICATIONS:

- Cierny-Mader Type IVC chronic osteomyelitis of the femoral and tibial metaphysis and diaphysis
- Cierny-Mader Type I, II, or III chronic osteomyelitis of the femoral and tibial metaphysis and diaphysis (Tables I and II)

PITFALLS:

- Failure to achieve radical débridement of all dead tissue until the observation of the so-called paprika sign (live cortical bone).
- Failure to determine débridement levels; decision-making is assisted by intravenous contrast-enhanced magnetic resonance imaging of the whole long bone, which displays all necrotic tissues and skipped abscesses.
- Failure to achieve good soft-tissue coverage of the débridement area; local or distant soft-tissue flaps are used as necessary.
- Failure to include culture-specific, heat-stable antibiotics into the polymethylmethacrylate.
- Failure to prepare the polymethylmethacrylate beads in small diameters and large numbers for the purpose of increasing the surface area for better drug elution kinetics.
- Failure to precisely determine the length and diameter of the intramedullary nail to be inserted and the level and number of custom locking holes with the preoperative use of templates and standing orthoradiographs.
- Failure to overream the medullary canal 1.5 mm larger than the diameter of the intramedullary nail to ensure easy gliding of bone segments over the nail.
- Failure to ensure that the inserted Schanz screws or Kirschner wires are at least 1 mm away from the nail.
- Failure to place the external fixator parallel to the intramedullary nail in both the frontal and sagittal planes.

AUTHOR UPDATE:

Recently, for patients needing ankle arthrodesis in conjunction with segmental transfer and lengthening of the tibia, a substantially longer intramedullary nail is initially left proud proximally. For those patients, the external fixator frame is temporarily extended proximally to include the distal portion of the femur. When the intramedullary nail glides sufficiently distal to free the knee joint during lengthening, the part of the frame that transfixes the knee joint is removed and physical therapy is begun.

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The line drawings in this article are the work of Joanne Haderer Müller of Haderer & Müller (biomedart@haderermuller.com).

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