Dealing with Bone Defects of the Foot, Ankle, and Lower Leg

NY Podiatric Clinical Conference, January 23, 2015

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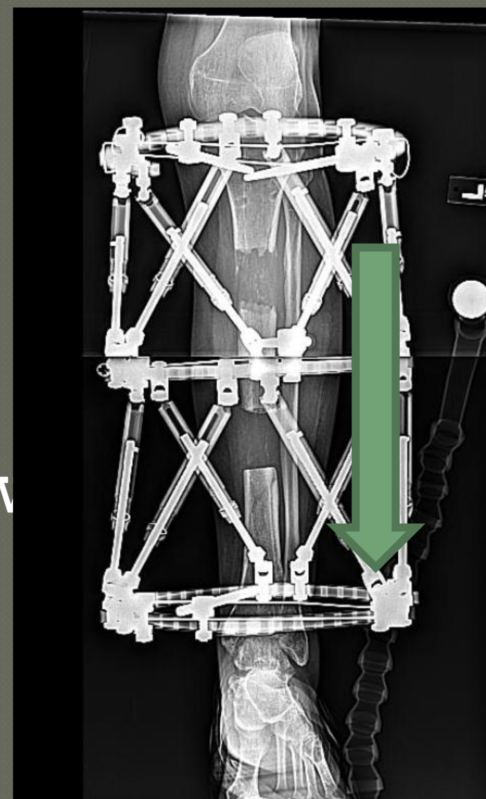
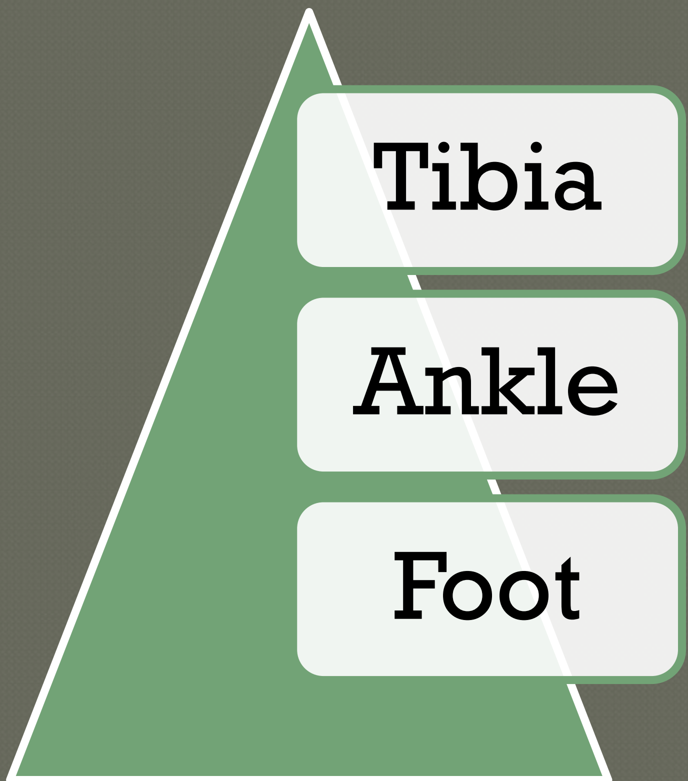
Disclosures

- Small Bone Innovations: consultant and royalties
- Smith and Nephew consultant

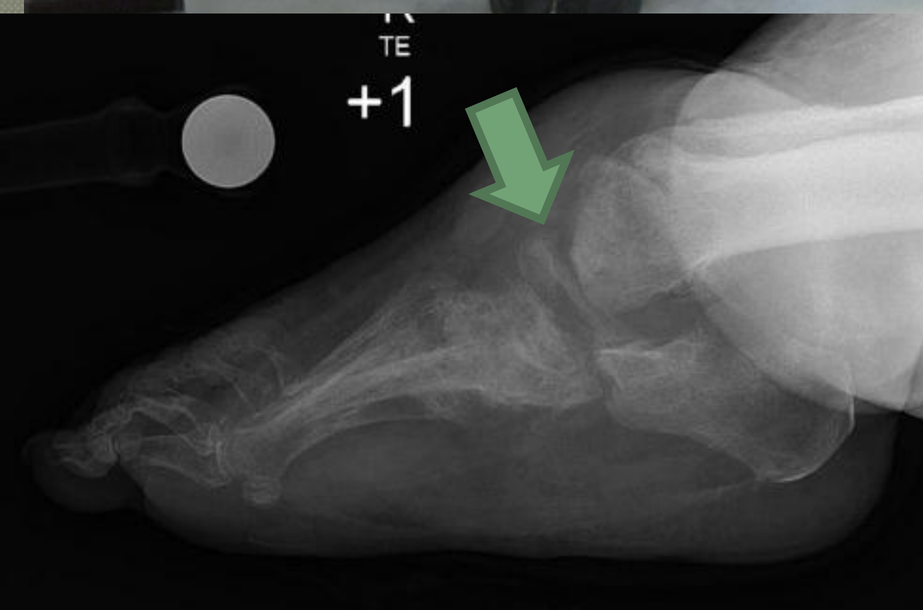


Bone Defects



- Infection
- Debridement
- Stability
- Deformity
- Soft-tissue envelope
- Leg length

Before: Infected, ulcer



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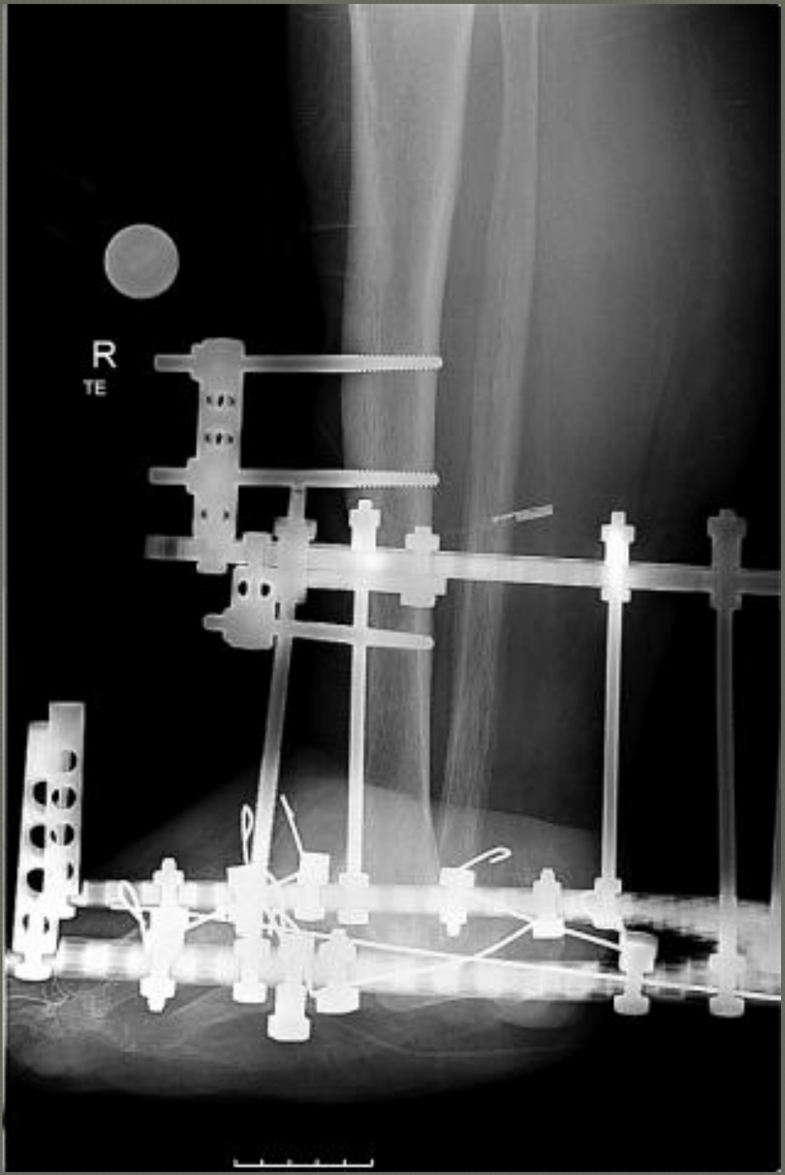

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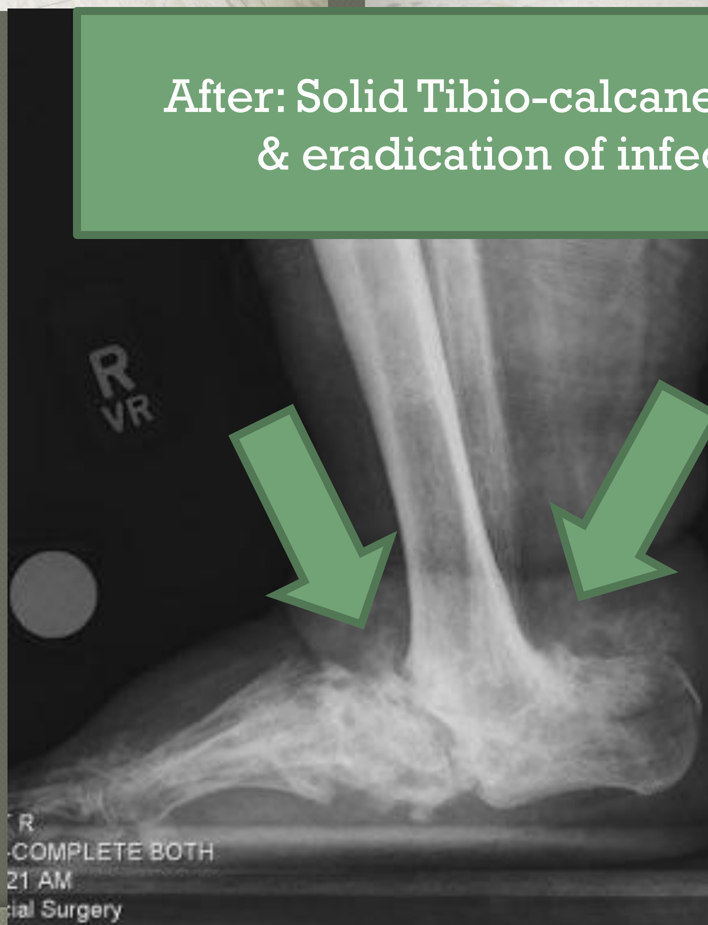
After: Solid Tibio-calcaneal fusion & eradication of infection



Foot & Ankle International

DOI: 10.3113/FAI.2012.0947

Circular External Fixator–Assisted Ankle Arthrodesis Following Failed Total Ankle Arthroplasty

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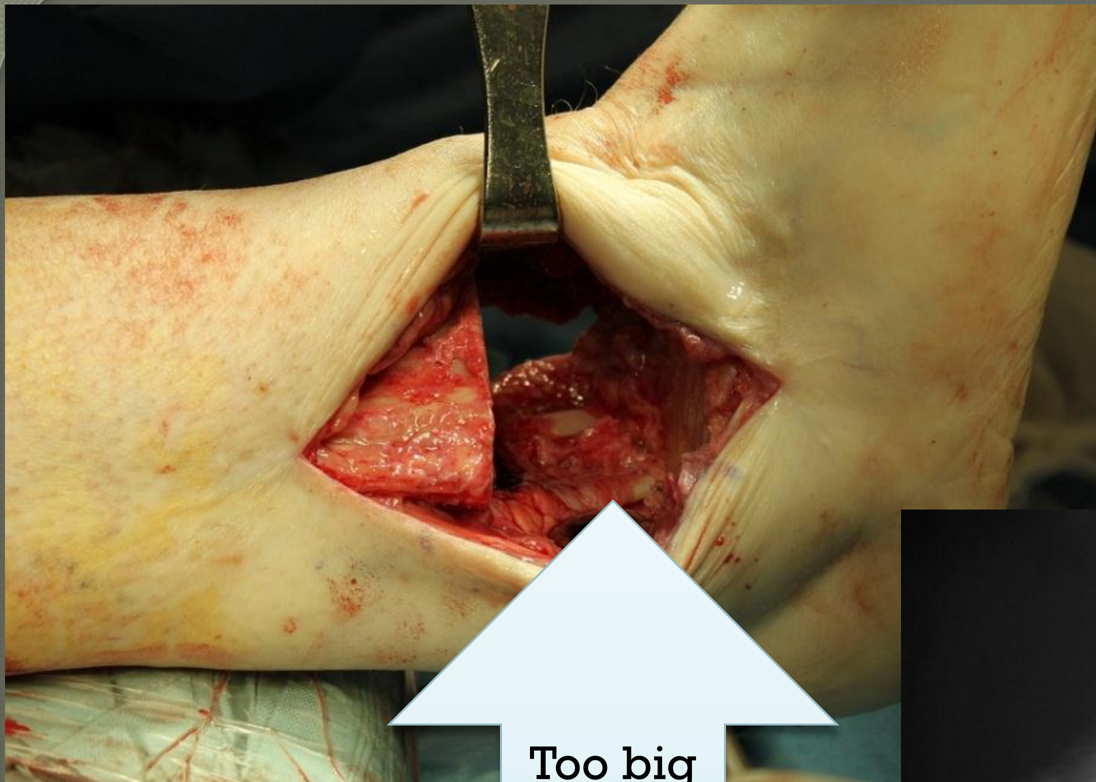
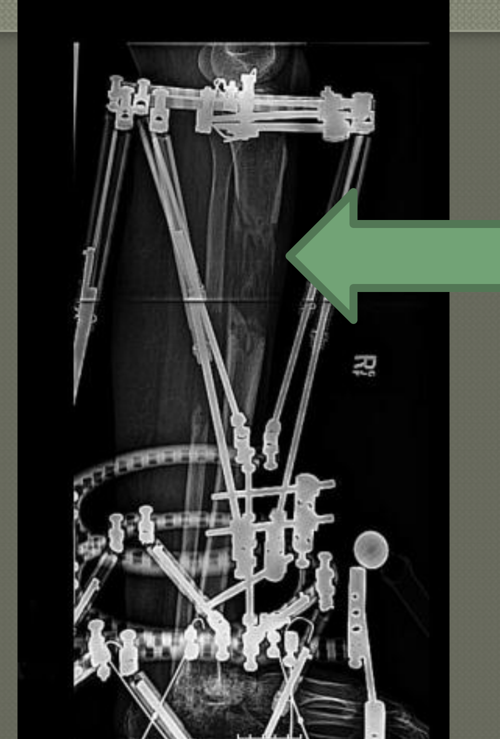
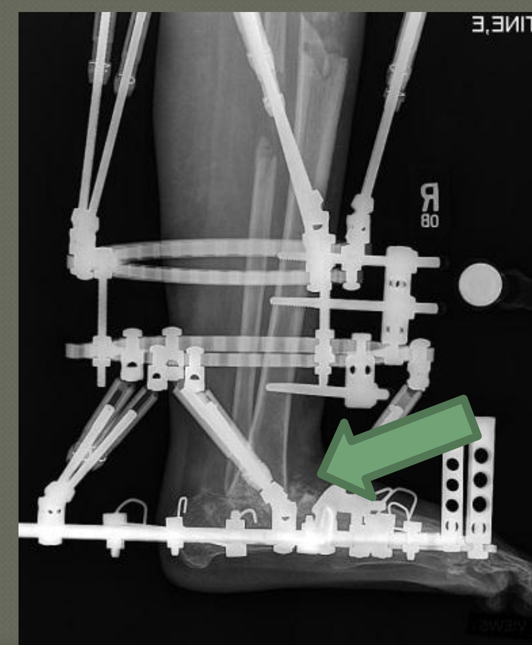
New York, NY

Failed TAR



Too big for acute shorten-ing





Distal tibial bone defect

- Trauma
  - Failed Pilon fracture
    - Fusion
    - Ankle salvage
      - Bone transport
      - Masquelet
- Tumor

HSSJ (2008) 4: 32–42
DOI 10.1007/s11420-007-9073-0

SURGICAL PROCEDURE

Limb Salvage Reconstruction of the Ankle with Fusion and Simultaneous Tibial Lengthening Using the Ilizarov/Taylor Spatial Frame

Nazzar Tellisi, MD · Austin T. Fragomen, MD · Svetlana Ilizarov, MD · S. Robert Rozbruch, MD

Received: 19 November 2007/Accepted: 21 November 2007/Published online: 8 December 2007

Key words angkle fusion · lengthening · Taylor spatial frame · TSF · limb salvage · ankle arthordesis

Introduction

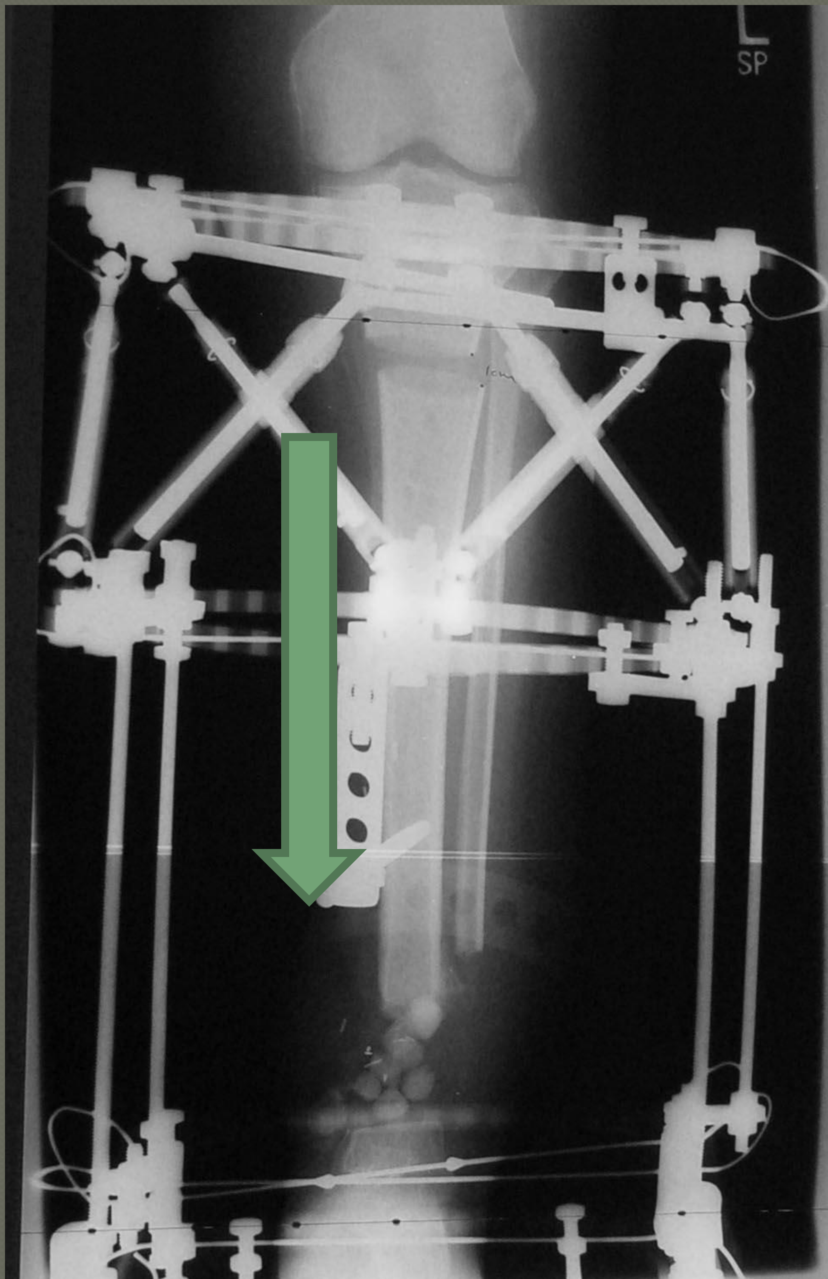
Despite early appropriate treatment with modern orthopedic trauma surgery protocols, distal tibia and ankle injuries do not uncommonly result in posttraumatic ankle arthritis. Ankle fusion offers reliable pain relief and improved

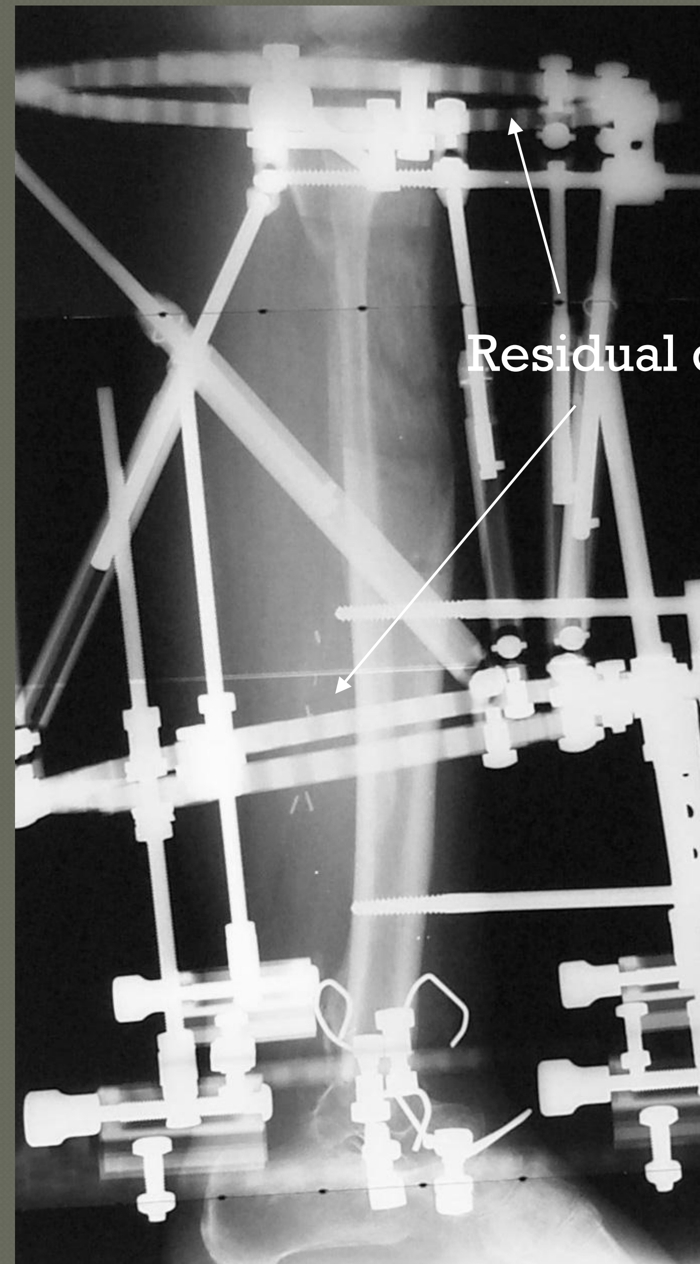
and compliance is low. The use of structural allografts with internal or external fixation has been advocated to reestablish length [17–19]. Problems with graft collapse, infection, and nonunion accompany this technique. Proximal tibial lengthening provides an alternative means of equalizing leg lengths and improving function and self-perception. The need to implant large devitalized bone graft at a compromised healing site is obviated by the use of the patients own bony regenerate at a separate lengthening site. This

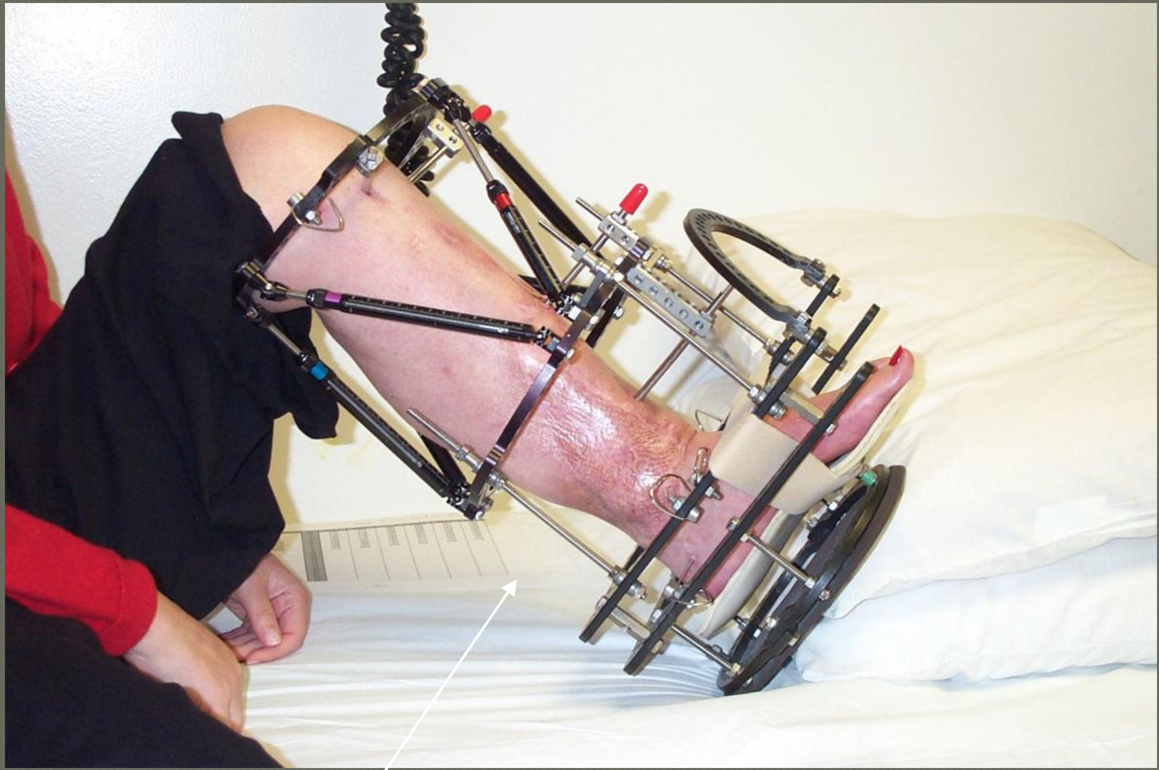
Boat explosion

Needs 7.5 cm lengthening and tibio-talar fusion

Infected

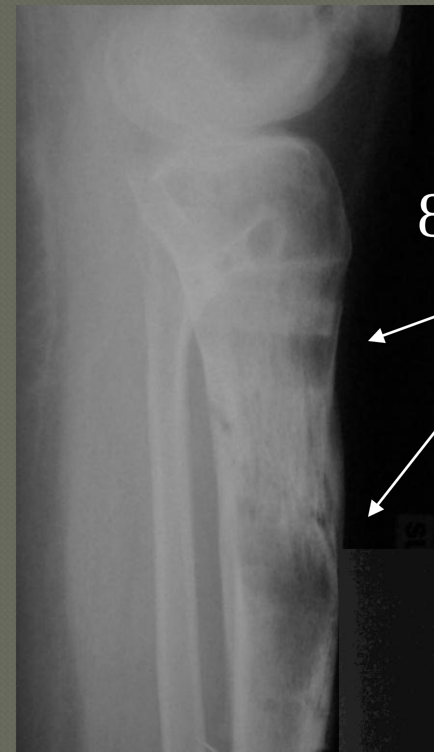



Residual correction



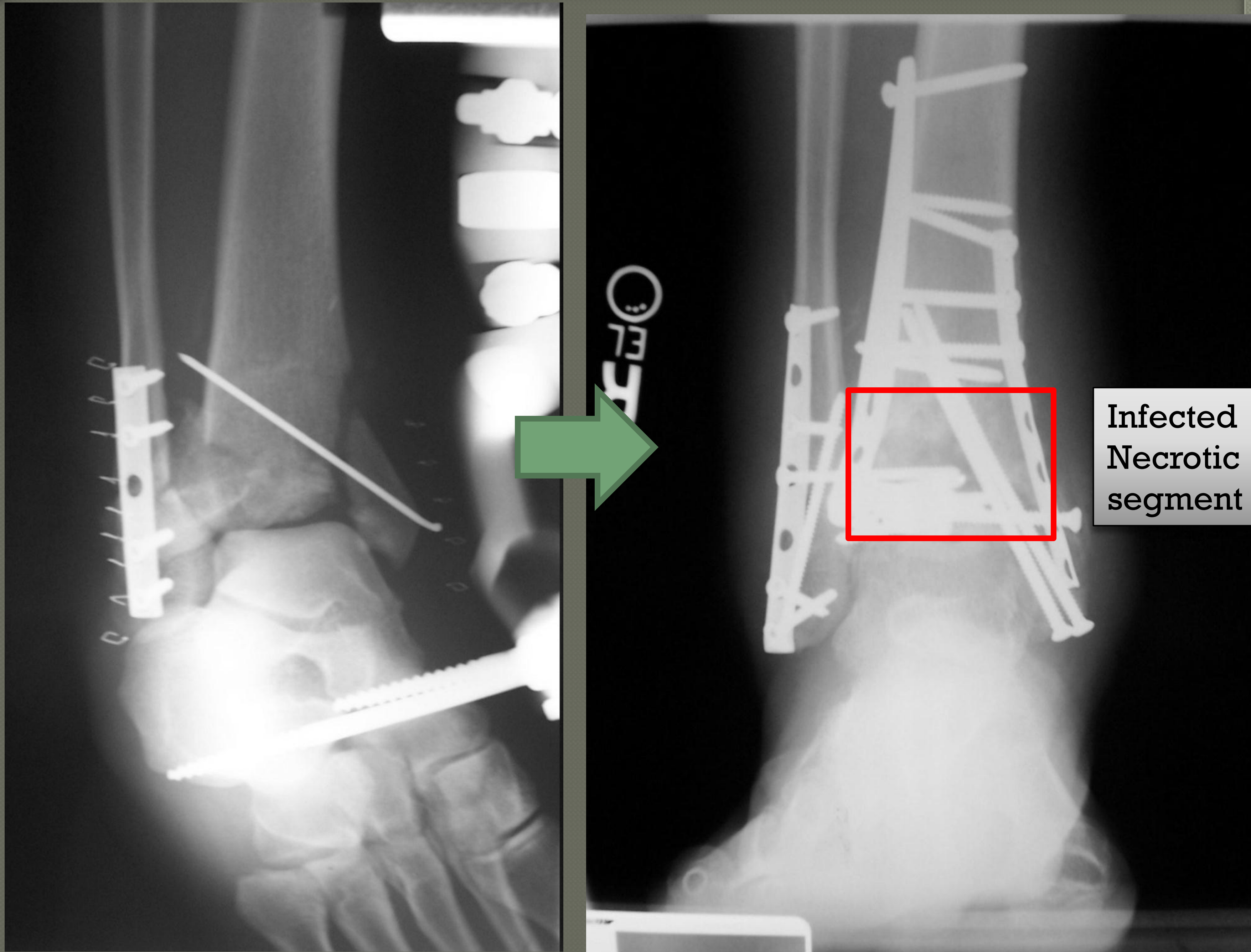
Ilizarov rods

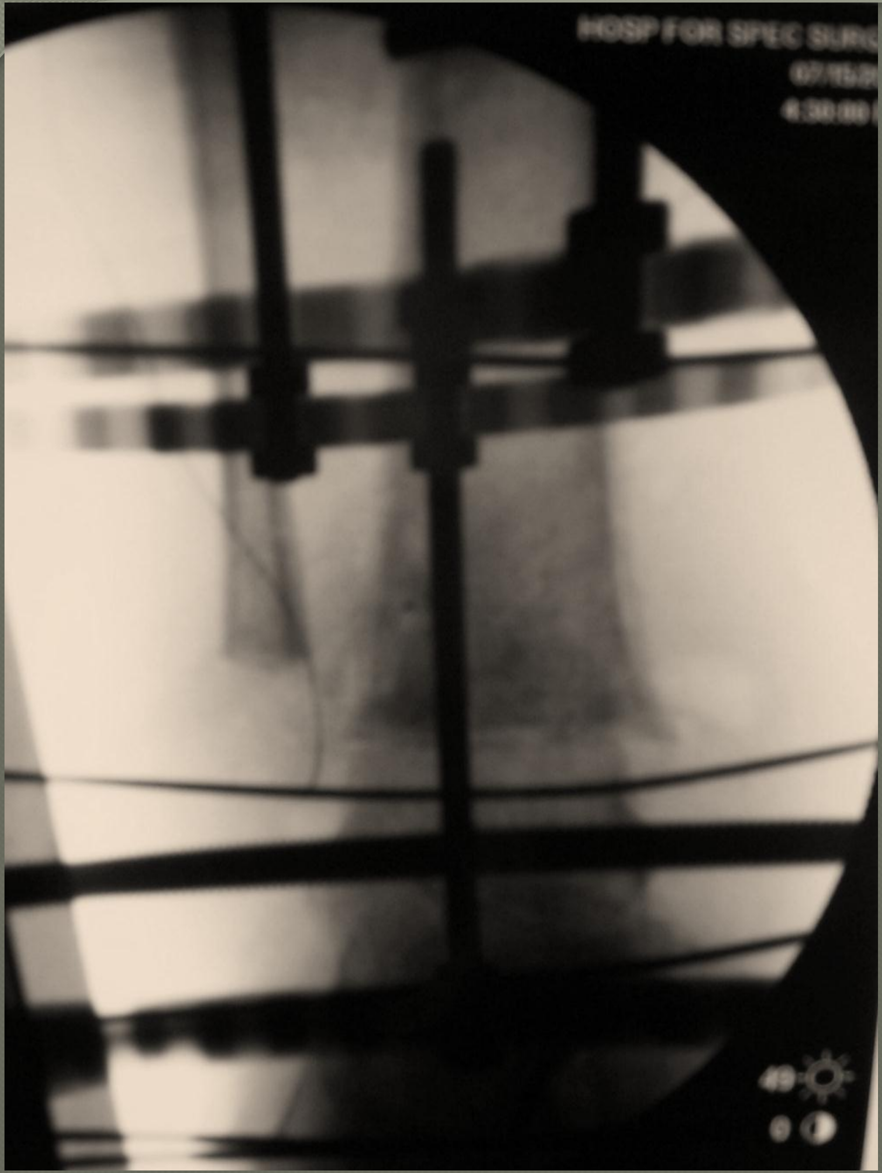
15 months



8 cm lengthening

Tibia
Diaphysis
To talus
fusion


Infected
Necrotic
segment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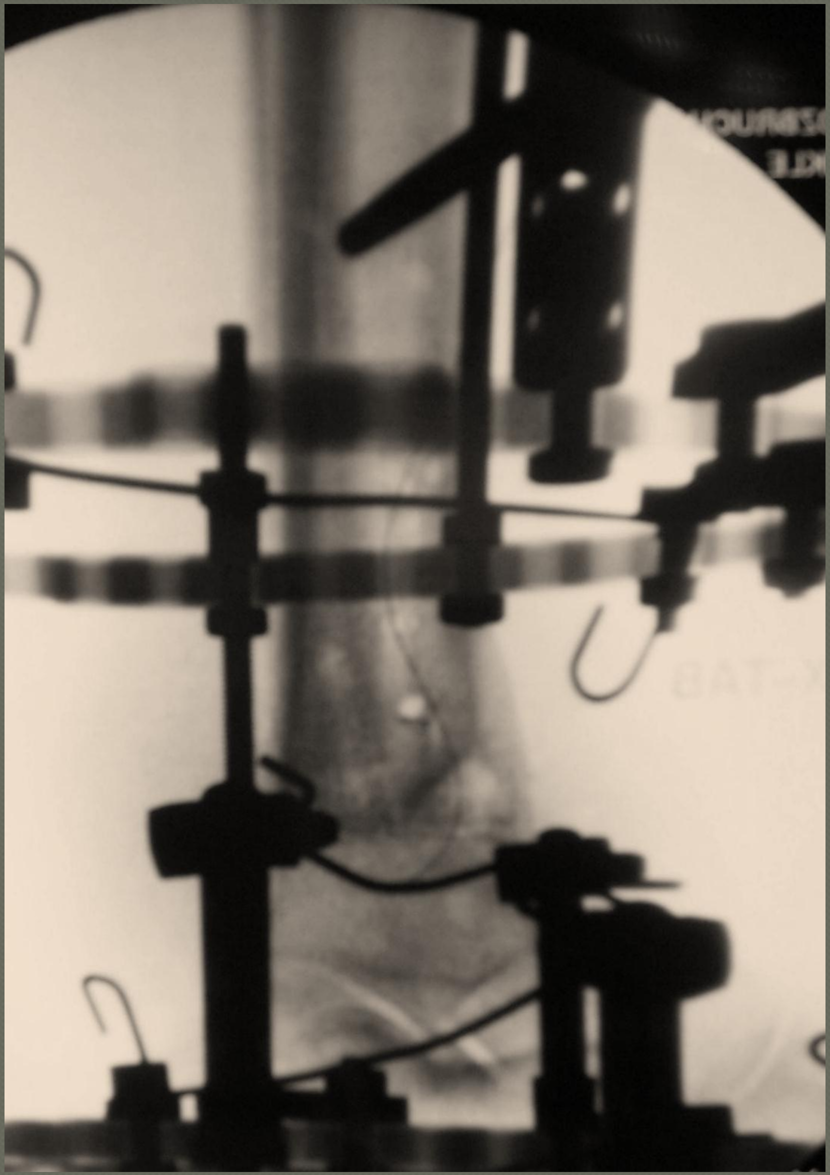

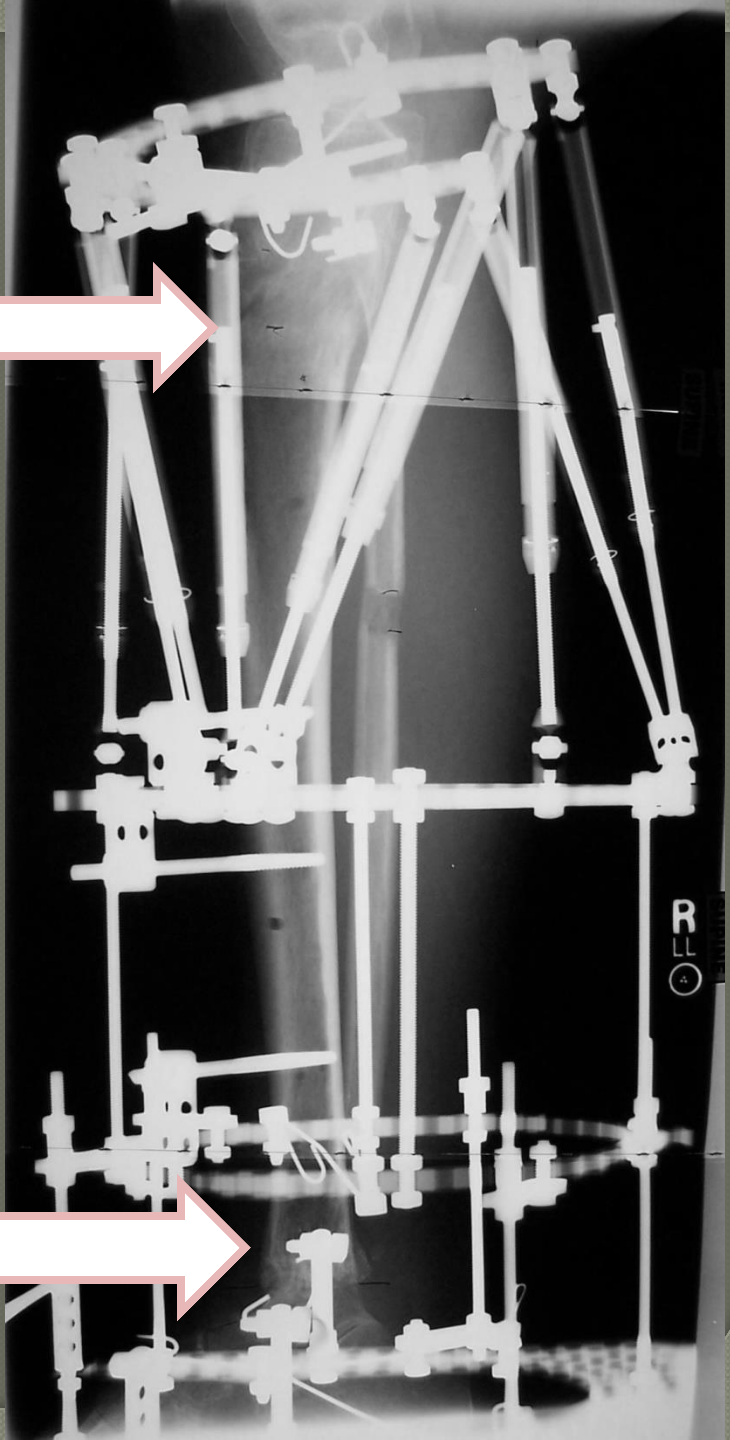
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Journal of Surgical Oncology

Bone Tumor Reconstruction With the Ilizarov Method

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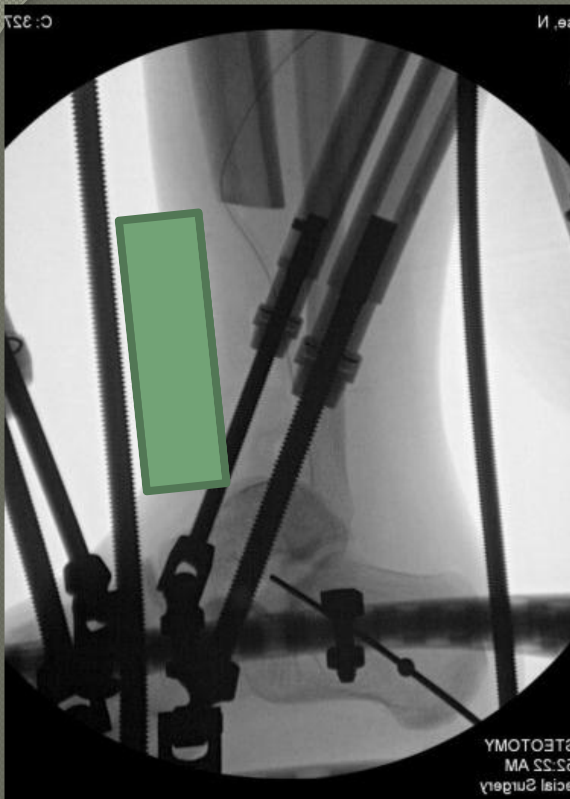
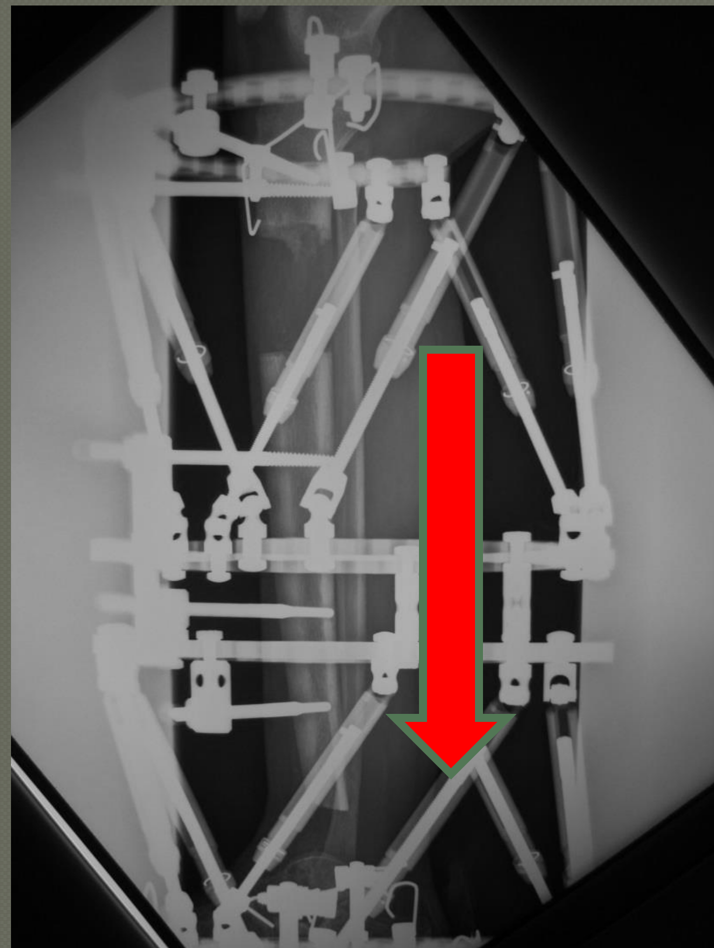
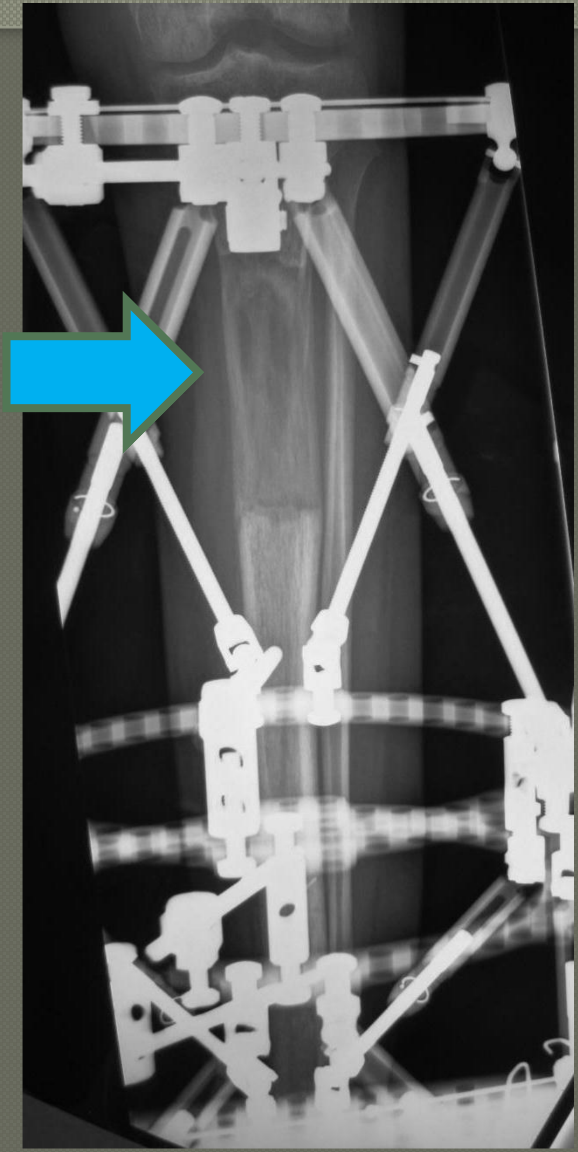
Background and Objectives: Patients with musculoskeletal tumors can face large bone deficiency, deformity, and nonunion. Distraction osteogenesis via the Ilizarov method may be useful for reconstruction of these deficiencies allowing limb preservation and optimizing function.
Methods: We reviewed 20 patients with a range of musculoskeletal tumors necessitating surgical treatment. The group included 9 females and 11 males with a mean age of 22.6 (8–58) years at a mean follow up of 81.7 (26–131) months. The mean bone deficiency was 7.9 (1.2–18.0) cm.
Results: The mean lengthening achieved was 7.1 (3.5–18.0) cm over an EFI of 33.5 (range, 9.5–58.3) days/cm. This treatment resulted in 10 excellent and 3 good ASAMI bone scores, 10 excellent and 3 good ASAMI function scores, a mean lower extremity MSTS score of 93% and a mean upper extremity MSTS score of 87%. Treatment resulted in 2 complications, 18 obstacles, and 6 problems.
Conclusion: The Ilizarov method is an effective technique for limb reconstruction of bone tumors, although extended time in external fixation is required. Since no one in this group received simultaneous chemotherapy or radiotherapy, we cannot comment on use of the Ilizarov method with these treatments. Further use and clinical follow-up is warranted.

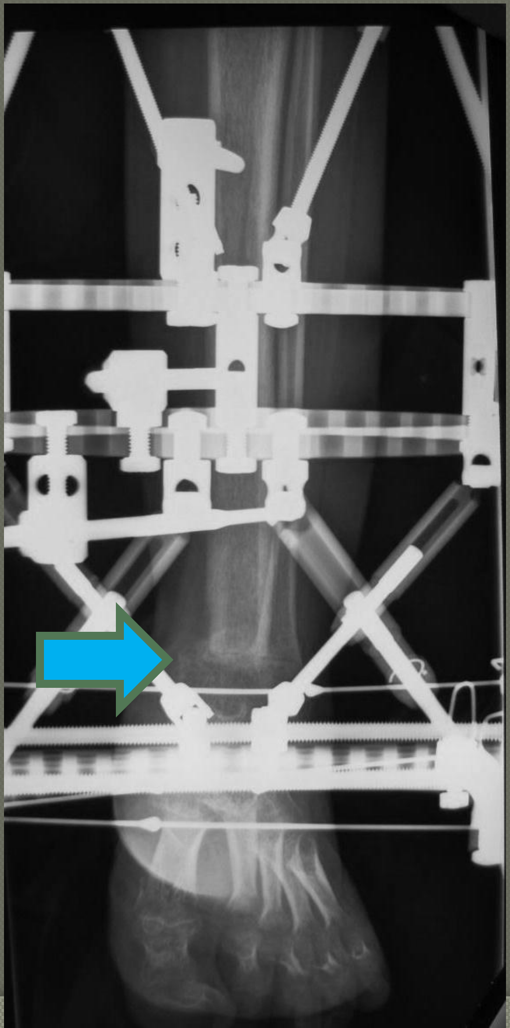
KEY WORDS: **Ilizarov method; limb salvage; limb reconstruction; limb length discrepancy; bone tumor**

Low grade osteosarcoma resected and filled with PMMA spacer



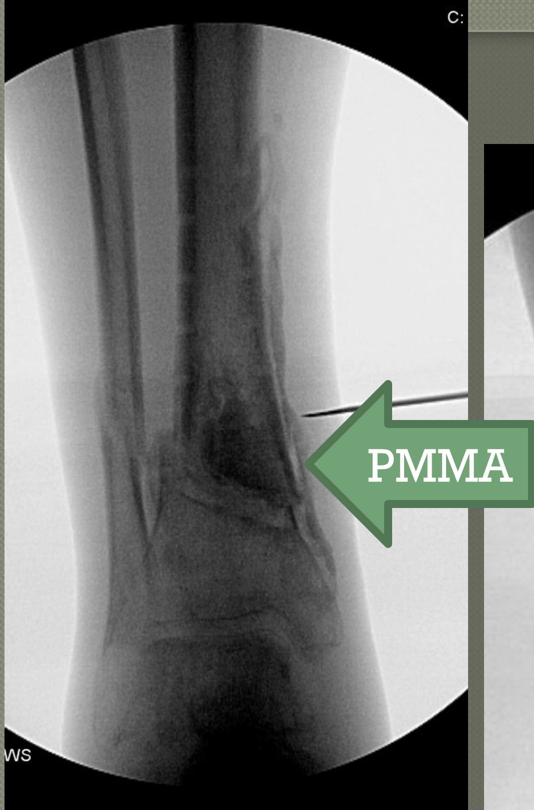


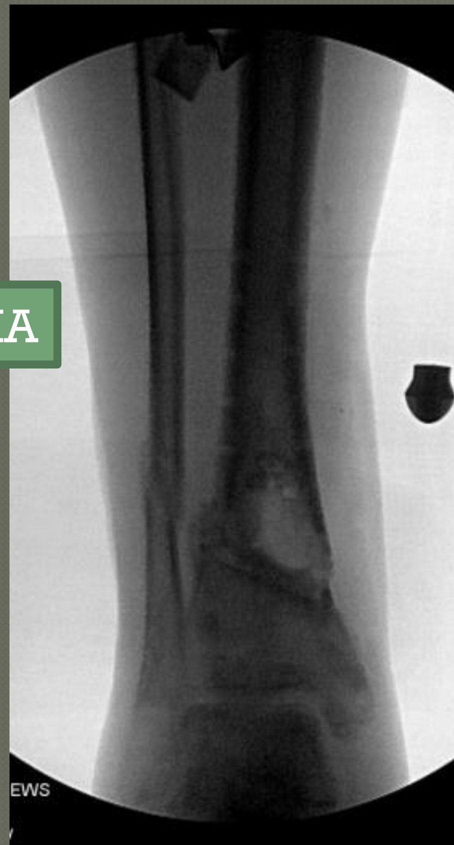




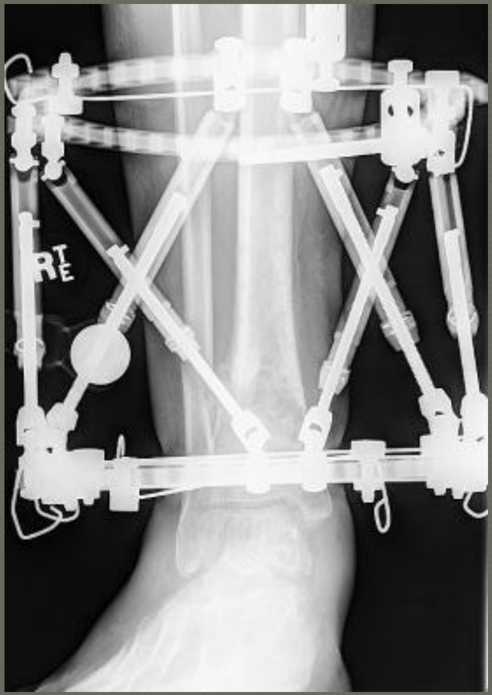
Periarticular bone loss

Masquelet technique and Joint salvage





Masquelet technique
Biomembrane around PMMA
Secondary bone grafting



Frame used for stability
And correction of varus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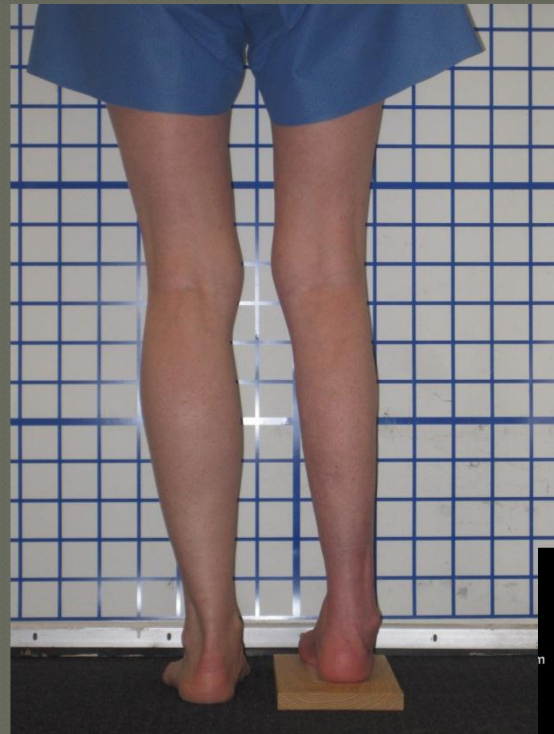
VR

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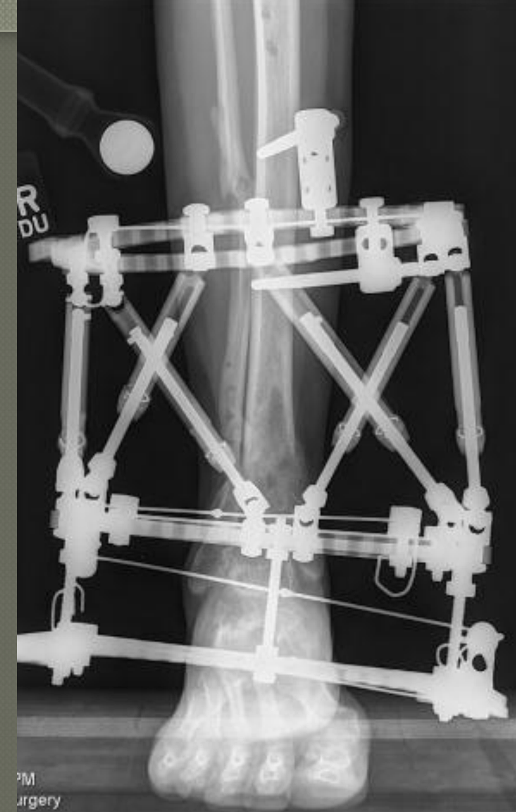
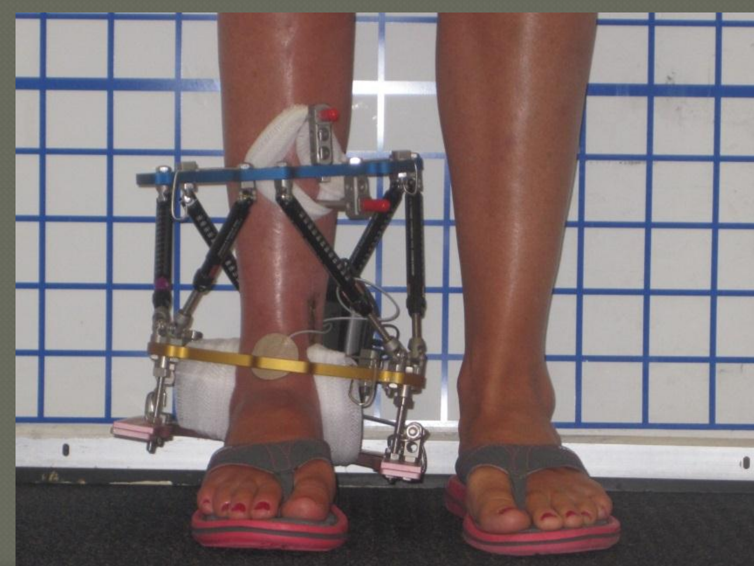
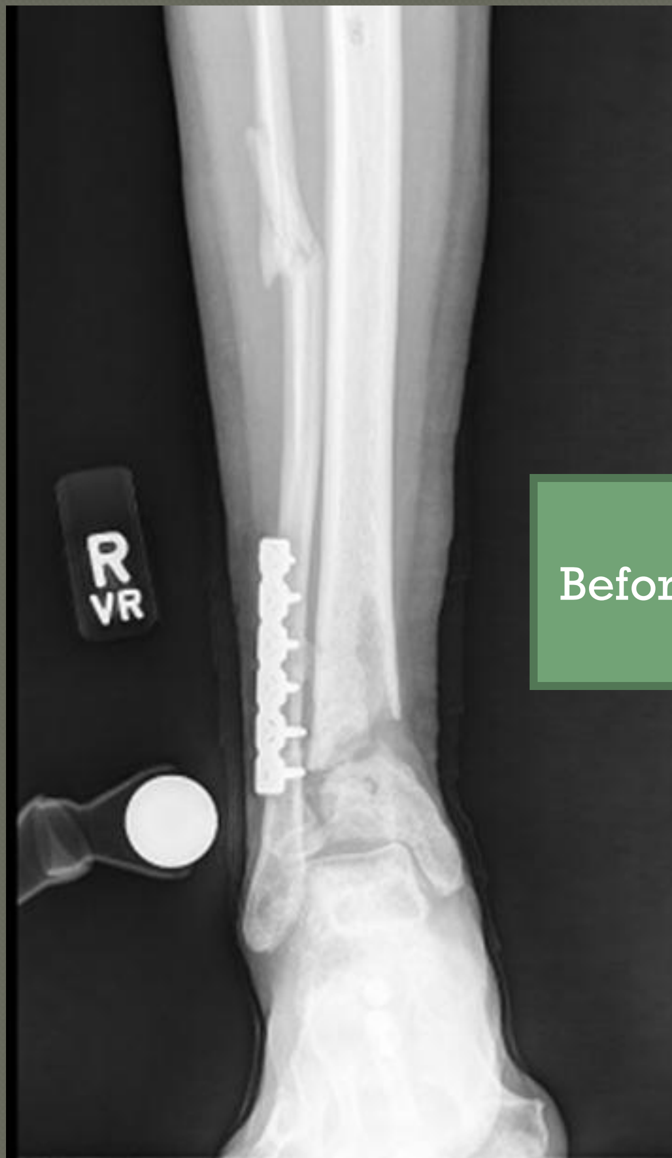


Bone graft
Correct varus
Distract ankle





Before → After

Distal Tibial Periarticular Nonunions: Ankle Salvage With Bone Transport

Patrick C. Schottel, MD, Saravanaraja Muthusamy, MD, and S. Robert Rozbruch, MD

Summary: A nonunion of the distal tibial metaphysis in close proximity to the articular surface is a challenging clinical problem. Many of the commonly used techniques in a surgeon's treatment armamentarium can be ineffective because of the relative lack of distal bone stock. This study describes a technique of en bloc excision of all infected or nonunited distal tibial bone with an application of a circular external fixator and limb shortening. After treatment with parental antibiotics, when appropriate, and docking of the distal excision site, distraction osteogenesis of the proximal tibia is performed with a second circular frame.

Key Words: distal tibial nonunion, bone transport, circular external fixator

(*J Orthop Trauma* 2014;28:e146–e152)

INTRODUCTION

Tibial nonunions are a challenging clinical problem often encountered by orthopaedic trauma surgeons. This difficulty is especially evident in cases that require extensive debridement of all nonviable or infected bone resulting in a large bone defect. Various treatment methods exist for addressing tibial nonunions with significant bone loss, and the choice of technique is dictated by the personality and extent of the injury, surgeon experience, patient preference, and implant availability. Possible treatment methods include primary autogenous bone grafting, a vascularized free fibula transfer, creation of an induced membrane with subsequent bone grafting (ie, Masquelet technique) or bone transport.[1–5] Arthrodesis or amputation should also be considered for cases involving substantial distal metaphyseal tibial bone loss in close proximity to the ankle joint.[6–8]

Periarticular distal tibial nonunions within 2 cm of the ankle joint present a unique treatment challenge because of the relatively small size of the distal articular bone fragment. The small articular fragment can limit the extent of stable screw fixation and, therefore, may preclude some of the more commonly used treatment methods. We present our surgical technique for patients with a periarticular distal tibial nonunion treated with en bloc excision of all nonunited or infected bone, acute limb shortening, and staged proximal tibial lengthening using a Taylor spatial frame (TSF; Smith & Nephew, Inc, Memphis, TN). All patients had a distal tibial articular bone fragment that was less than 2 cm in longitudinal length and a nonunion that was best managed with excision.

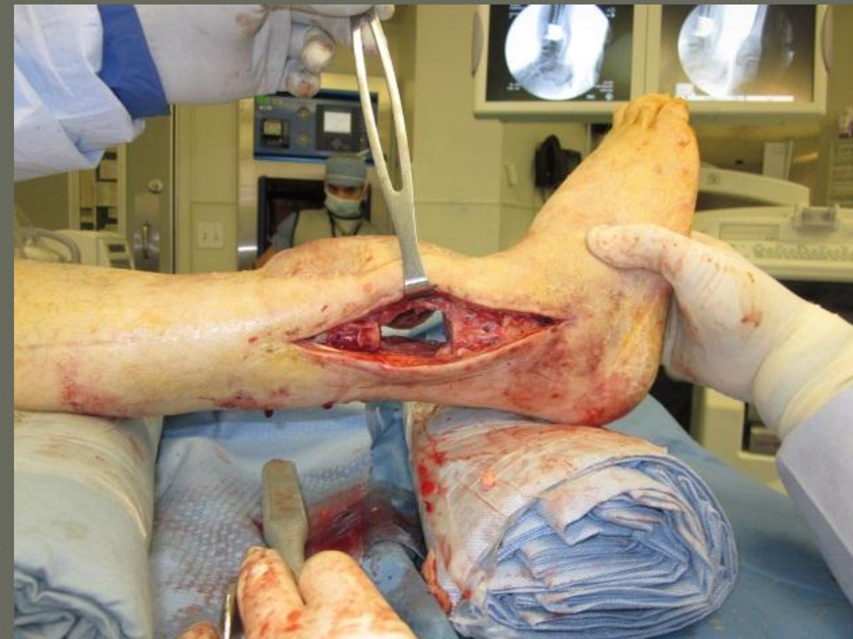
SURGICAL TECHNIQUE

Patients were first clinically examined, and orthogonal radiographs of the tibia and ankle were obtained (Fig. 1). Basic laboratory blood tests including a complete blood count, C-reactive protein, and erythrocyte sedimentation rate were collected. Computed tomography imaging of the distal tibia was also performed in all cases for preoperative planning purposes (Fig. 2).

After obtaining informed consent, the patients were brought to the operating room and positioned supine on a radiolucent table with a bump under the ipsilateral hip. A nonsterile tourniquet was then applied to the proximal aspect of the operative extremity. After standard prepping and draping, the extremity was elevated, and the tourniquet was inflated to 250 mm Hg. All antibiotics were held until the collection of microbiology cultures.

The distal tibial nonunion site was approached using either the previous skin incision or a standard anteromedial ankle incision (Fig. 3). Subperiosteal dissection was then performed, and Hohmann retractors were placed to protect the anterior and posterior neurovascular structures. Wires of 1.8 mm were placed next perpendicular to the mechanical axis of the tibia at the proximal and distal extent of the nonunion site based on the preoperative imaging (Fig. 4). A microsagittal saw was used to excise the nonunion with emphasis on making the cuts parallel to the previously placed wires (Fig. 5). Frequent cooling of the microsagittal saw was performed using saline and intermittent pauses to minimize the extent of osseous thermal necrosis. The bone was then removed either en bloc or piecemeal with the use of a rongeur. The bone and surrounding soft tissue was sent as 5 separate cultures to the microbiology laboratory, and 1 specimen was sent to our institution's musculoskeletal pathologist. Any remaining bone that was suspected to be nonviable or infected was either debrided or additional horizontal cuts with the microsagittal saw was made until adequately excised. Finally, the proximal and distal surfaces of exposed tibia were trephinated with a 1.8-mm wire and fish scaled with a sharp 3-mm osteotome in areas with sclerotic bone.

Accepted for publication September 12, 2013.
From the Limb Lengthening and Complex Reconstruction Service, Hospital for Special Surgery, New York, NY.
S.R. Rozbruch receives consulting fees and product royalties from Small Bone Innovations. He also receives consulting fees and lecture payment from Smith & Nephew. The other authors report no conflicts of interest.
Approval for this study was obtained from the Hospital for Special Surgery's Institutional Review Board.
Reprints: Patrick C. Schottel, MD, Limb Lengthening and Complex Reconstruction Service, Hospital for Special Surgery, 535 East 70th St, New York, NY 10021 (e-mail: schottelp@hss.edu).

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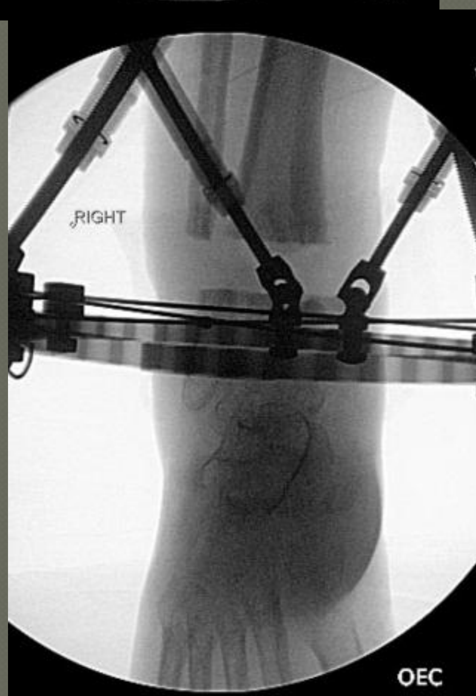
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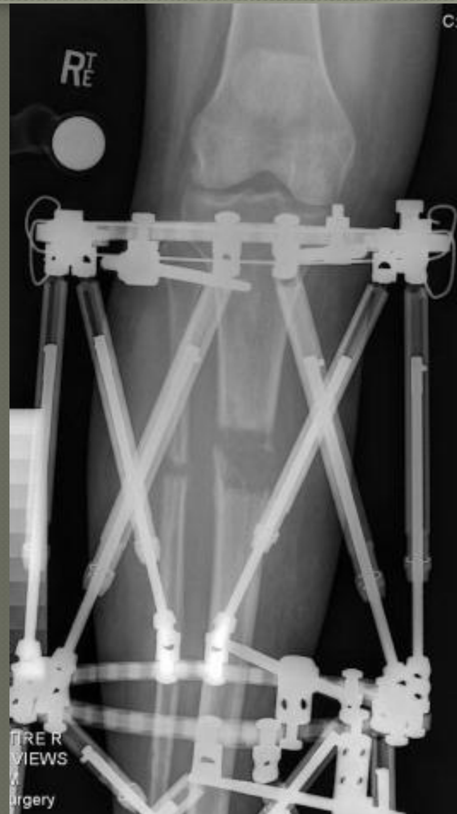
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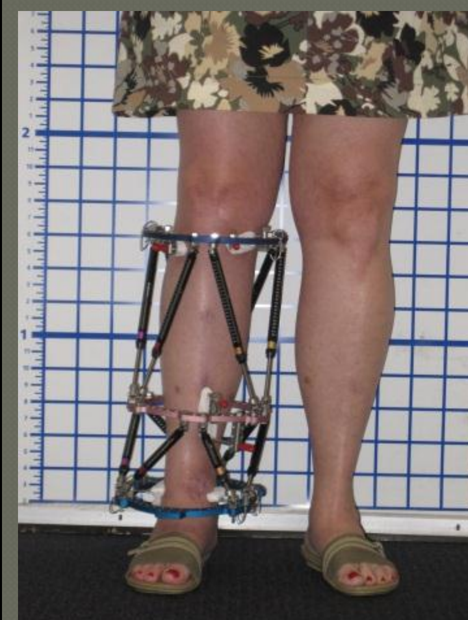
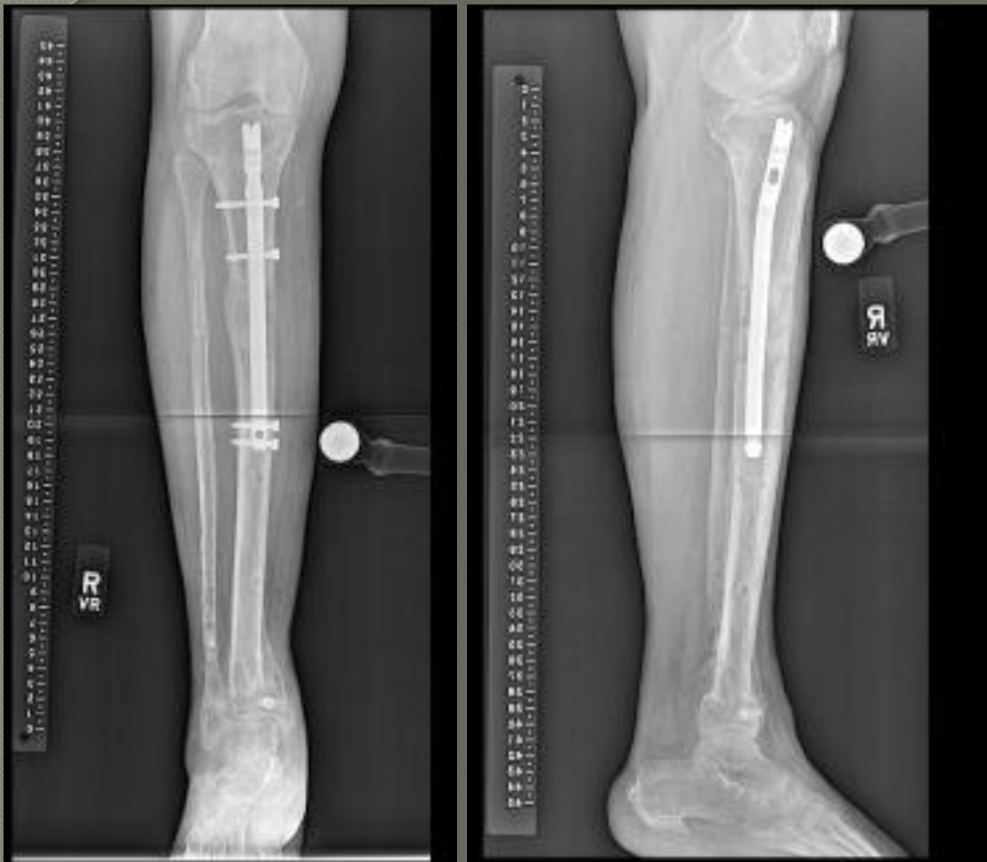




LATN, Shortens time
In the External Fixator

Simultaneous Treatment of Tibial Bone and Soft-tissue Defects With the Ilizarov Method

S. Robert Rozbruch, MD, Adam M. Weitzman, BA,† J. Tracey Watson, MD,‡ Paul Freudigman, MD,§ Howard V. Katz, MD,‖ and Svetlana Ilizarov, MD**

Objectives: To evaluate the potential for limb salvage using the Ilizarov method to simultaneously treat bone and soft-tissue defects of the leg without flap coverage.

Design: Retrospective study.

Setting: Level I trauma centers at 4 academic university medical centers.

Patients/Participants: Twenty-five patients with bone and soft-tissue defects associated with tibial fractures and nonunions. The average soft-tissue and bone defect after debridement was 10.1 (range, 2–25) cm and 6 (range, 2–14) cm respectively. Patients were not candidates for flap coverage and the treatment was a preamputation limb salvage undertaking in all cases.

Intervention: Ilizarov and Taylor Spatial Frames used to gradually close the bone and soft-tissue defects simultaneously by using monofocal shortening or bifocal or trifocal bone transport.

Main Outcome Measurements: Bone union, soft-tissue closure, resolution or prevention of infection, restoration of leg length equality, alignment, limb salvage.

Results: The average time of compression and distraction was 19.7 (range, 5–70) weeks, and time to soft-tissue closure was 14.7 (range, 3–41) weeks. Bony union occurred in 24 patients (96%). The average time in the frame was 43.2 (range, 10–82) weeks. Lengthening at another site was performed in 15 patients. The average amount of bone lengthening was 5.6 (range, 2–11) cm. Final leg length discrepancy (LLD) averaged 1.2 (range, 0–5) cm. Use of the trifocal approach resulted in less time in the frame for treatment of large bone and soft-tissue defects. There were no recurrences of osteomyelitis at the nonunion site. All wounds were closed. There were no amputations. All limbs were salvaged.

Conclusions: The Ilizarov method can be successfully used to reconstruct the leg with tibial bone loss and an accompanying soft-tissue defect. This limb salvage method can be used in patients who are not believed to be candidates for flap coverage. One also may consider using this technique to avoid the need for a flap. Gradual closure of the defect is accomplished resulting in bony union and soft-tissue closure. Lengthening can be performed at another site. A trifocal approach should be considered for large defects (> 6 cm). Advances in technique and frame design should help prevent residual deformity.

Key Words: Ilizarov, tibia, wound, nonunion, bone defect, Taylor spatial frame

(*J Orthop Trauma* 2006;20:197–205)

Accepted for publication October 4, 2005.

From the *Hospital for Special Surgery, New York, NY; †Weill Medical College of Cornell University, New York, NY; ‡St. Louis University School of Medicine, St. Louis, MO; §Baylor School of Medicine, Waco, TX; and ‖Beth Israel Medical Center, New York, NY.

The lead author receives research and educational support from Smith and Nephew.

The legal and regulatory status of the devices that are the subject of this manuscript is not known by the authors.

This study was not supported by a research grant.

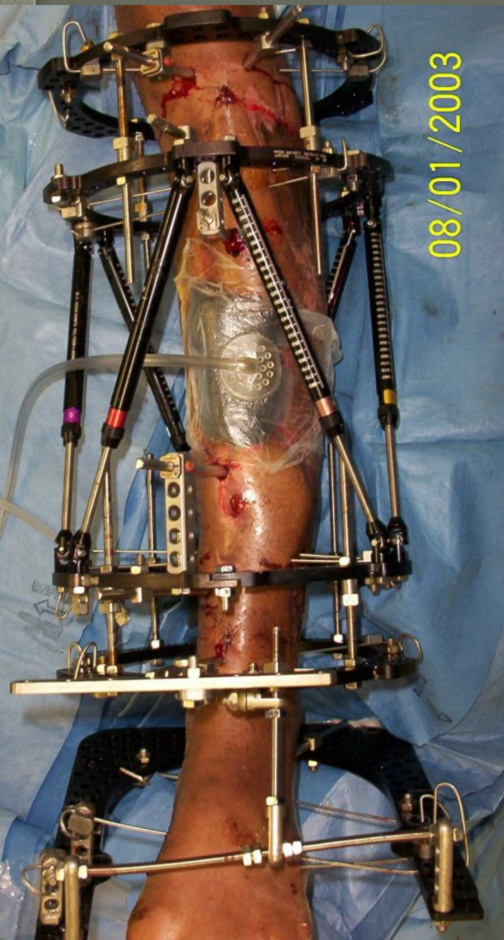
The devices that are the subject of this manuscript are FDA-approved (The Ilizarov and the Taylor Spatial Frame; Smith & Nephew, Memphis, TN, and the V.A.C.; Kinetic Concepts, Inc., San Antonio, TX).

Reprints: S. Robert Rozbruch, MD, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021 (e-mail: RozbruchSR@hss.edu).

Tibial diaphyseal fractures are among the most common types of open fracture and > 50% are classified as high-energy Gustilo-Anderson type III fractures.[1–3] Management of these fractures is further complicated by accompanied vascular and soft-tissue injury, putting these limbs at risk for infection, bone loss, and even amputation.[4–7] Even if bony union is achieved, these difficulties may still lead to impaired function of the treated limb and result in poor functional outcome from limb length discrepancy, deformity, and joint contractures.[8]

The Ilizarov method has been used successfully in the treatment of tibial fractures, nonunions, and malunions, deformity, and shortening.[8–12] The dynamic frame enables gradual lengthening, deformity correction, and nonunion or delayed union compression while remaining minimally invasive.[5,11,13–16] The Ilizarov method of intercalary bone transport has been used to deal with tibial bone loss and achieve limb salvage.[8,17,18]

The soft-tissue damage found in these fractures and wound management often are the main factors affecting outcome.[6,19,20] The preferred treatment of these wounds during tibial fixation is early application of a local flap if the defect is in the proximal two-thirds of the tibia or a free muscle flap if it is in the distal one-third.[21–23] Local flaps can, however, be suboptimal because the tissue that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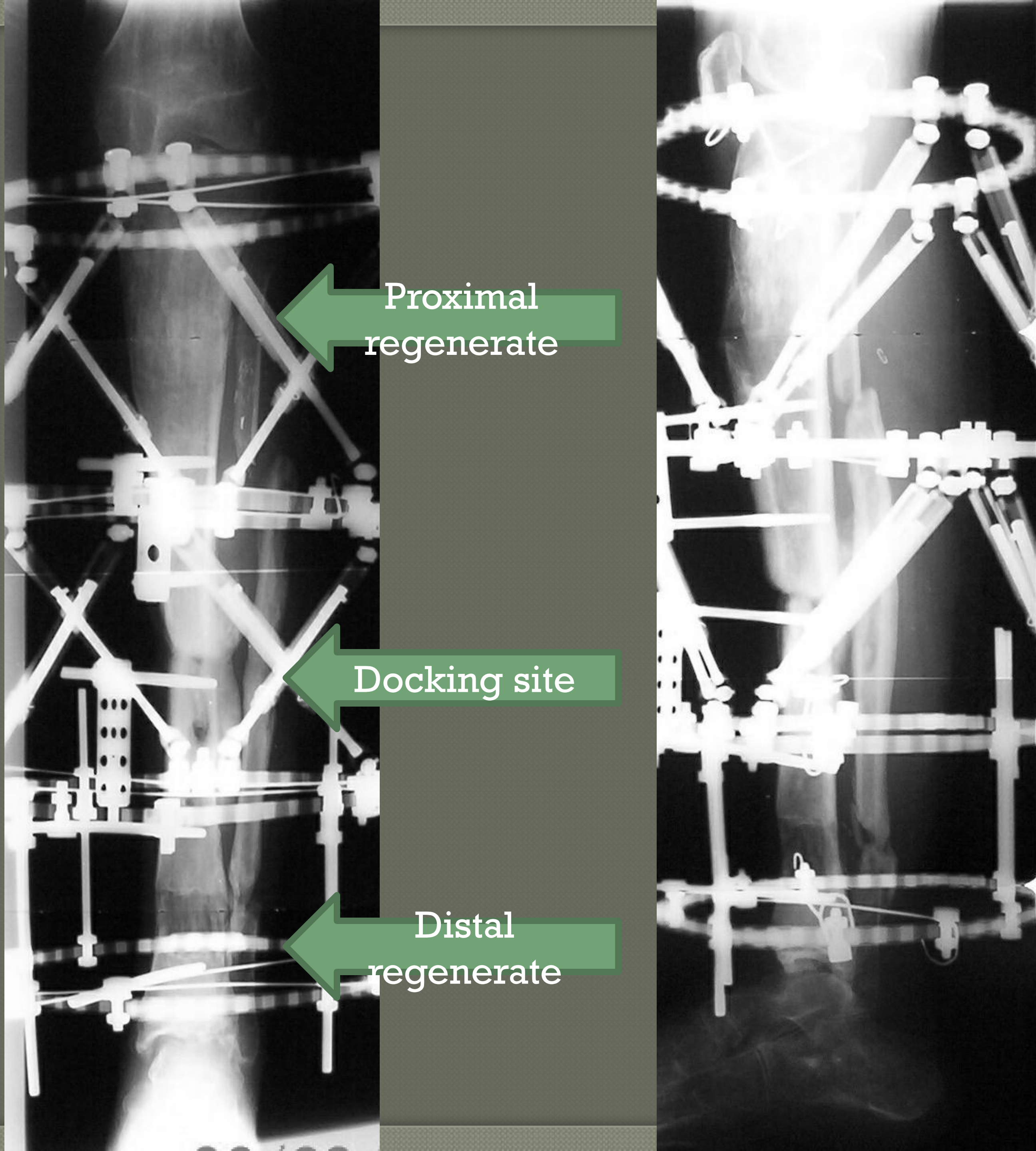
Proximal regenerate
Docking site
Distal regenerate



Temporary Intentional Leg Shortening and Deformation to Facilitate Wound Closure Using the Ilizarov/Taylor Spatial Frame

Shane J. Nho, MD, David L. Helfet, MD, and S. Robert Rozbruch, MD

Summary: Infected tibial nonunions with bone loss pose an extremely challenging problem for the orthopaedic surgeon. A comprehensive approach that addresses the infection, bone quality, and overlying soft-tissue integrity must be considered for a successful outcome. Acute shortening with an Ilizarov frame has been shown to be helpful in the treatment of open tibia fractures with simultaneous bone and soft-tissue loss. Cases in which the soft-tissue defect considerably exceeds bone loss may require an Ilizarov frame along with a concomitant soft-tissue procedure; however, there are a number of potential difficulties with vascularized pedicle flaps and free tissue flaps, including anastomotic complications, partial flap necrosis, and flap failure. The technique described in this report involves acute shortening and temporary bony deformation with the Ilizarov apparatus to facilitate wound closure and does not require a concomitant soft-tissue reconstructive procedure. Once the wound is healed, osseous deformity and length are gradually corrected by distraction osteogenesis with the Ilizarov/Taylor Spatial frame.

Key Words: Ilizarov, Taylor Spatial frame, nonunion, acute shortening, deformity correction, wound closure

(*J Orthop Trauma* 2006;20:419–424)

The Ilizarov method has been described alone or in combination with soft-tissue reconstruction for the management of open tibia fractures, limb shortening, deformity, joint contractures, and infections. Shortening with bifocal compression-distraction has been successfully used in the treatment of open tibia fractures with primary wound closure or delayed primary wound closure.[1–3] The technique is called bifocal because there are 2 segments with activity. One segment (the defect) is undergoing compression/shortening, and 1 segment (the bony regenerate) is undergoing distraction/lengthening to maintain the length of the limb. Bone defects < 3 cm can usually be acutely shortened, and defects of > 3cm should usually be gradually shortened.[1] Acute shortening is easier and safer to accomplish in the acute rather than chronic situation. Acute shortening of > 3 cm may be safe if the vascular physical examination does not change. Bifocal compression-distraction not only leads to solid osseous union but also corrects limb length discrepancy, deformity, joint contractures, and infection throughout the treatment period. The Ilizarov method does not eliminate or "correct" the infection solely because it is applied to the bone. Removal of the dead bone, sequestrum, debridement, irrigation, local, and systemic antibiotics, etc., all contribute to the elimination of the infection from the bone. It does supply stability as an adjunct to the whole process. Additionally, the absence of internal fixation may be safer in the setting of active or history of infection.

In the present article, the authors present the technique of acute shortening and intentional temporary bony deformation to facilitate wound closure, thereby avoiding a soft-tissue flap, along with an illustrative case example. With the leg stabilized in the Ilizarov/Taylor Spatial frame (TSF; Smith & Nephew, Inc., Memphis, TN), the wound was allowed to completely heal in the deformed position. The deformed leg was gradually corrected until anatomic reduction of the bony fragments was achieved, and through a second tibial osteotomy, the leg was lengthened to correct the leg length discrepancy (LLD). The TSF, which is particularly useful for this technique, is an evolution of the Ilizarov frame that allows simultaneous correction of length, angulation, translation, and rotation about a virtual axis.[4–6] With the TSF, a crooked frame mounted on a deformed bone can be used to gradually correct the leg deformity.[4]

SURGICAL TECHNIQUE

Surgery is usually performed under regional anesthesia. Preoperative antibiotics are withheld until after intraoperative cultures are obtained. Bony edges are debrided with the goal of removing all dead bone. The bony edges are cut flat and perpendicular to the axis of the tibia with a power saw cooled with saline. An equal-sized segment of the fibula must be removed at about the

Accepted for publication October 31, 2005.
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No authors received financial support for the research or preparation of the manuscript.
The devices that are the subject of this manuscript are FDA approved.
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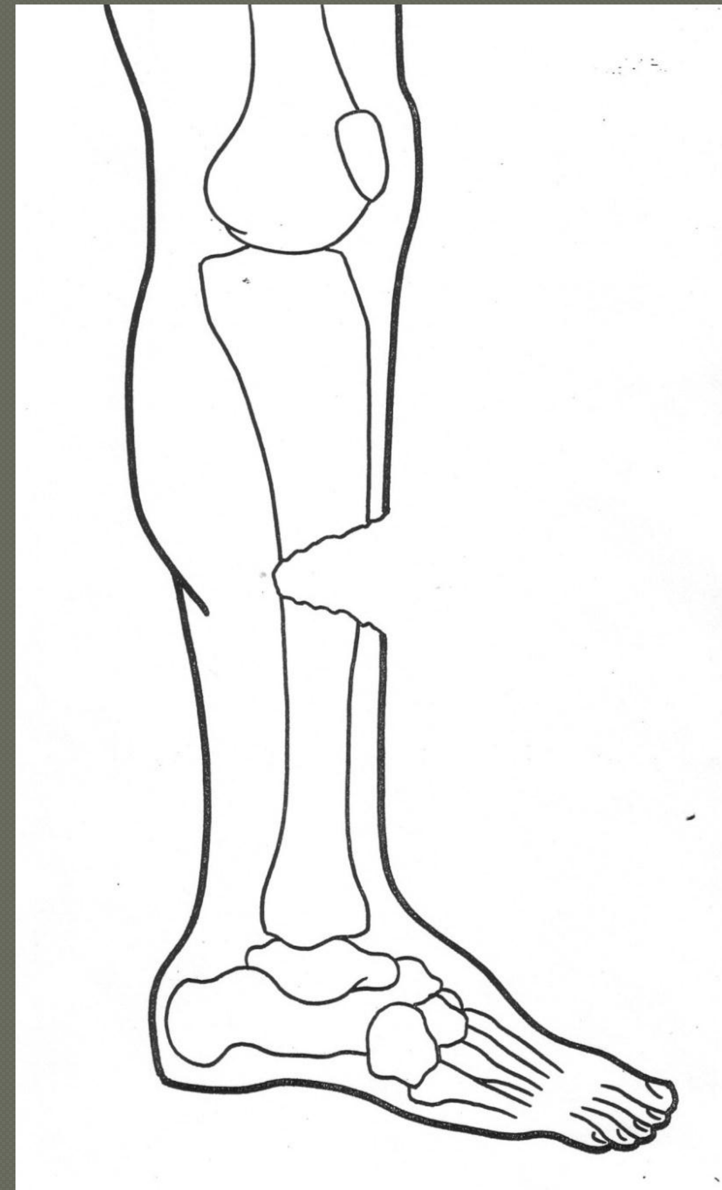
Infected nonunion, bone loss, soft-tissue defect

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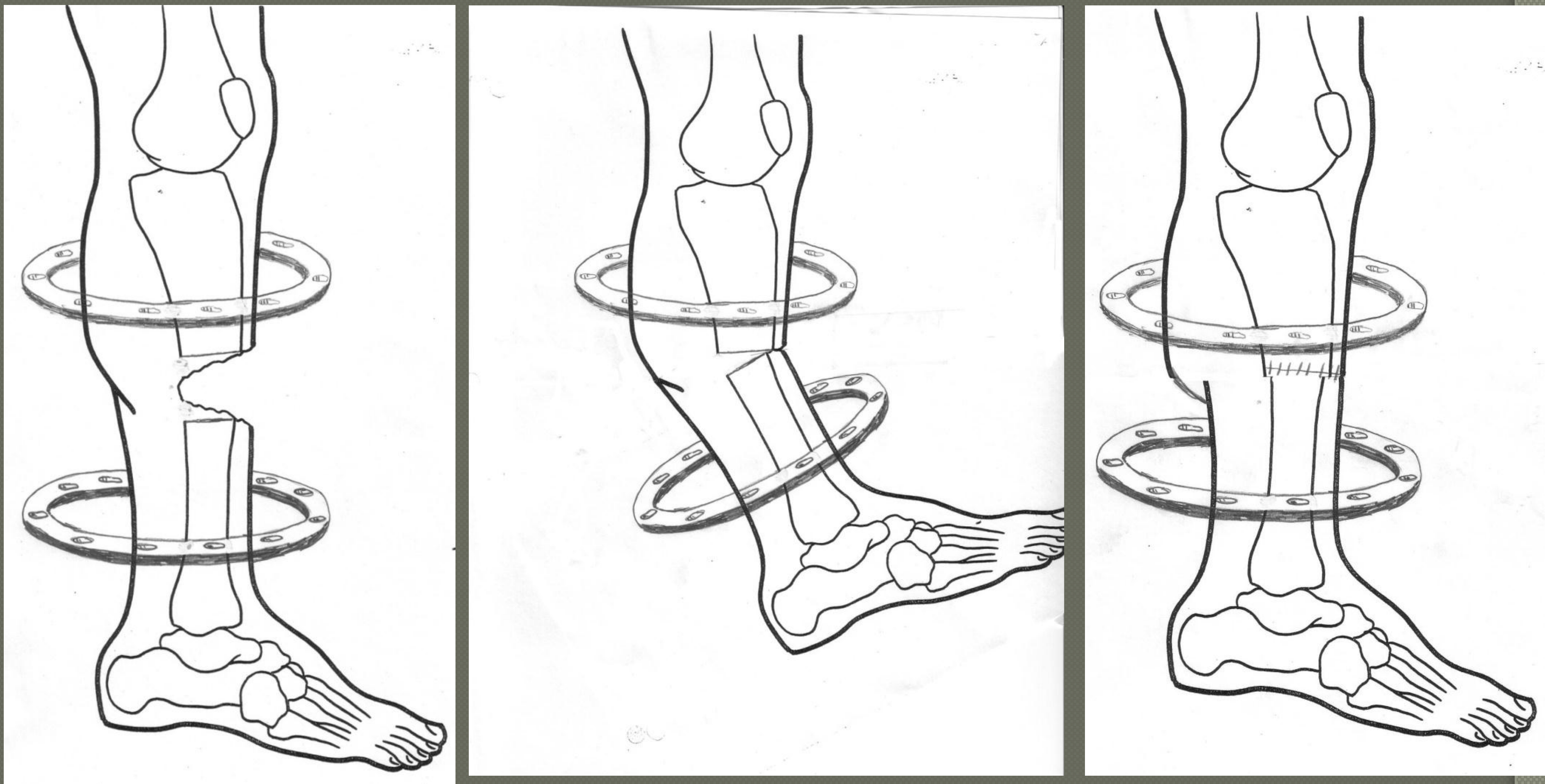

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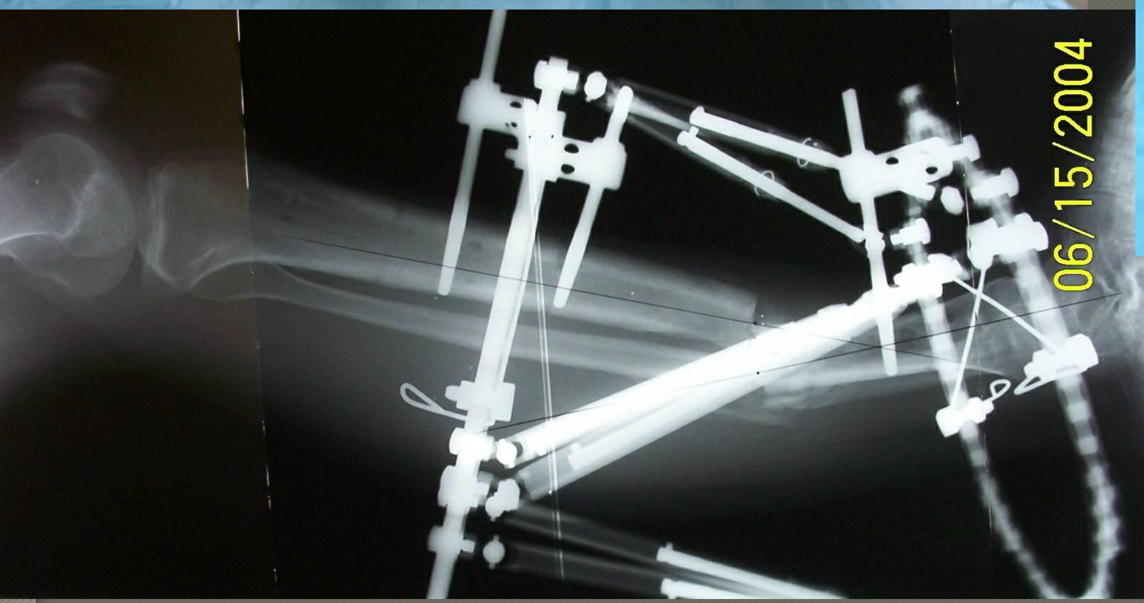

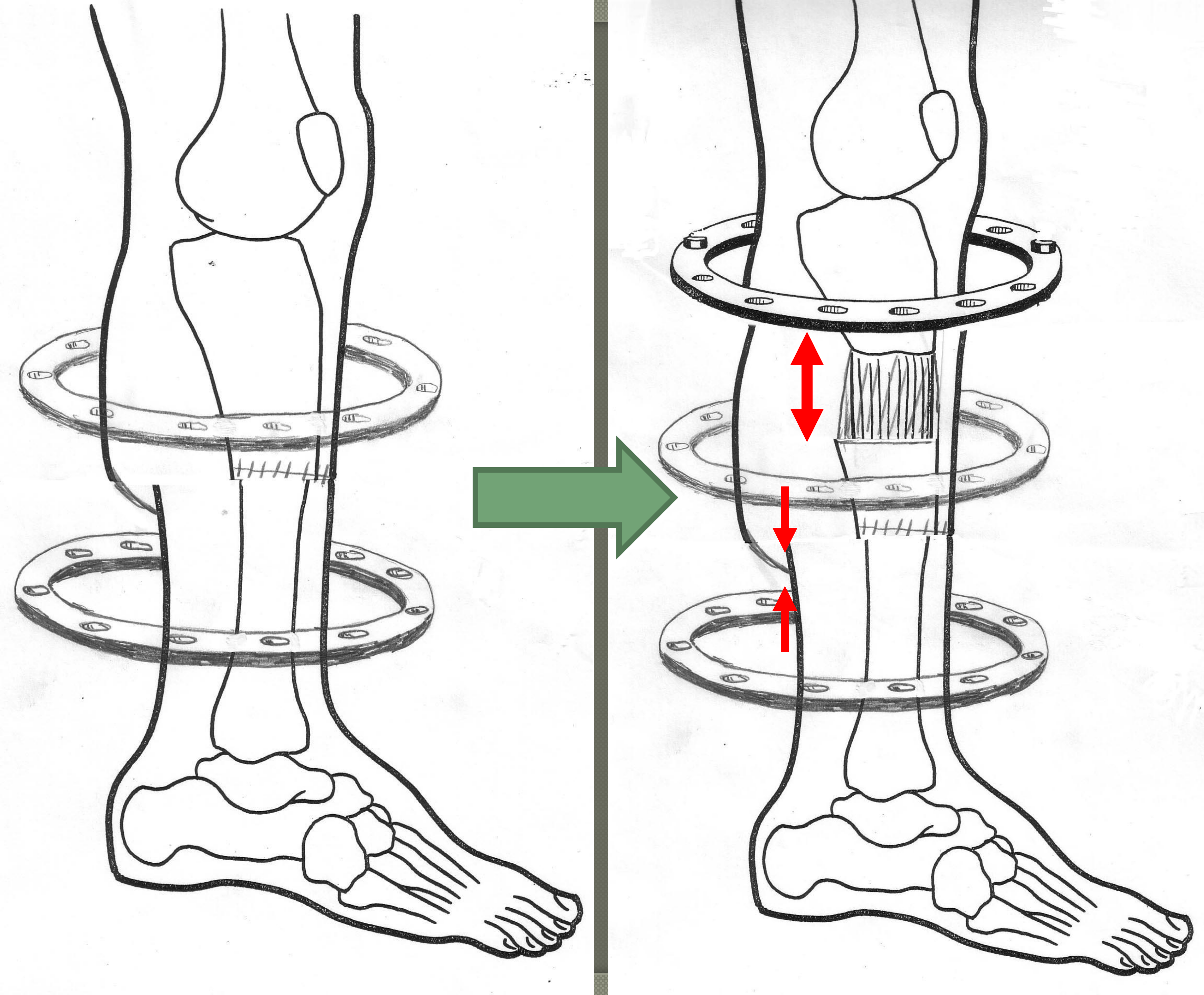

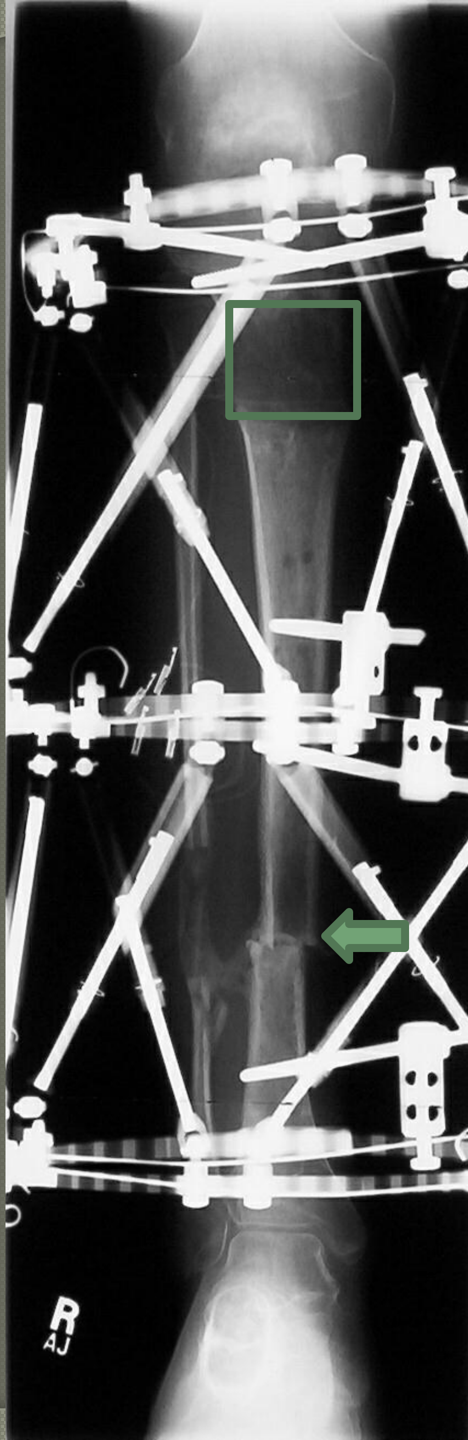
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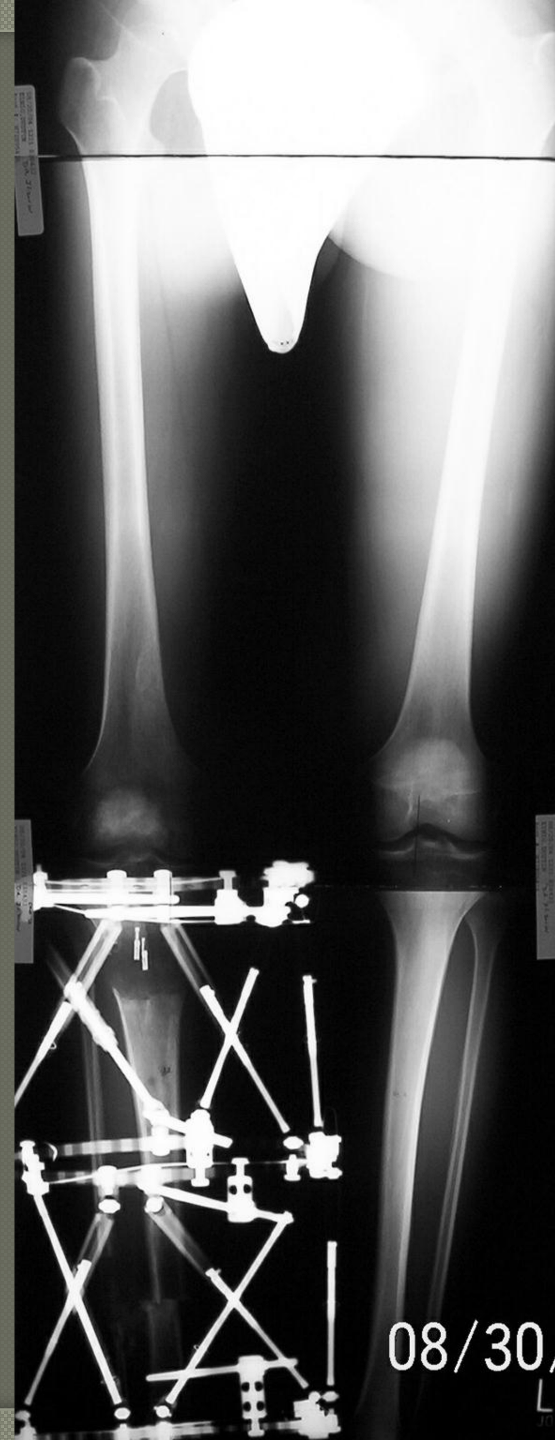
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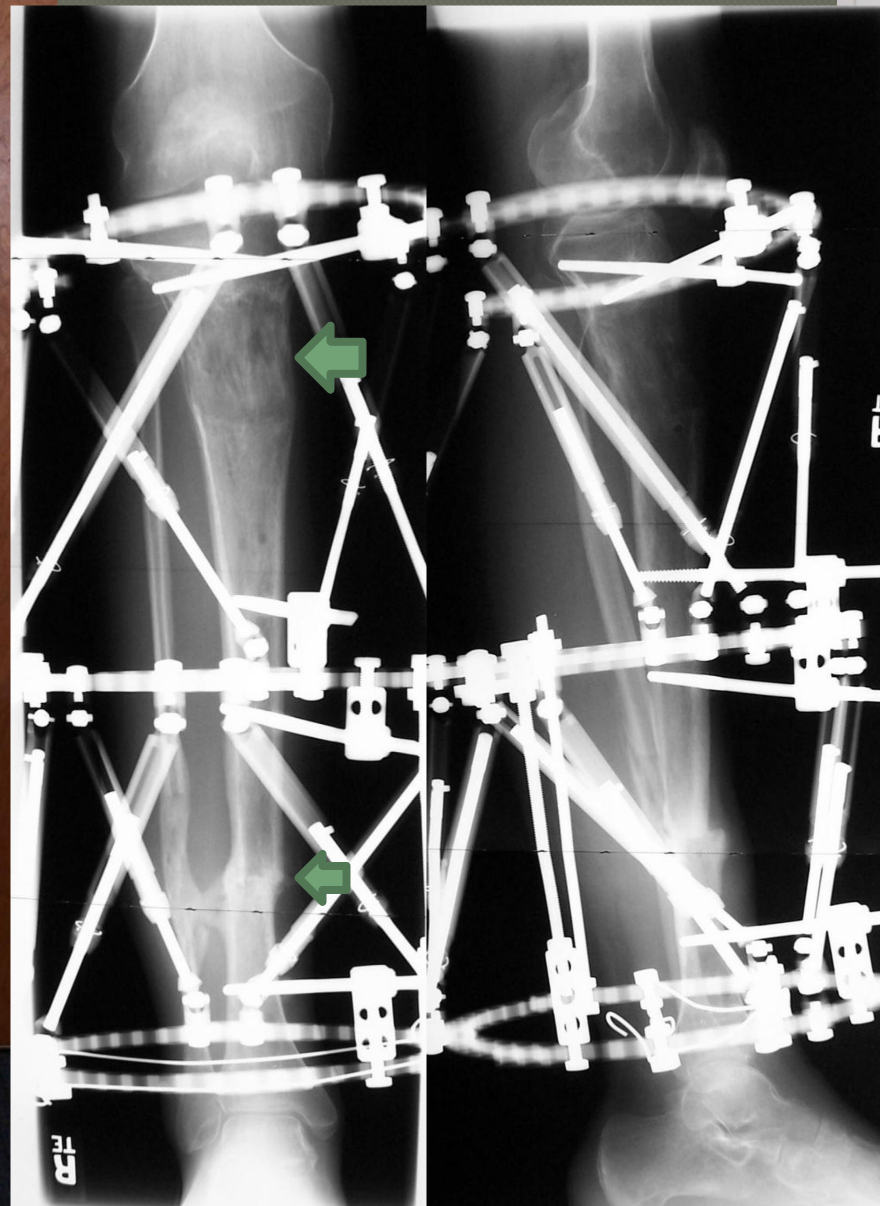



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Trifocal transport

Repair of Tibial Nonunions and Bone Defects with the Taylor Spatial Frame

S. Robert Rozbruch, MD, Jacob S. Pugsley, MD, Austin T. Fragomen, MD, and Svetlana Ilizarov, MD

Objective: To investigate the outcomes of tibial nonunions and bone defects treated with the Taylor Spatial Frame (TSF) using the Ilizarov method.

Design: Retrospective.

Setting: Limb Lengthening and Deformity Service at an academic medical center.

Patients: Thirty-eight consecutive patients with 38 tibial nonunions were treated with the TSF. There were 23 patients with bone defects (average 5.9 cm) and 22 patients with leg-length discrepancy (LLD) (average 3.1 cm) resulting in an average longitudinal deficiency (sum of bone defect and LLD) of 6.5 cm in 31 patients (1–16). The average number of previous surgeries was 4 (0–20). At the time of surgery, 19 (50%) nonunions were diagnosed as infected.

Intervention: All patients underwent repair of the nonunion and application of a TSF. Patients with bone loss were additionally treated with lengthening. Infected nonunions were treated with 6 weeks of culture-specific antibiotics.

Main Outcome Measurements: Bony union, time in frame, eradication of infection, leg-length discrepancy, deformity, Short Form-36 (SF-36) scores, American Academy of Orthopaedic Surgeons (AAOS) lower-limb scores, and Association for the Study of the Method of Ilizarov (ASAMI) bone and functional results.

Results: Bony union was achieved after the initial treatment in 27 (71%) patients. The presence of bone infection correlated with initial failure and persistent nonunion ($P = 0.03$). The 11 persistent nonunions were re-treated with TSF reapplication in 4, intramedullary rodding in 3, plate fixation in 2, and amputation in 2 patients. This resulted in final bony union in 36 (95%) patients. The average LLD was 1.8 cm (0–6.8) (SD 2). Alignment with deformity less than 5° was achieved in 32 patients and alignment between 6° and 10° was achieved in 4 patients. Significant improvement of Short Form-36 (SF-36) scores was noted in physical role ($P = 0.03$) and physical function ($P = 0.001$). AAOS lower-limb module scores significantly improved from 56 to 82 ($P < 0.001$). ASAMI bone and functional outcomes were excellent or good in 36 and 34 patients, respectively. The number of previous surgeries correlated inversely with the ASAMI bone ($P = 0.003$) and functional ($P = 0.001$) scores.

Conclusions: One can comprehensively approach tibial nonunions with the TSF. This is particularly useful in the setting of stiff hypertrophic nonunion, infection, bone loss, LLD, and poor soft-tissue envelope. Infected nonunions have a higher risk of failure than noninfected cases. Treatment after fewer failed surgeries will lead to a better outcome. Internal fixation can be used to salvage initial failures.

Key Words: Taylor Spatial Frame (TSF), Ilizarov method, tibial nonunions, bone defects

(*J Orthop Trauma* 2008;22:88–95)

INTRODUCTION

Tibial nonunions have been treated with a variety of surgical methods including plate osteosynthesis with bone graft,[1–3] intramedullary nailing,[4–7] and external fixation.[8–16] The complexity of a tibial nonunion can be variable and depends on several factors. The "personality of a fracture" is a term and concept introduced by Schatzker[17] and its use underscores the complexity of a particular problem and helps organize a treatment approach. We have found it helpful to apply this concept to nonunion. The personality of a tibial nonunion is determined by a number of factors including bone loss; radiographic appearance and stiffness as they relate to the nonunion biology; deformity; leg-length discrepancy (LLD); presence or history of infection; soft-tissue envelope; retained hardware; and patient factors including diabetes, smoking, and neuropathy. Although the use of internal fixation is effective in the treatment of selected tibial nonunions, these techniques have their limitations.

The Ilizarov method has gained many advocates for the treatment of tibial nonunions over the last 2 decades, particularly hypertrophic nonunions[8,12,13,15,16,18,19] and nonunions associated with bone loss,[9,12,20–23] infection,[9,24,25] and a poor soft-tissue envelope.[12,20,26] The classic Ilizarov frame has been used to correct all deformity,[10,18,27–30] including lengthening and bone transport.[20,22,26] However, deformity correction with components of angulation, translation, and rotation requires a staged correction and frame modifications.

The TSF (Smith and Nephew, Inc., Memphis, Tennessee) is an evolution of the original Ilizarov frame and uses the same concepts of distraction osteogenesis as the classic frame. However, it uses a virtual hinge and a computer program to

Accepted for publication November 19, 2007.
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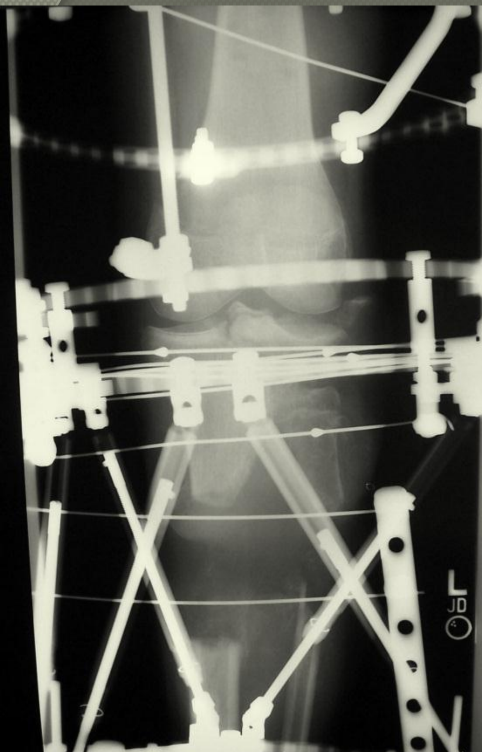
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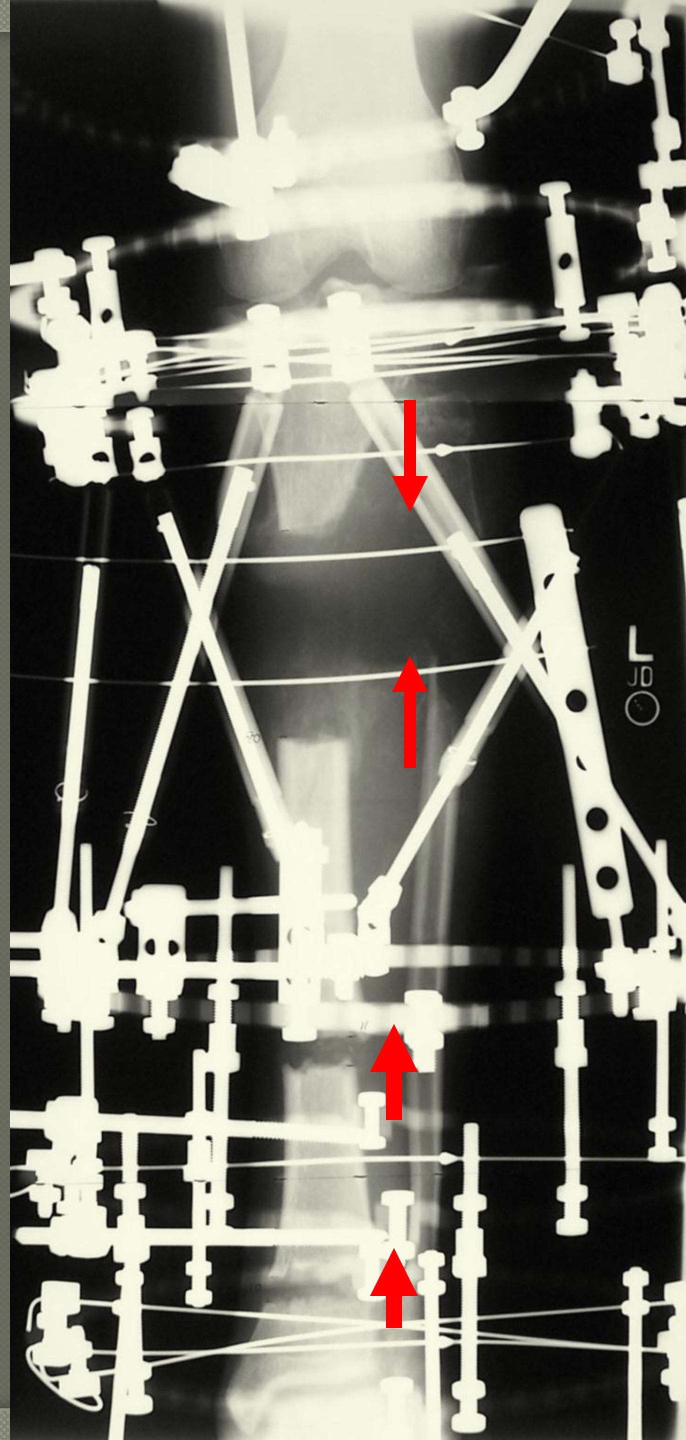
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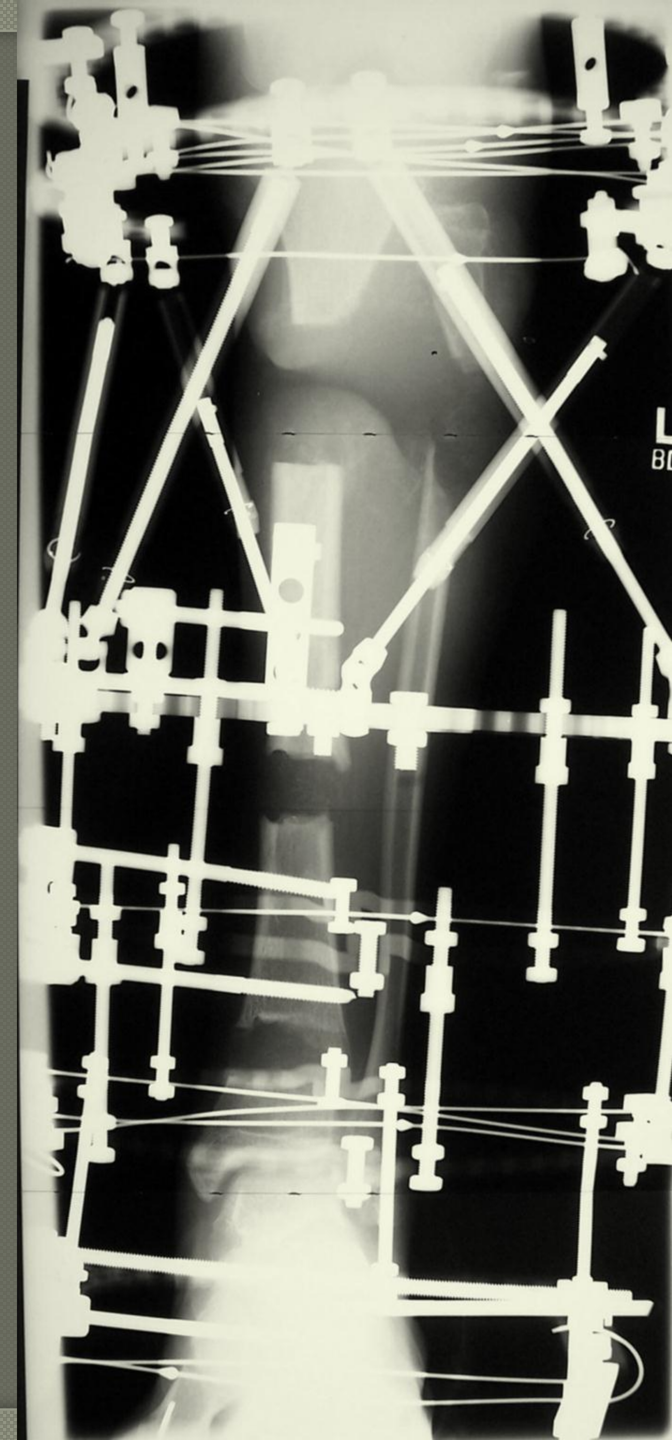
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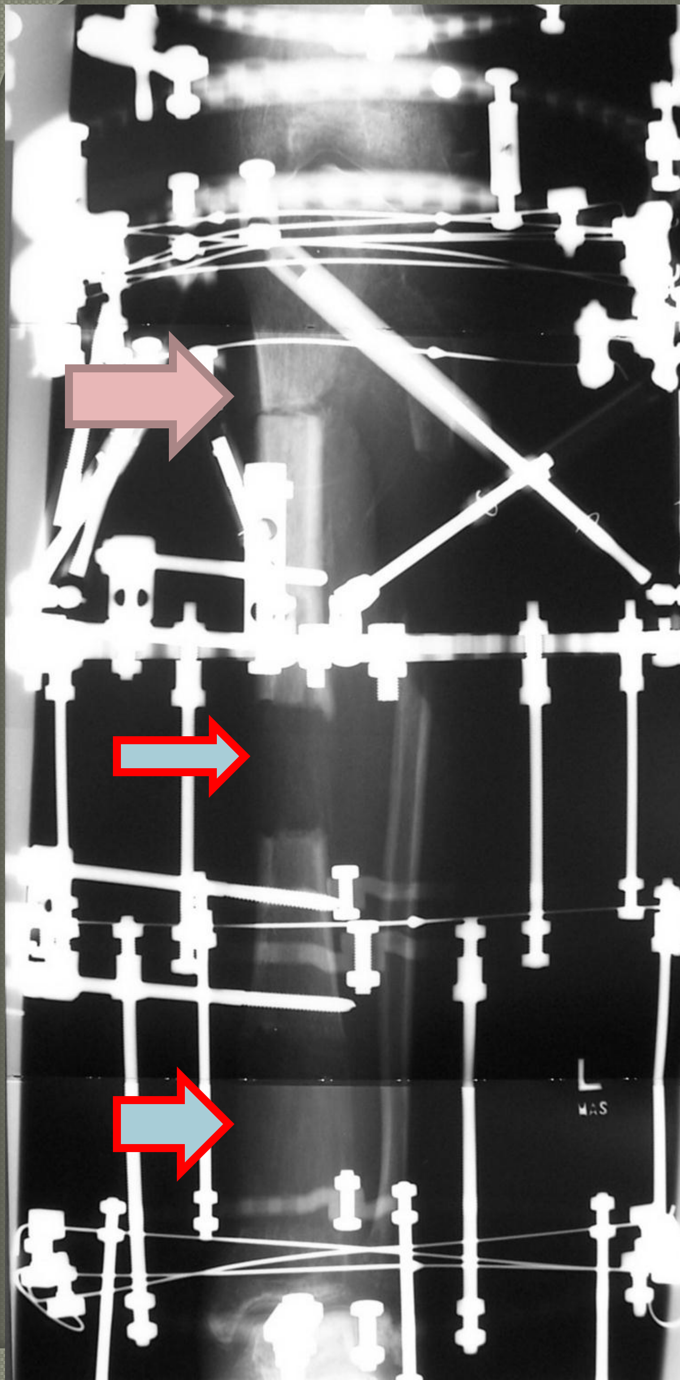
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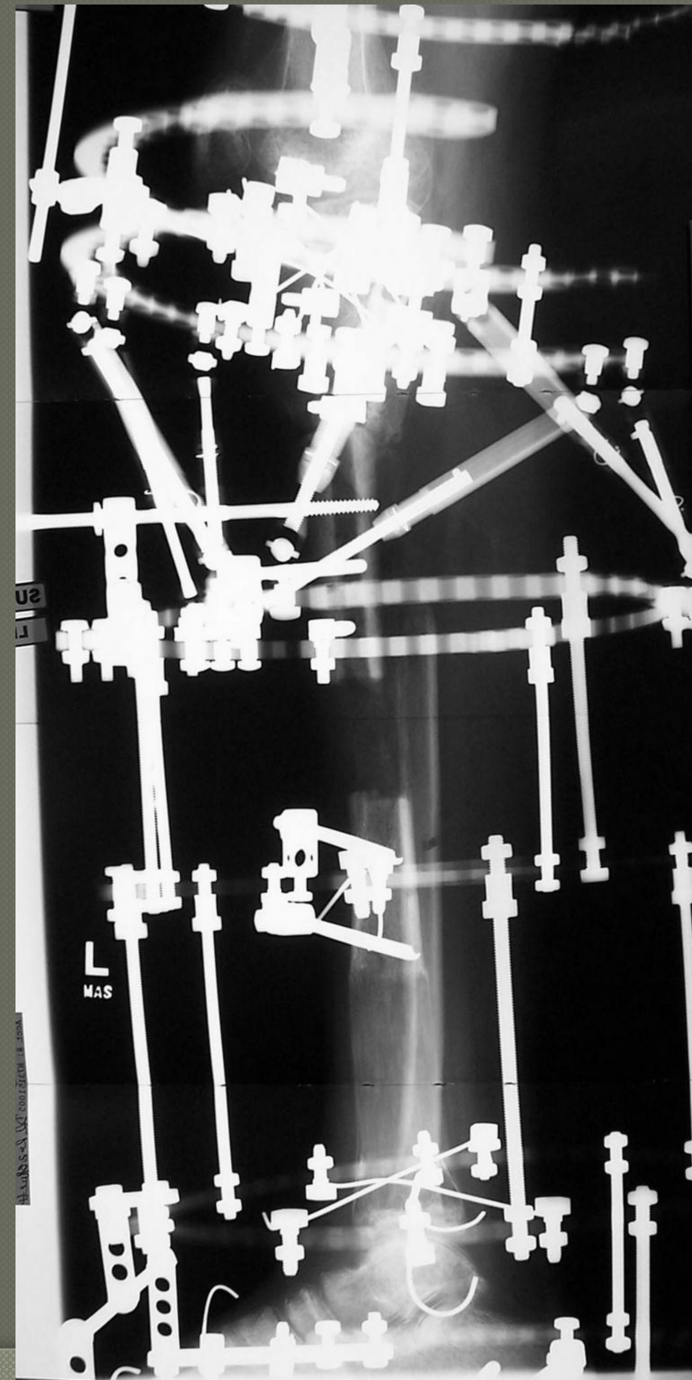
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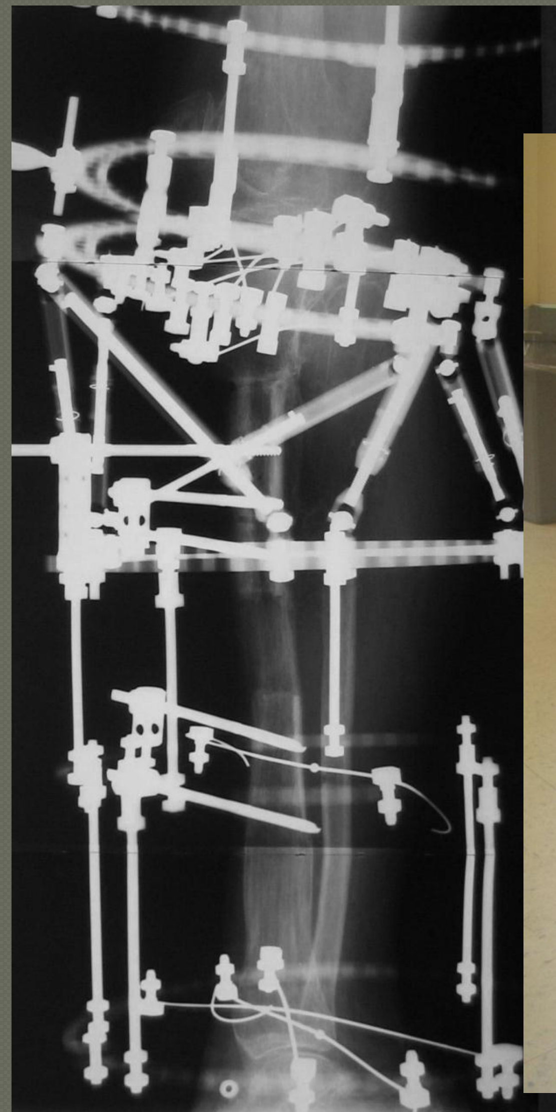




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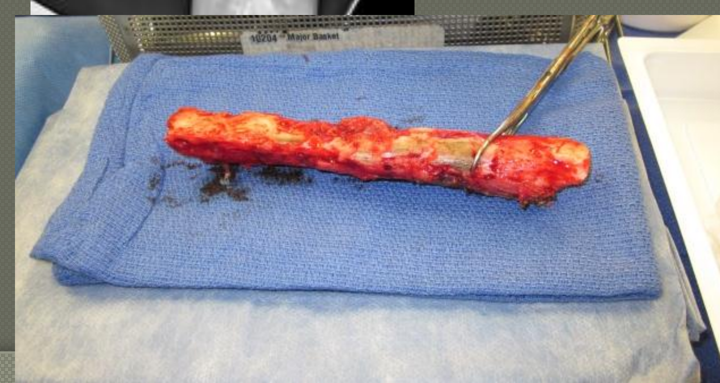
Bone Transport Over a Nail

Infected Tibial Nonunion with 17 cm bone defect: Treatment with Bone Transport over a nail

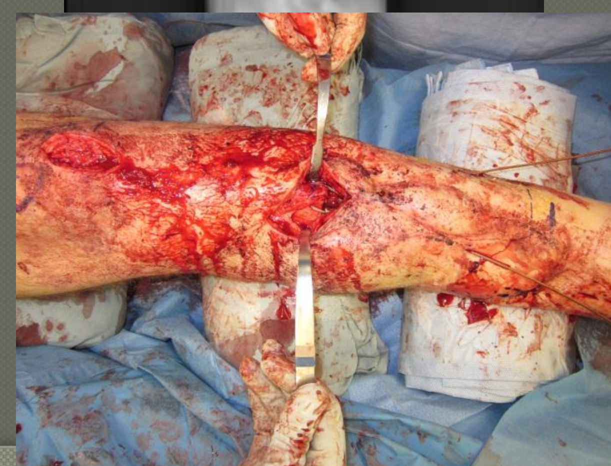
Step 1: Aggressive Debridement

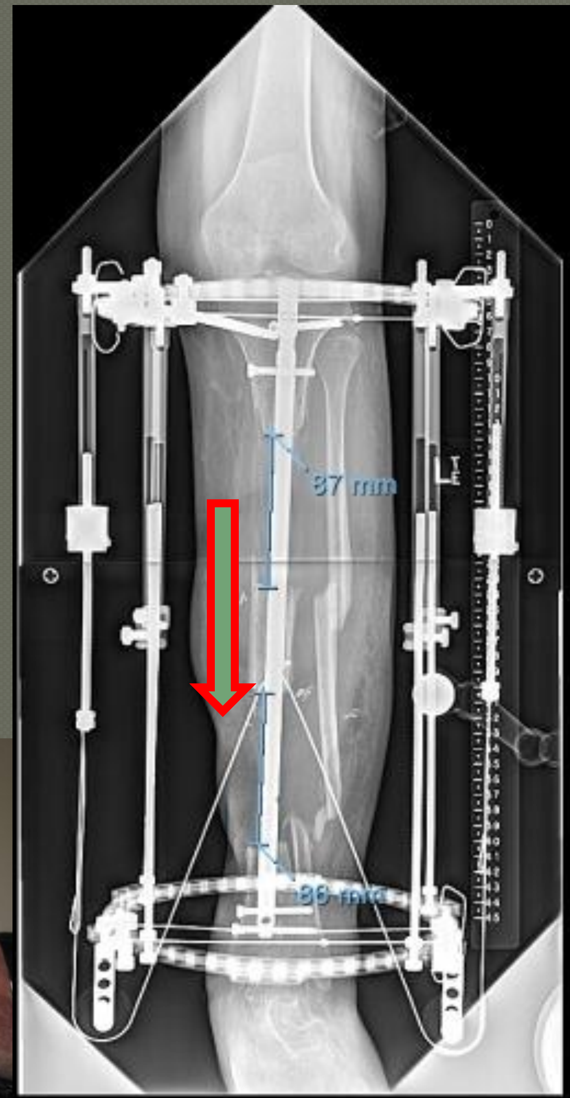
Segmental excision

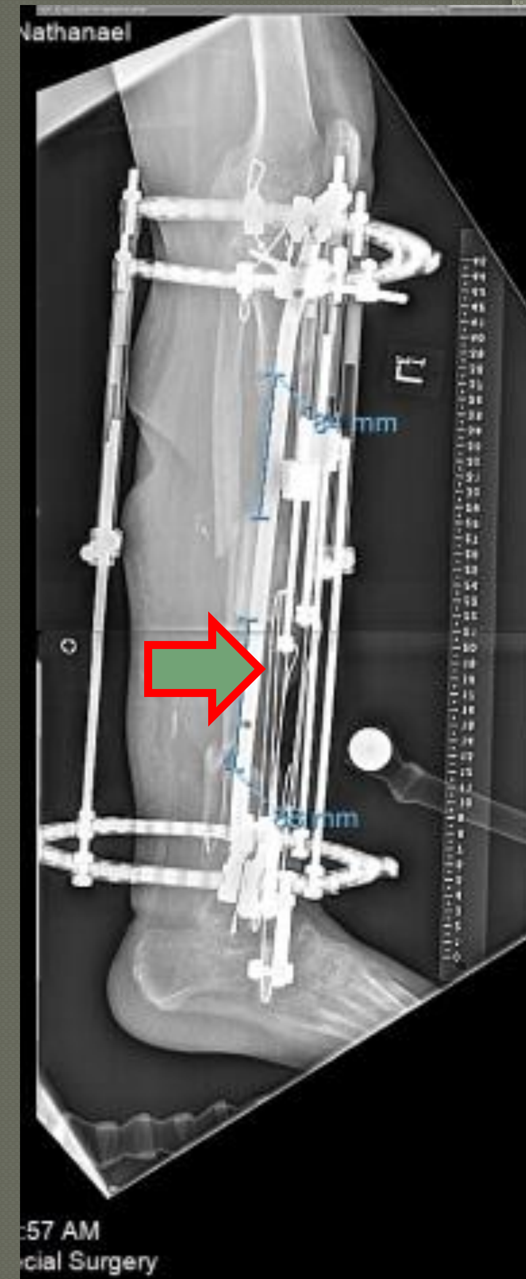


Insertion of antibiotic coated IM nail (locked)

Step 2:
After IV antx rx
6 weeks later
Exchange Nail
BTON
Cable technique




87 mm
86 mm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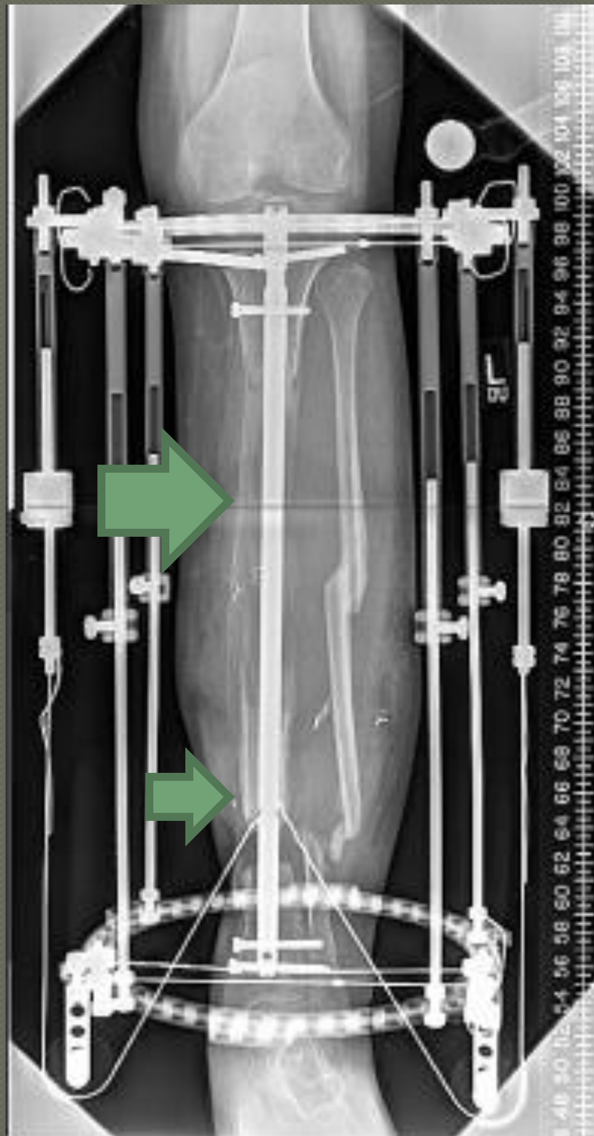
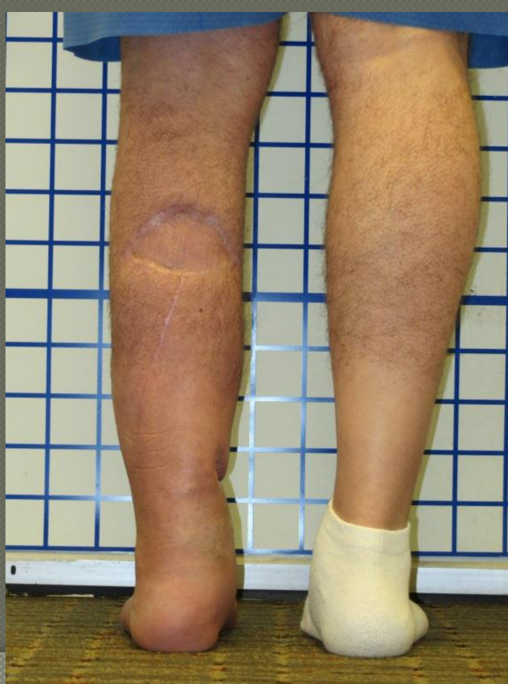
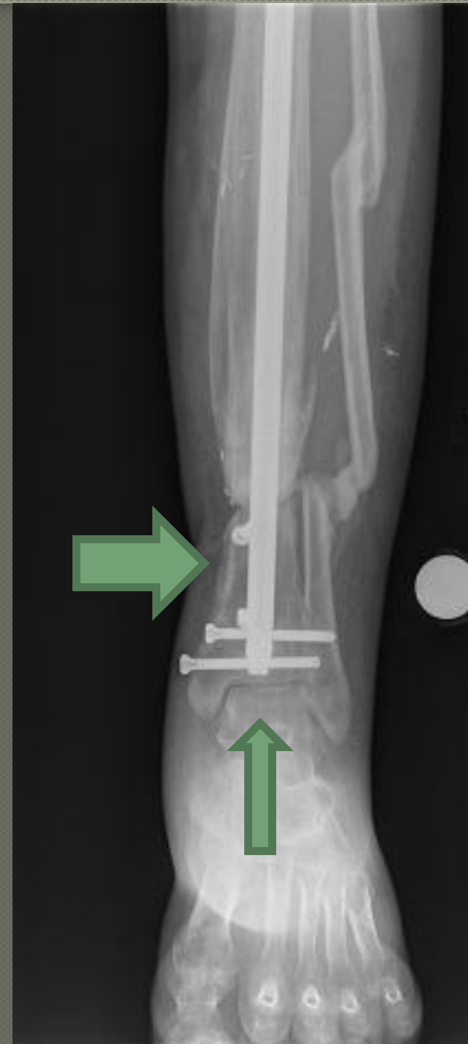
85 mm







Blocking screws help optomize rod position
In distal tibia → solid bony union

Usefulness of the Ilizarov method

- Infection
- Bone loss
- Multiple levels of treatment
  - Simultaneous lengthening
  - Simultaneous joint fusion
- Poor skin
- Large deformities
- Integrated techniques
  - Decrease time in external fixation
  - E.g., LATN, BTON

Thank You

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