Definitive Management of Distal Tibia and Simple Plafond Fractures With Circular External Fixation

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Summary: Obtaining optimal results in the treatment of extra-articular distal tibia fractures can be challenging. Plate and screw and intramedullary fixation have proven to be effective treatments, but are associated with significant complication rates when used for open fractures and patient with severe medical comorbidities. External fixation is a third alternative that is less often employed, but provides a very effective means of treatment. Circular external fixation offers great flexibility in obtaining anatomic alignment and stable fixation for even the most challenging distal tibia fractures. In addition, it provides advantages in limiting the risk of deep infection, dealing with bone loss, and obtaining soft tissue coverage. The greater ease of treatment and potential economic advantage in patient cohorts with low complication rates, such as closed fractures, supports the preferential use of internal fixation. However, circular external fixation may be the preferred treatment for patients with higher-grade open fractures, a poor soft tissue envelope with limited fixation options distally, and major comorbidities (diabetes, immune deficiency) with an associated high risk of complications.

Key Words: distal, tibia, pilon, external, fixation, fixator, ring, circular, Ilizarov, spatial frame

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INTRODUCTION

The preferred treatment of displaced extraarticular distal tibia fractures remains a controversial topic. The lack of diaphyseal fit and short distal bone segment make achieving anatomic alignment and adequate fixation with intramedullary nail (IMN) techniques more difficult than in the midshaft. Consequently, there is a great deal of literature comparing the use of plates with IMN fixation for treatment of these fractures. This literature demonstrates an overall decreased incidence of malalignment with plates versus nails, but functional results are equivocal.[1–9] Despite the many successful results, there are significant rates of infection, malunion, and nonunion with both treatments, especially with open fractures and multiple comorbidities.[1,4,7] External fixation offers an additional treatment alternative for these fractures. There are a number of features of treatment with circular external fixation that can be advantageous such as immediate weight-bearing, decreased dissection and soft tissue stripping, absence of deep hardware that can become infected, the option of distraction osteogenesis to address bone defects, and greater flexibility in the treatment of soft tissue defects. There is less literature reporting results of treatment of extraarticular distal tibia shaft fractures with external fixation, especially for circular external fixation, compared with what is available for plates and IMNs. However, the available prospective data are generally very favorable for circular fixation, indicating that it can be a powerful treatment alterative.[10–11]

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EVOLUTION OF MONOLATERAL AND CIRCULAR EXTERNAL FIXATION

External fixation (ex-fix) was first introduction by Malgaigne in 1843[12] and as early as 1938 Hoffman developed a monolateral frame that allowed for acute fracture reduction.[13] This system is very similar in concept to the pin-to-bar external fixators used today. Monolateral ex-fix systems have the benefit of being relatively easy and rapid to apply and being minimally invasive and biologically friendly. This makes them excellent provisional spanning devices for high-energy fractures awaiting soft tissue recovery. However, they are not ideally suited for definitive care because they are relatively unstable at maintaining fracture alignment, especially over longer working lengths, and do not allow early weightbearing.

Although first introduced by Bittner in 1929, the use of circular frames was limited until the late 1980s/early 1990s when Ilizarov popularized this type of device with his external fixation system and method for distraction osteogenesis.[14,15] Similar to monolateral frames, circular frames are minimally invasive and very biologically friendly. However, circular frames provide greatly enhanced stability that allows for immediate weightbearing and excellent maintenance of fracture reduction throughout definitive fracture treatment. In addition, Ilizarov's method of distraction histeogenesis allows for reliable creation of high-quality regenerate bone eliminating the need for bone graft to address bone loss.[14,15]

The introduction of the Taylor Spatial Frame (TSF) in 1996 further improved the power and ease of use of circular ex-fix.[16] The TSF is a hexapod platform that allows fracture reduction or deformity correction in 6 planes simultaneously. The TSF is fundamentally different than Ilizarov-style fixators. Ilizarov-style frames have rings connected by threaded

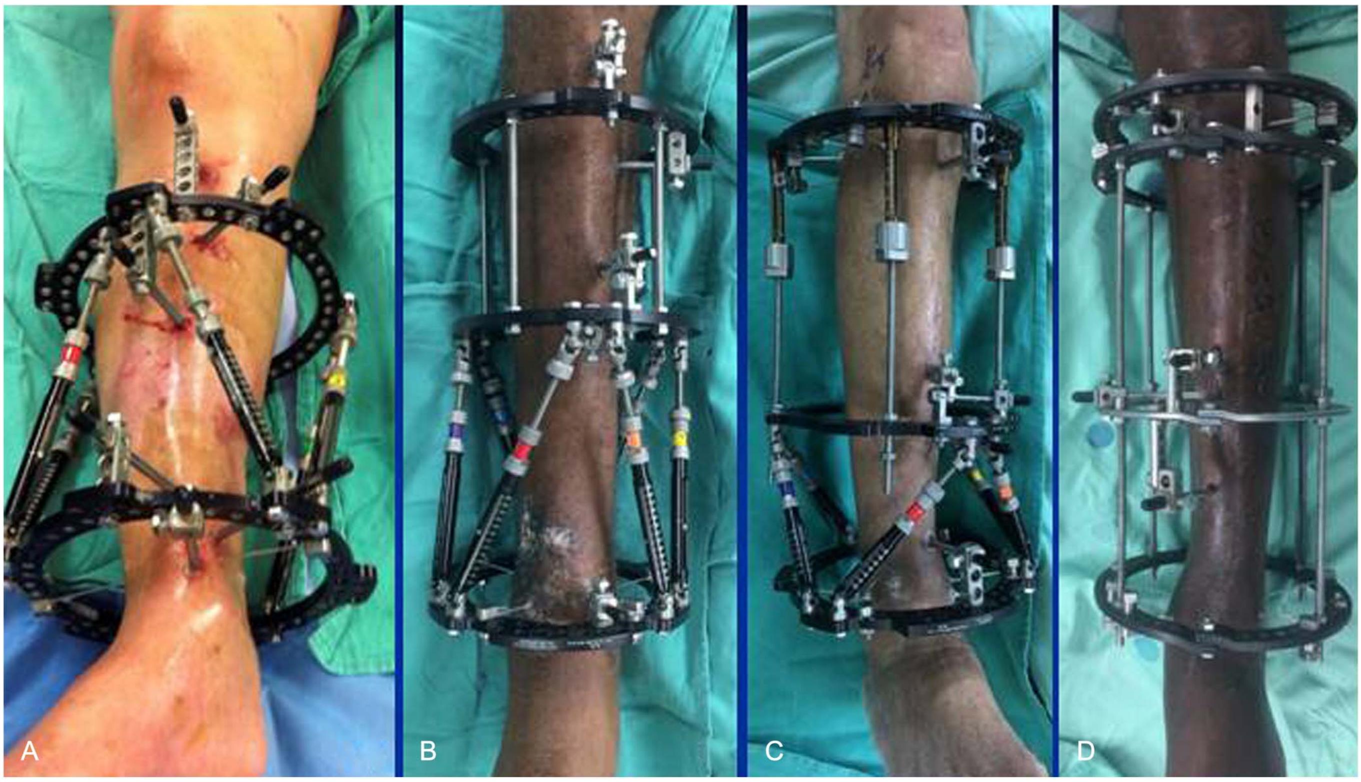

FIGURE 1. A, Open distal tibia fracture with minimal bone loss and adequate distal segment for all HA coated half pin fixation blocks. B, Open distal tibial shaft fracture with a long working length due to a large zone of comminution requiring a 2-ring proximal fixation block for adequate stability. C, Bifocal transport frame with telescopic rods "clickers" proximally and hexapod "Spatial Frame" struts distally. Shaft fixation with half pins and distal fixation with metaphyseal wire cluster and AP half pin. D, Traditional Ilizarov transport frame using stainless steel transport ring with attached square nuts as motors. The shaft is fixed with HA half pins. Distal fixation is with a metaphyseal wire cluster only. A foot plate with calcaneal wires was originally attached to the frame for additional distal fixation, but was removed in clinic 6 weeks after transport docking.

rods that act as a static scaffold to which wires and pins are attached, and fracture reduction is achieved by manipulating the wires and half pins during frame application. The TSF, by contrast, uses the pins and wires for fixation to stable bases on each of the bony segments and fracture reduction is achieved through frame movement. This advance is especially powerful for extraarticular fractures, such as those of the distal tibia, because it provides the unique ability to adjust fracture reduction postoperatively. In addition, it provides greater flexibility in dealing with traumatic wounds and soft tissue defects.

An additional practice-changing advance was the introduction of hydroxyapatite-coated (HA) half pins. Superficial pin infection and pin loosening have long been recognized as the most common problems with external fixation.[17,18] Uncoated half pins tend to loosen rapidly and develop infection when used for definitive care; additionally, unlike wires they are impossible to retension for stability. Animal studies demonstrated decreased pin infection rates and increase pin fixation strength over time with HA pins as opposed to the gradual loss of fixation seen with uncoated pins.[19–21] Clinical data confirming greatly decreased loosening and infection rates with HA pins were first published in 1998[22] and have subsequently been confirmed by many others.[23,24] The improved fixation and longevity of HA-coated half pins is especially important for definitive fracture management for which their use is now considered standard by many surgeons. Factors such as HA pins, type of frame, and construct stability are all especially important to consider in evaluating the literature because of the greater clinically significant variability seen with ex-fix than with other treatment modalities.

EXTERNAL FIXATION VERSUS INTERNAL FIXATION

Ex-fix has been used in tibia fracture treatment for more than a century, but it was the prospective comparison of ex-fix with plates published by Bach and Hansen[25] in 1989 that established the potential advantages of external fixation over plating for the treatment of grade II and III open tibia fractures. This study used monolateral ex-fix, but still achieved superior results in these severe injuries. Li reported on 121 patients randomized to 3 groups including minimally invasive plate osteosynthesis (MIPO), IMN, or monolateral ex-fix combined with absorbable screws.[10] They found no difference in healing rate or ankle function. MIPO had an increased rate of soft tissue infection, whereas the IMN group had increased knee pain and ex-fix had more pin tract infections. There were more deep infections, nonunions, and

FIGURE 2. A, B, 34-year-old man with open distal tibia fracture with simple extension into the tibial plafond. C, D, Postoperative X-ray anatomically reduced plafond with 2.4-mm lag screws beneath a metaphyseal wire cluster and AP half pin. Screws are placed adjacent to joint surface below the 12 mm distance for safe wire passage.

malunions with either plates or IMN than with ex-fix, but none of these reached statistical significance. Sun reported on 44 patients randomized to MIPO or monolateral ex-fix combined with titanium elastic nails.[26] All fractures healed with no difference in healing time. The MIPO group had more superficial wound infections (18%), whereas the ex-fix group had more pin tract infections (9.1%).

The first prospective data on circular fixation go back to 1993 when Tornetta reported favorable results in 26 patients including 9 with extraarticular distal tibia fractures.[27] Until recently, the only comparative studies were retrospective, which are very difficult to interpret due to very substantial selection bias toward the worst injuries receiving ex-fix.[28] However, a prospective, randomized study comparing circular fixation with internal fixation was published by Fadel in 2015.[11] He reported on 40 patients comparing plate osteosynthesis with Ilizarov ex-fix. He reported better outcomes with ex-fix (excellent 10, good 10) versus plating (excellent 2, good 8, poor 6). In addition, the rate of healing was faster at 130 versus 196.5 days and there were no delayed unions or nonunions with ex-fix. However, it should be noted that the plating group was fixed with DCP plates through an anterolateral approach instead of using MIPO ± locking implants. Also, all patients returned to immediate weightbearing as laborers due to lack of other resources.

CIRCULAR EX-FIX TECHNIQUES FOR DISTAL TIBIA SHAFT FRACTURES

Stable Construct for Distal Tibia Shaft Fractures

Distal tibial shaft fractures typically have a long proximal segment with robust cortical bone and a short distal

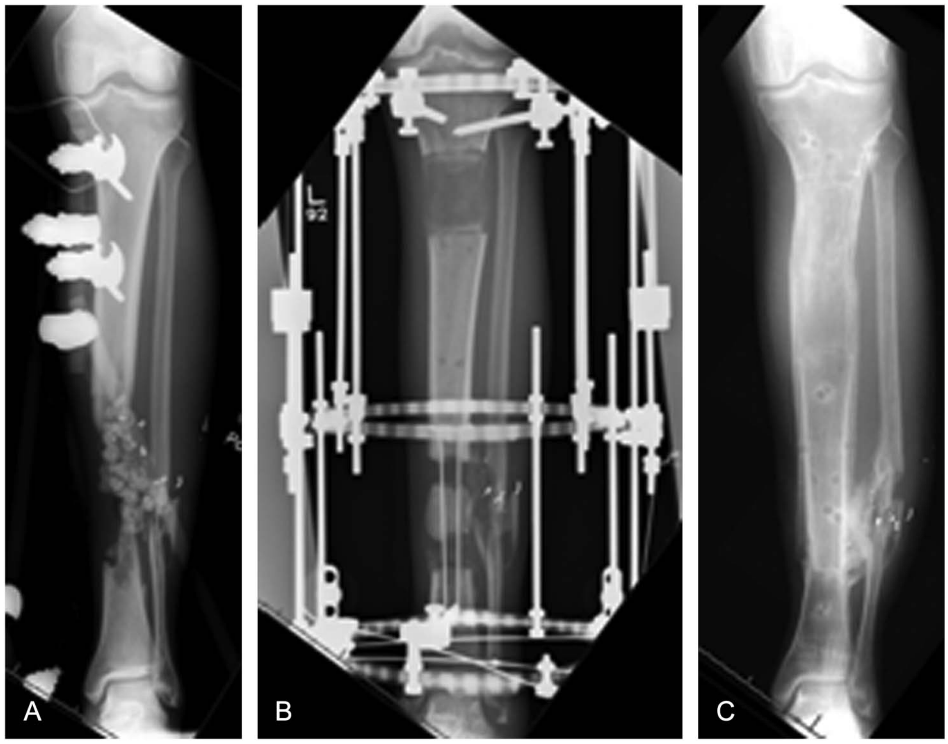

FIGURE 3. A, 35-year-old man s/p GSW from assault rifle with open fracture and massive bone loss. B, X-rays during cable transport. Note there is a cannulated antibiotic cement spacer in the bony defect and each of the bone ends has been prepared for docking with removal of devascularized bony spikes. C, Healed after frame removal.

segment with soft metaphyseal bone. This makes them amenable to a proximal fixation block with all HA half pins spread over a long distance in multiple planes (Figs. 1A, B). It is also mechanically sound to use wires placed at various levels, but patient comfort is much improved with HA half pins. If more robust rings are used, eg, 8-mm spatial frame rings, then one ring may suffice for the entire fixation block assuming the fixation is adequately spread. If smaller and more flexible rings such as 6-mm Ilizarov rings are used, there is a long zone of fracture comminution, or the construct has wires at different levels, then 2 or more rings are necessary (Fig. 1B).

In contrast, the distal fixation block typically achieves adequate fixation using a metaphyseal wire cluster and at least one sagittal plane half pin[29] (Figs. 1B–D). Wires are often preferred in a short distal segment, despite being more symptomatic for the patient, because they are mechanically superior and provide better control of the short segment of soft metaphyseal bone. If there is adequate space for more than one distal half pin, this can be incorporated for additional stability and to provide an option for fewer wires or early removal of the wires[29] (Figs. 1B, C). If there is not adequate space for even a single sagittal plane half pin, then temporarily extending the frame to incorporate the foot should be considered for additional stability[30] (Fig. 1D). The distal block typically is comprised of only one ring unless either the foot is incorporated or 6-mm rings are used for a fracture with a relatively long distal bone segment.

Extension Into the Tibial Plafond

Simple plafond fractures can be treated in a similar manner to distal tibial shaft fractures, but require additional consideration. When nondisplaced fracture lines extending into the joint are present, wires can be applied without the need for internal fixation to address the joint. In this circumstance, it is typically best to assemble the distal fixation block by first applying crossed olive wires to assure no joint displacement occurs. If fracture extensions have joint line displacement, it is best to first achieve an anatomic reduction with percutaneous clamps and then add percutaneous lag screws before placing the distal fixation block. Generally, I prefer 2.4-mm, 2.7-mm, and occasionally 3.5-mm screws for this fixation. These smaller screws are preferred because when placed close to the joint surface, there is adequate space proximally that they will not interfere with wire pathways (Fig. 2).

Associated Bone Loss

Circular fixation is especially advantageous for treating bone loss because it provides the option of distraction osteogenesis. Bone grafting can be used with circular fixation as described by Masquelet[31] in his report on the induced membrane technique. However, distraction osteogenesis can deal effectively with even large bone defects without the morbidity and risk of infection associated with massive bone grafting. In addition, the quality of new bone created by distraction osteogenesis is essentially equivalent to native bone as opposed to the sclerotic bar bone formed with successful bone grafting. There are several factors that may contribute to the decreased risk of deep infection with ex-fix including the absence of hardware at the fractures site, limited insult to the local vascularity, and the tendency for a more thorough debridement of open fracture sites. In fact, more aggressive debridement is often an integral part of optimally

FIGURE 4. A, 21-year-old man shot with an assault rifle causing a complete soft tissue defect across 8 cm of the anterior and lateral compartment. B, Intentional shortening and deformity allows apposition of the muscle bellies that were subsequently skin grafted. C, Clinical photo of leg at time of frame removal after gradual correction of alignment and a 4 cm bone transport.

preparing the bony surfaces for apposition at transport docking. This preparation includes removing the frequently devascularized bony spikes at the fracture edge even though they are attached to the intact bone segment (Fig. 3). In contrast, when bone grafting is planned, these devascularized spikes are typically left in place to minimize the volume of graft that must incorporate to bridge the fracture site. Bone transport with circular fixation can be accomplished with a many different constructs including a transport ring driven by square nuts (Fig. 1D), a bifocal frame with telescopic rods proximally and struts distally (Fig. 1C), or cable transport (Fig. 3). Each of these has advantages in different clinical scenarios, but all are effective.

Soft Tissue Coverage

Circular ex-fix provides great flexibility for dealing with soft tissue loss. When internal fixation is used, it is frequently necessary to deal with soft tissue defects using either rotational or free flap coverage of the defect. This is necessary to cover the fracture site and the hardware used to treat the fracture. It is frequently possible to treat smaller soft tissue defects with local modalities instead of flap coverage when using ex-fix because there is no underlying hardware at risk. In addition, larger defects can be addressed with intentional shortening and deformation to oppose soft tissues.[32] After healing of the soft tissue envelope, correction of the deformity can easily be performed using TSF (Fig. 4). This method frequently eliminates the need for flap coverage or allows for use of a local rotational flap instead of free tissue transfer, which decreases morbidity and allows limb salvage for patients who are poor candidates for free tissue transfer.[33]

Challenges With External Fixation

Circular ex-fix has many advantages, but there are also challenges to consider. The related problems of superficial cellulitis, deep pin infection, and loosening have improved with HA pins, but remain the most common problem for both surgeon and patient. Pin cellulitis causes increased pain, the need for additional clinic visits, and infrequently may require hospital admission for IV antibiotics or pin removal. Most cases of pin cellulitis are successfully treated with a short course of oral antibiotics and do not compromise the final outcome of reconstruction, but the short-term burden for both patient and surgeon is significant. Apart from cellulitis, HA half pins can mature to be painless but discomfort around wire sites generally persists to some degree until removal. This discomfort can lead to greater pain medication use during treatment. In addition, the weight of the frame can be a challenge for some patients, such as the elderly, with limited strength reserve.

Another consideration is the difference in cost with plate and screw or IMN hardware being less expensive than circular ex-fix. The greater cost of caring for complications with internal fixation could easily shift the balance of cost favorably toward ex-fix. However, patient cohorts with low complication rates are likely more economically treated with internal fixation. The final challenge is surgeon training and experience. Almost all orthopaedic surgeons, and especially orthopaedic trauma surgeons, have substantial experience and training with the use of plates and IMNs. However, surgeon training in the optimal use of circular ex-fix is far less adequate with most having limited formal training and experience, and very few have dedicated fellowship training in this area. Experience and skill are important in all areas of orthopaedics, but are especially important in achieving optimal outcomes with circular ex-fix.[34] As a result, it may be difficult for institutions with limited experience to realize its full potential benefit.

BEST INDICATIONS FOR CIRCULAR EXTERNAL FIXATION

Most closed and grade 1 open extraarticular distal tibia fractures can be treated with very good expected

FIGURE 5. A–C, Clinical photo and radiographs of 68-year-old woman with an extraarticular distal tibia fracture in leg with skin changes from chronic edema and diabetes. Extraarticular distal tibia fracture with limited options for intramedullary nail fixation. D, Postoperative AP after application of Taylor Spatial Frame with a foot plate. The foot plate was removed in clinic 6 weeks later. E, F, Clinical photos and X-ray of the injured leg at the time of frame removal 4.5 months after injury.

outcomes using either plates or IMNs. However, outcomes with severe open fractures, poor soft tissue envelope, diabetes mellitus, immunodeficiency, and other comorbidities are not nearly as favorable with internal fixation. In the treatment of severe open fractures, the use of circular external fixation may be preferred because of the potential to limit further surgical insult to the zone of injury, eliminate the possibility of deeply infected surgical implants, and take advantage of the opportunity to treat bone loss or soft tissue defects with distraction histiogenesis. In addition, situations in which there are either chronic skin changes or extensive comorbidities that place the patient at high risk for complication with the use of internal fixation may be better treated with ex-fix. For example, the patient in Figure 5 has chronic skin changes from edema and diabetes overlying the fracture site and few distal options for IMN fixation, making circular fixation a highly preferable solution. More literature is needed to determine what patients most benefit from ex-fix, but as a general rule ex-fix should be considered for patients at high risk of complications with internal fixation.

CONCLUSIONS

Plate and screw, IMN, and ex-fix are all effective treatment options for extraarticular distal tibia fractures. Internal fixation with plates or IMNs is especially advantageous for the treatment of closed and grade 1 open fractures where the risk of complications is low. Circular external fixation offers great flexibility in obtaining anatomic alignment and stable fixation for even the most challenging distal tibia fractures. In addition, it provides advantages in limiting the risk of deep infection, dealing with bone loss, and obtaining soft tissue coverage. For these reasons, circular ex-fix may be the preferred treatment for patients with higher-grade open fractures, a poor soft tissue envelope with limited fixation options distally, and medical comorbidities (diabetes, immune deficiency) with an associated high risk of complications.

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