MENTORS IN ORTHOPEDICS

TREATMENT OF POST INFECTION TIBIA BONE DEFECTS WITH ILIZAROV EXTERNAL FIXATION

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SUMMARY

Background: Infected bone defects in the lower extremity present significant challenges in orthopedic trauma, requiring a multidisciplinary approach involving thorough debridement, infection eradication, and complex reconstruction. While various techniques exist, including vascularized grafts and the Masquelet method, the Ilizarov external fixator (IEF) remains a primary modality for addressing segmental loss, though its application in resource-limited settings requires simplified diagnostic and therapeutic frameworks.

Objective: This article aims to present a simplified classification system for bone and soft tissue defects tailored for clinicians in low- and middle-income countries (LMICs) and to evaluate the clinical outcomes of various IEF techniques in managing infected tibial nonunions.

Key Points: A retrospective analysis of 43 patients with infected tibial shaft defects (average age 30 years) was conducted. The proposed classification categorizes defects as small (<3 cm) or large (>3 cm), integrating soft tissue status and host optimization. Surgical strategies included monofocal acute docking, bifocal or trifocal bone transport, and fibular transfer. All nonunion sites achieved consolidation within an average of 8.8 weeks, with total healing times ranging from 6 to 15 months. Complications included pin tract infections (n=9), ankle stiffness (n=15), and persistent mild drainage (n=10), though these did not preclude successful limb salvage. Biologic adjuncts such as bone marrow aspirate and bone morphogenetic proteins are also discussed as potential treatment enhancers.

Conclusion: The Ilizarov method is an effective and versatile treatment for infected tibial defects, allowing for simultaneous infection control, bone transport, and deformity correction. The simplified classification system facilitates rapid clinical decision-making in diverse surgical environments.

KEYWORDS

Ilizarov Technique; Tibia; Fractures, Nonunited; Osteogenesis, Distraction; Bone Diseases, Infectious

INTRODUCTION

Infected bone defects represent one of the most difficult and challenging conditions to treat in orthopedic trauma. Successful treatment requires appropriate preoperative workup and a staged approach to surgical management. Preoperative workup should consist of imaging and laboratory studies (white blood cell counts, erythrocyte sedimentation rate, and C-reactive protein). In addition, patients should be investigated and treated for any nutritional or metabolic deficiencies, immune compromise and other comorbidities impacting healing. The initial surgical stage is focused on eradication of infection with a combination of surgical and antibiotic treatment.

Many different approaches for management of leg bone defects are described and various techniques have been developed to address this issue [1],[2]. The Ilizarov external Fixator (IEF) is a revolutionary technique that involves the use of a circular external fixator to stabilize the limb, lead to bone union, and address malalignment, leg length discrepancy, and soft tissue defects [1],[3]. This method has been used to treat fractures, nonunions, deformities, and other bone defects. Although bone defects treated by IEF have reached satisfactory outcomes in most studies, there were still some unsatisfactory results with relatively high complications reported in some studies [1],[4]. Other methods have also been developed to manage leg bone defects, such as the vascularized fibular graft and the induced membrane (Masquelet) technique. These methods have shown promising results in terms of faster healing, shorter external fixation time, and lower complication rates. However, they also have their own limitations and drawbacks [5].

In the first part of this paper the treatment with IEF will be described together with a simple classification of bone defects, derived from our practical experience. This might allow rapid diagnostic criteria for middle-income (LMIC) countries. In the second part we will report on a case series using this classification system in combination with IEF technique.

PRIMARY TREATMENT GOALS

1. Removal of all loose or chronically infected hardware.

2. Debridement of all infected or nonviable bone and soft tissue.

3. Multiple deep tissue biopsies for culture and sensitivity to guide antibiotic treatment (minimum of 3–5 specimens).

4. Revision of fracture fixation (using either temporary or permanent fixation).

5. Placement of local antibiotic treatment if possible.

6. Soft tissue management as required (e.g, primary closure, vacuum-assisted closure, or flap coverage) [9].

EVALUATION OF BONE DEFECTS

Classification according to size of bone defect [10]:

- Group 1: bone defect less than 2 cm.
- Group 2: bone defect from 2- 6 cm.
- Group 3: bone defect from 6- 12 cm.
- Group 4: bone defect more than 12 cm.

We find the above classification, very detailed and of valuable results in research and well qualified center, as well as limb reconstructive surgery (LRS) specialized unites. To facilitate bone defect classification for resident, junior orthopedic specialist in LMICs, we prefer to separate into 2 groups only according to bone defect sizes:

Small defects (<3 cm):

Defects less than 15 mm may be left to heal by obliterating the defect through shortening the limb to facilitate contact between the bone ends and subsequent union. The shortened limb may then be managed by orthotic means or not at all if less than 15 mm. However, larger defects towards 3 cm may be amenable to management by bone grafting after the soft tissues have recovered well or using the Masquelet technique as a planned procedure. IEF is another option to close the defect and provide early weight bearing tool.

Large defects (>3 cm):

Regarding the bone defects more than 3 cm, the defect area has to be debrided and all necrotic and dead tissue are removed. The bone is explored and debrided and infected or necrotic edge of the bone are removed. In patients with infected bone defect sites, we applied antibiotic locally or used Masquelet-induced membrane technique until laboratory and clinical evidence of healthy noninfected bone gap area is confirmed. IEF has its merits to reconstruct the bone defect even associated with soft tissue loss.

EVALUATION OF SOFT TISSUE DEFECTS

Some of these cases represent soft tissues defects which need specific procedures which can be classified in 3 types (Table 1).

Soft tissue defect type	Host category	Bone defect size			
		< 2cm	2-6cm	6-12cm	>12cm
alpha	A	Primary bone grafting with internal fixation	Masquelet with primary internal fixation or non-vascularized graft	Acute and gradual shortening and lengthening with Ilizarov fixator trifocal or Masquelet with primary internal fixation or fibula graft in a child or upper limb defects	Acute and gradual shortening and lengthening with Ilizarov fixator or vascularized fibula graft or Masquelet with primary internal fixation
	B	Shortening	Acute and gradual shortening and lengthening with Ilizarov fixator bifocal	Acute and gradual shortening and lengthening with Ilizarov fixator Trifocal	Acute and gradual shortening and lengthening with Ilizarov fixator
beta	A	Acute shortening/flap for wound management or Masquelet induced membrane technique	Masquelet-induced membrane technique or open bone transport	Bone transport through the induced membrane or Masquelet-induced membrane technique	Osteo-myo-cutaneous vascularized fibula graft in upper limbs or Bone transport through the induced membrane
	B	Acute shortening for wound healing/flap and fixation by Ilizarov	Open bone transport or bone transport through the induced membrane	Open bone transport or bone transport through the induced membrane	Consider amputation in type B and C host
gamma	A	Convert a gamma to beta/alpha wound, bony stabilization with ex-fix	Convert a gamma to beta/alpha wound, bony stabilization with ex-fix	Convert a γ to β/α wound, bony stabilization with ex-fix	Convert a γ to α wound, bony stabilization with ex-fix Consider amputation
	B	Make every effort to convert a B to A host and a gamma to beta or alpha wound	Make every effort to convert a B to A host and a gamma to beta or alpha wound	Consider amputation, especially in C host	Consider amputation in type B and C host

Table 1 shows the combined approach for soft tissue defect types and bone defect sizes for the management of Segmental Bone defects [10]

• Type alpha: No soft tissue deficit.

No additional soft tissue reconstruction is required before or following bony reconstructive procedures.

• Type beta: Soft tissue defects which require soft tissue reconstruction

The soft tissue envelope will need augmentation to support the underlying bony reconstruction which are higher up on the reconstruction ladder including random, axial and free flaps.

• Type gamma: Unable to reconstruct the soft tissue defect [10].

Negative-pressure wound therapy (NPWT) also known as vacuum-assisted closure (VAC) was initially viewed as a revolution in wound management to the extent a new reconstructive ladder incorporating NPWT was proposed [11]. Advantages of NPWT included an increased rate of granulation tissue formation, decreased peri wound oedema, decreased time to wound closure, less frequent dressing changes, control of bacterial proliferation and potential financial advantages [12].

HOST OPTIMIZATION

This should also be included into the management and can be determined according to the host type (Modified McPherson) [13]. The importance of host optimization during limb reconstruction surgery cannot be emphasized enough. The host status serves as the primary indicator of the patient's ability to affect the healing of bone and soft tissues, as well as their ability to launch an effective immune response against infection.

- Type A: Good immune system and delivery.

- Type B: Compromised locally (BL) or systemically (BS).
- Type C: Requires no treatment; minimal disability; treatment worse than the disease; not a surgical candidate.

ROLE OF BIOLOGICS IN BONE DEFECT MANAGEMENT

The ability to augment the treatment of bone defects with biologic materials or strategies represents an attractive alternative to conventional treatment options. Several biologic materials or treatments are currently available for use including cellular therapies with bone marrow aspirate, platelet-rich plasma (PRP), BMP, and distraction osteogenesis [14].

Bone marrow aspirate concentrate

Concentrated bone marrow aspirate contains a viable population of osteoprogenitor cells that can participate in osteogenesis. This material has been combined with multiple different adjuvants or composites that serve as osteoconductive carriers to deliver the osteogenic marrow elements. This represents a single-step biological strategy for bone defect management. Marrow progenitor cells are harvested from the iliac crest, concentrated in the operating room, and seeded onto an osteoconductive substrate with a microporous structure that provides the cells with a potentially stable and well-vascularized environment. This osteogenic construct is then implanted into the defect. Scaffolds used include particulate demineralized bone matrix (DBM), collagen sponges, and porous hydroxyapatite ceramics.

Platelet rich plasma (PRP)

Currently, there is no Level I evidence to indicate that using PRP alone or in combination with other materials has a substantial effect on bone healing. The available evidence (Levels III and IV) indicates that PRP may have a positive effect as an adjunct to local bone graft, and its use has been suggested to increase the rate of bone deposition and improve the quality of bone regeneration and fusion in nonunion situations.

Bone morphogenetic proteins (BMP)

The use of inductive proteins (BMPs) has been approved for open tibial shaft fractures and has demonstrated encouraging results for the reconstruction of segmental defects. Jones et al used BMP-2 combined with allograft bone for the treatment of acute segmental tibial defects and compared this with a group treated with autograft alone. In this Level 1 clinical trial, the average defect size was 4 cm (up to 7 cm). There were no significant differences in complication rates or functional outcomes between the 2 groups, with similar union rates noted. This study suggested that rhBMP-2/allograft is safe and as effective as autogenous bone grafting for the treatment of tibial defects [14].

ROLE OF IEF IN BONE AND SOFT TISSUE RECONSTRUCTION

Ilizarov external fixator (IEF) is helpful and malleable procedure for bone defect fixation. To close the different sizes of bone defect, IEF can be applied with different strategies. This includes acute compression in some cases, acute compression followed by distraction compensating lengthening, gradual compression followed by distraction, corticotomy compensating lengthening from the healthy metaphyseal region, bone transport using gradual compression with distraction at the corticotomy site, bone transport using gradual compression with distraction at 2 corticotomy sites, free vascularized fibular graft, free non-vascularized fibular graft and Ilizarov assisted fibula transportation were used. One of its merits, IEF might be used to compensate the bone defect as well as the soft tissue defects.

REPORT OF A CASE SERIES USING IEF TECHNIQUE

This study includes bone defects due to infected nonunion of tibia in patients treated between September 2015 and 2020 in our hospitals.

Patients and Methods

43 cases (6 females) of post traumatic bone defect due to infected tibia shaft with average age 30 years (range: 18-62) were included. History of infection was less than 6 months in 8 patients. All had failed previous surgical attempts for management of bone defects pre or post debridement. There was history of more than 2 previous surgical attempts for management in all cases. Patients presented with discharging sinus in 27 cases, intermittent discharging sinus in 8 cases. Nonunion was associated with stiff ankle in 21 cases. All treated 43 cases were followed for at least two years (24-36 months).

Surgical Technique

The wound was debrided, and excision of the sinus was performed. The bone was explored, debrided, sequestrectomy was performed, and local antibiotic was added, if financially possible.

To close different sizes of defects, different IEF techniques were used :

- Osteotomy was performed percutaneously using multiple drills and an osteotome for lengthening or bone transport technique at metaphyseal area proximally or distally if bone or soft tissue permitted. In most cases, early guided weight bearing and independent walking using crutches had been performed. Bone healing and functional results were assessed according to ASAMI criteria (Association for the Study and Application of the Method of Ilizarov) and according to Paley's classification for complications [7].

- Monofocal technique in 14 cases:
- 4 Patients (defect 3 cm or less) accepted acute docking and union with shortening 3 cm or less.
- 6 Patients (defect 3 cm or less) did not accept any discrepancy from other limb length, treated by acute shortening, followed by gradual lengthening, from the same site of bone defect, to attain the discrepancy of 3 cm and less.
- 4 Patients (defect 3 cm or less) did not accept any discrepancy from other limb, treated by Masquelet technique.

- Bifocal bone transport in 21 patients (one with acute docking).

- Trifocal bone transport in 1 patient.

- Free vascularized fibular graft in 1 patient.

- Free non-vascularized fibular graft in 3 patients.
- Ilizarov assisted reconstruction of comminuted and soft tissue traction of lower 1/3 leg bones in 1 patient (Fig 1).
- Fibula Ilizarov assisted technique in 2 patients (Fig 2).

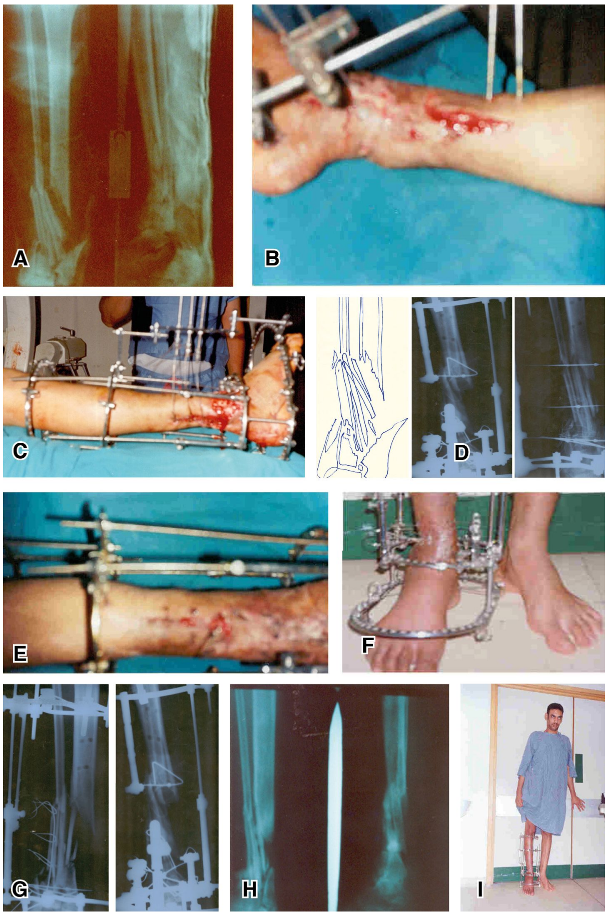

Figure 1: A. Multiple trauma, 21 years old, male patient, had a crush foot injury, post debridement there was open fracture Grade III B. Bone shattered, comminuted, with deficient parts, and open distorted joint - B. Skin loss, crushed muscles and exposed tendons and bone. Aggressive debridement was done, no wound closure, unilateral frame application to give the chance for plastic surgery. Posterior skin release and skin grafting. Unfortunately, STSG failed. - C. A skin traction technique using Ilizarov apparatus, longitudinal and multiple perpendicular wires with hooked ends to drag the soft tissues. The skin follows the direction of traction system to close the gap - D. Left diagram of the shattered lower 1/3 leg bones, middle and right X- Rays with Ilizarov apparatus, augmented by multiple olive wires were added to reconstruct the shattered disturbed bony fragments. - E. Anterior view, soft tissue loss improved. - F. The skin traction construct was removed after 3 weeks. - G. AP and Lat views show disorganized, shattered, bony and articular fragments - H. Arranged bony fragments last follow up - I. Clinical situation at the last follow up.

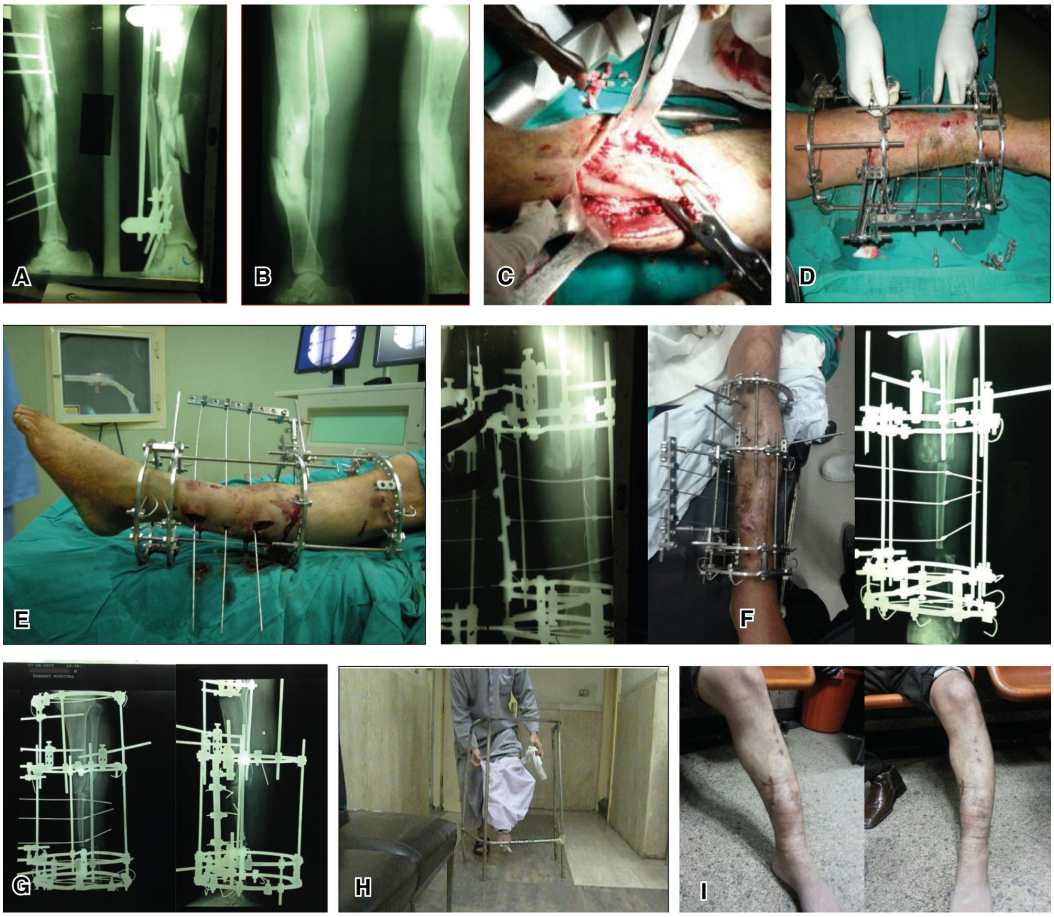

Figure 2: A. Male patient, 50yrs old, presented with comminuted infected fracture tibia fixed by uniplanar external fixation - B. Removal of external fixator, debridement of bone and soft tissues, systemic AB, local AB - C. 2nd debridement with removal of 15cm dead bone - D. Ring fixator 4 weeks later with application of olive wires through the fibula - E. 2 skin incisions at the lateral sides of the leg at the levels of proximal and distal fibular to do cortectomies. - F. During fibular transfer - G. After fibular transfer - H. Mobilized with walker while waiting graft union - I. Clinical situation after frame removal

Outcomes

All nonunion sites united, and soft tissue healed between 6 and 15 months. Complete consolidation of the regenerate bone was obtained within an average of 8.8 weeks.

Complications

Ten limbs with mild intermittent discharging sinus needed continued local dressing and antibiotics, and 6 limbs re-debridement had to be performed but all finally healed. Further complications included pin tract infection in 9 cases, ankle stiffness in 15 cases and refracture after frame removal in one case. The complications did not preclude the surgical outcome.

CONCLUSION

Ilizarov external fixator is effective in management of bone defect pre or post debridement of infected nonunion of the tibia shaft. It provides advantages of many variable technique with Ilizarov application. Acute docking, lengthening, and correction of deformity could be practiced if needed, in the same procedure, with early rehabilitation.

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