

## TIBIAL NONUNIONS

### General Considerations

In the treatment of nonunions, the tibia represents an area of special interest since fractures occur relatively frequently. Fractures of the tibia result in nonunion more frequently, relative to other sites, but in our experience these nonunions are more easily treated. Use of the Ilizarov method, when properly applied, results in nearly 100 percent ultimate union. In this special part we will discuss in detail the constructions which are applicable in the treatment of tibial nonunions. For simplicity and clarification, the treatment of nonunions is divided into the following categories :

Monofocal treatment

Bifocal treatment

Trifocal treatment

Bone transport

Partial bone transport

Use of the fibula

### Monofocal treatment

Monofocal treatment isolates treatment to the site of nonunion. The primary indication (as discussed previously) is in the treatment of stiff nonunion. Monofocal treatment has the following variations:

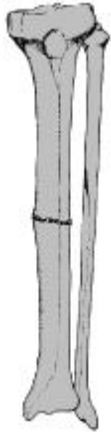
Compression alone

Compression with deformity correction

Compression and distraction

Distraction alone.

### Monofocal in compression



It is best, as in all applications of the Ilizarov Method, to preassemble the fixator frame in order to maximize frame configuration and minimize anesthesia time.

Preassembly of fixator frame:

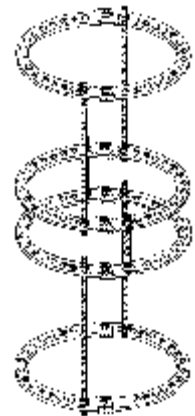
The ring size selection is chosen to allow at least 2 cm of circumferential clearance between the skin and the ring at the limb's maximum diameter. Ideally all rings are chosen to be the same size. Next the rings are

connected with three pairs of threaded rods, anteriorly and posteriorly (as diagrammed), with each pair opposite each other across the rings and alternating on each side of the connector bolts respectively at each level.

The proximal ring is placed at the level of the fibular head and the distal ring is placed 2-3 cm proximal to the tibio-talar joint. The middle rings are located 5 to 6 cm apart ( 2.5 - 3.0 cm on either side of the site of nonunion). This placement of the middle rings provides enough space to

allow for compression at the nonunion site and allows for adequate visualization by radiography.

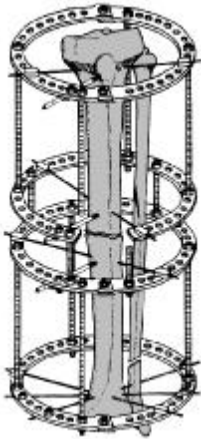
The tibial wires are always placed perpendicular to the tibial axis and this results in a frame which is parallel to the tibial axis. The leg is centered in the rings, but because the tibia is eccentrically located in the leg it is also eccentric in the frame. However, the tibia remains parallel to the frame. Each level (ring) requires placement of one 1.8 mm wires, Except the distal ring where 2 or 3 wire are applied. Every Ring need 1 or 2 Half pins 6 mm diameter to improve the stability; for osteopaenic bone the half pine are coated with Hydroxiapatitis.



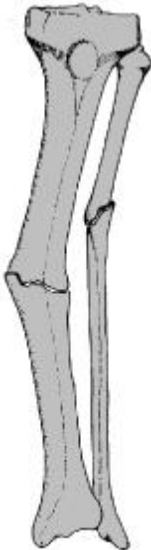
The final step is to resect a 1/2 - 1 cm segment of fibula so that compression can be applied without axial interference being caused by the fibula. At the completion of the operation a compression dressing is placed at the site of the fibular resection and the wire sites are dressed in the usual fashion.

The day after surgery the patient is instructed to begin partial weight-bearing (at 30-40 % of body weight) and continuous progressive compression is begun at the site of pseudoarthrosis. The compression is applied at a rate of 1/4 mm each day for 3 weeks, followed by 1/4 twice weekly for 4 weeks, and thereafter at 1/4 weekly until adequate callous is observed at the site of pseudoarthrosis. The reason that this rate of compression is used is that acute compression might result in necrosis of the fibrocartilaginous tissues which are interposed between the ends of the bones.

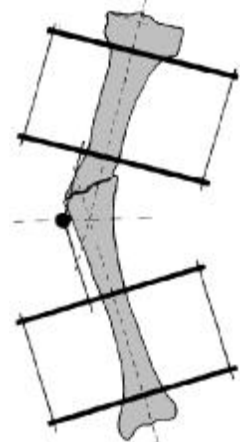
Furthermore, in every repair process of bone there is a period when resorption of the bone ends occurs, so compression must be continued to maintain stability.



### Monofocal treatment with deformity correction.



When a tibia has a deformity at the site of nonunion, the treatment approach is as follows : After an evaluation to determine the true plane and extent of the deformity a frame is preassembled with two blocks (2 rings per block) on each segment. The blocks are connected by a pair of hinges with the center of rotation at the apex of deformity (convex side of deformity) When the deformity includes translation, the hinges are located with the center of rotation at the crossing point of the axis of the segments. After the placement of the frame over the leg, two reference wires are placed (one proximally and one distally) as was previously described. These two wires are then tightened without tensioning and centralization on the limb is verified. The proximal block must be parallel to the proximal segment and the distal block parallel to the distal segment. Proper location of the hinges must be verified. Ideally an x-ray is taken to check these parameters. Only after these parameters have been met are these initial wires tensioned. When the alignment is achieved, The connection

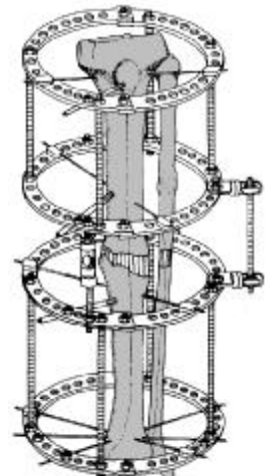
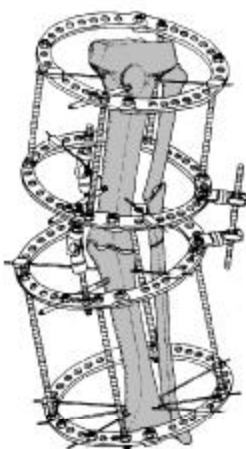


between the frame and the bone is applied with other wires and Half pins (see the Atlas)

To finalize the frame, threaded rods are placed laterally on each block to increase frame stability and one pushing system is applied on the concavity side connecting the two blocks to progressively correct the deformity.

The final step is to operate on the fibula. When the fibula lies on the side of convexity (valgus and procurvatum), a fibular resection must be performed to avoid opposition to correction. When the fibula lies on the side of concavity (varus and recurvatum), it is adequate to perform an osteotomy; as much as is possible, the level of the fibular procedure should lie at the level of the deformity. At the end of the procedure, dressings are placed in the usual fashion.

On the fourth postoperative day, distraction is begun through the pushing system. This is achieved with a



rhythm of 3 per day such that a diastasis of about 1 mm per day is produced between the ends of the bones on the side of the concavity.

In the ideal situation an opening wedge will be created from the side of concavity which is filled with regenerated bone. At this point a nonunion with deformity has been transformed into a more simple nonunion without deformity and treatment can proceed correspondingly (replacing the pushing system and hinges with four threaded rods). Furthermore, to encourage more rapid consolidation (after correction of the axial deformity), and to increase internal stability, it is possible to proceed with axial compression (as previously described).

### **Bifocal**

Bifocal technique is that which focuses the attention of the surgeon at two sites, one at the site of nonunion and the other at a site of Osteotomy. As was described in the general chapter of nonunion, osteotomy and the subsequent distraction not only stimulates the regeneration of new bone, but also increases the vascularity of the entire treated segment. For this reason, bifocal treatment is indicated for the treatment of lax-hypotrophic nonunion where vascularity of the bone is deficient. For historical reference, Paltrinieri, described a more primitive technique of parafocal osteotomy to stimulate callous formation and vascularity in cases of nonunion.

### **Preconstruction.**

The frame consists of 3 blocks interconnected with block consisting of two rings on the shorter nonunion segment, one epiphyseal block of 2 rings on the longer segment and a one ring block on the intermediated segment created by corticotomy. The two rings of the epiphyseal blocks are connected with either 2 or 3 cm sockets depending on the size of the patient (preferably utilizing 3 cm sockets). The proximal and distal most rings of the frame, should be (as always) at the head of the fibula proximally and 2-3 cm proximal to the tibia-talar joint distally. The frame is placed over the limb and initially two reference wires are placed, one proximally and one distally (perpendicular to the respective nonunion segment) and utilizing these two wires the frame is centralized on the limb (as previously described). Since we are dealing with lax nonunions, the bones are mobile and it is not always easy to align the nonunion segments. Therefore, after centralizing the frame, radiographs are taken to assess the alignment of the bone ends. Then two additional wires are placed on the two rings adjacent to the pseudoarthrosis. With these wires it is possible to align the bone ends. Once the correct alignment has been achieved, the wires placed up to this point are tensioned. Next the frame is completed by insertion and tensioning of the remaining wires and half pins to increase stability. Frame stability is complete by adding 4 rods, an osteotomy of the fibula is performed. Usually this is done distally. Ten or fifteen days after surgery, transport of the intermediate segment is begun at a rate of 1/4mm, 2 to 3 times per day. The slower rate is used initially until evidence of new bone formation is seen radiographically, after which the rate may be accelerated. After contact between the bone ends is achieved, distraction at the osteotomy site is discontinued and compression at the level of nonunion is continued at a rate of 1/4 mm per day for three weeks, followed by a rate of 1/4 mm one to two times each week until callous formation is seen at the site of nonunion (traditional technique). Actually, in our department we prefer to apply bone graft at the docking site at the time of contact to achieve more rapid consolidation:

### **Removal of Apparatus**

Regarding the removal of the fixator apparatus, the surgeon needs to pay close attention to two important factors, those of consolidation at the site of nonunion and maturation of the regenerate bone. Therefore, double attention must be paid to both the site of nonunion and the site of pseudoarthrosis when dynamizing the frame (as was previously described in the chapter of lengthening).

### Brace Application

When after dynamization the stability of the nonunion site and consolidation of the regenerate bone are both felt to be adequate, the apparatus is removed. Following removal of the apparatus and proper dressing of the pin sites, a brace is applied that permits movement of the joints and weight-bearing through the treated segment. The amount of weight-bearing is individualized for each patient. Usually partial weight-bearing is allowed initially and this is gradually increased to full weight-bearing. The use of crutches is recommended for at least two to three weeks. The type of bracing is determined by the site of least stability.

Bracing is selected to include the knee, ankle, or both depending on the segment of the bone which is being protected. If proximal site of either nonunion or regenerate bone needs protection, a hinged knee brace is used. If on the other hand the site which requires protection is distal, a functional leg brace with a hinged ankle is utilized. It is the judgement of each surgeon to direct the choice of orthosis and its duration of wear. Remembering in general that prudence never compromises a good result.

### Bone Transport

Bone transport is a variant of bifocal treatment. It is used in cases of bone loss or in cases of hypotrophic nonunion when the surgeon determines that resection of bone is necessary.

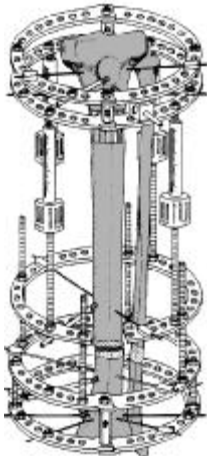
### Bone Loss



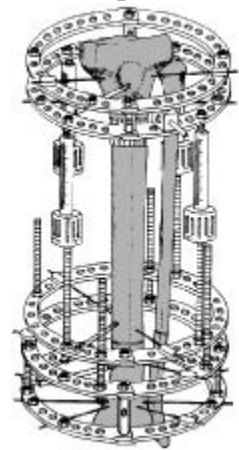
Frame assembly is similar to that used in simple bifocal. A simple bifocal frame consists of one epiphyseal block, on short segment, one intermediate block (one ring alone, one ring plus wire, one ring plus drop half pin, two rings), and one epiphyseal block on the short nonunion segment (fig.43). Application of the frame has been described to realign the bone ends. It is important to not only realign the angular deformity, but also to obtain proper rotational alignment. Rotational alignment must be verified using the anterior tibial crest and not relying on the relationship of the foot to the patella. In some patients, a preoperative subtalar or forefoot deformity may mask the true axis of the tibia. When the correct axis is achieved and the frame made sufficiently stable an osteotomy is performed with the usual technique and in the timing previously described lengthening at the site of osteotomy and compression at the site of nonunion is performed.

The rate (1/2 - 1 mm per day) will be the same at the sites of lengthening and compression. Because the length of the limb is not changed and only internal transport is performed, an osteotomy or resection of the fibula is not necessary.

During treatment regenerate bone forms at the site of osteotomy (internal lengthening) and the ends of the bone at the site of nonunion are brought into contact. At this point it is necessary to evaluate the contact of bone ends at the site of nonunion.

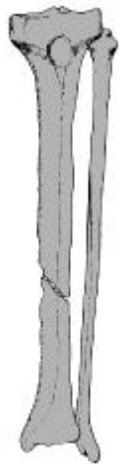


If the bone ends have satisfactory alignment and contact, it is sufficient to maintain interfragmentary compression for consolidation to occur. If on the other hand there is insufficient contact between the bone ends, or the bone ends tend to slide past one another, or the bone ends now appear sclerotic with loss of the medullary canal, it is necessary to intervene surgically. A resection of the bone ends is then performed to provide adequate opposing surfaces of healthy, vascularized bone and to augment the internal stability of the system. The procedure is performed in the following sequence: The site of nonunion is opened and the ends are resected with an oscillating saw, or preferably with a gigli saw or rongeur; if the medullary canal is sclerotic, it is reopened using a drill. If the

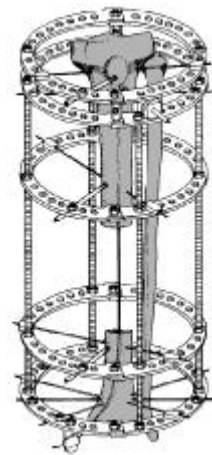


resection of bone does not exceed 1 - 2 cm, it is reasonable to resect a comparable length of fibula and perform an acute shorting to bring the bone ends into contact. Additionally, autogenous bone graft can be utilized and is generally obtained from the iliac crest. Following closure of the wound and placement of dressings, progressive continuous compression at the pseudoarthrosis site is resumed in the manner and at the rate previously described. Lengthening at the osteotomy level is continued until the complete elimination of discrepancy created by the resection.

### Infection with resection

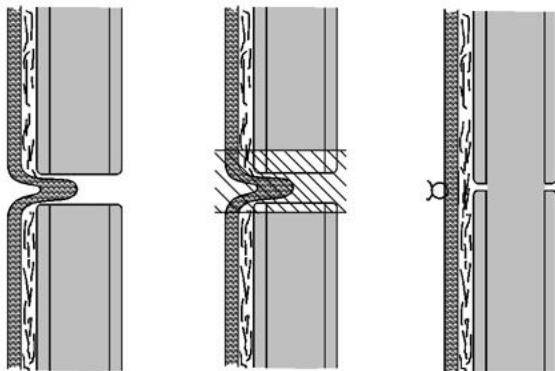


The main way to treat infected nonunion is to perform an open resection of infected bone and follow with bone transport. In preparing the preassembled frame the ring of the short segment which is adjacent to the pseudoarthrosis and the ring of transport segment are left free on the frame so that they may be placed at their ideal locations following the resection of bone. The site of infected nonunion is opened and an adequate resection performed. An adequate resection is one where the sclerotic bone is removed and bleeding is seen at the ends of the bone. The ideal placement of the rings spanning the site of pseudoarthrosis is 3 cm proximal and distal from the resected bone ends, for further stability of the transport segment a wire is inserted intramedullary, this wire is called the centralizing guide wire. This wire represents a rail along which the transport segment can slide so that the end of the transport segment is in good contact with the opposite bone end. A fibular osteotomy is not necessary. The wound is closed to cover the bone ends leaving 2-3 cm open into which is packed iodofoam gauze.



At this point the field is resterilized and a cover is placed over the site of resection. Broad spectrum antibiotic coverage is continued for 10 days after surgery. Target antibiotic coverage is unnecessary, because after resection of the necrotic, infected tissues, the immune response is able to arrive at the site of pseudoarthrosis. Wound dressings are changed daily, removing the iodofoam gauze and replacing the iodoform gauze only after thorough irrigation of the wound.

At the end of transport an additional operation is performed to resect and freshen the ends of the bones as previously describe. In this case bone graft placement is discouraged, unless there is no remaining evidence of infection and the condition of the soft tissues is ideal.



Another event common with bone transport is rapid healing of the skin resulting in invagination of the skin between the ends of bone. When this occurs the only solution which allows rapid elimination of the problem is to perform a transverse resection which includes the invaginated skin, and the intervening soft tissues. In addition, the opportunity to freshen the bone ends is taken. In this case the incision is made transversely and any wound gap is not considered a problem, as this will close spontaneously during the continuing bone transport.

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### Trifocal Technique

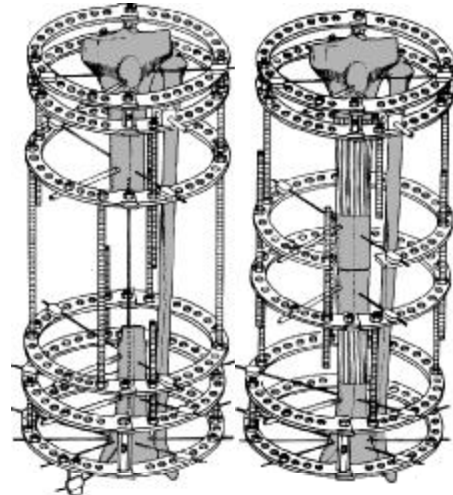
Trifocal technique means that the surgeon concentrates his attention at three sites. Since it is not possible to accelerate the rate of lengthening at one osteotomy site, the solution is to perform a osteotomy at a second site so that the rate of internal lengthening can be effectively doubled. This allows the rate of approximation of the bone ends at the site of nonunion to be doubled and shorten the

time to consolidation. There are two variants of trifocal treatment that can be defined as : converging trifocal and tandem trifocal.

### Converging Trifocal.



This technique is well suited for defects which are mid diaphyseal. The preconstructed frame consists of two epiphyseal blocks (one proximal and one distal) and two intermediate rings, one located 3 cm proximal and one 3 cm distal to the nonunion gap. After the preconstructed frame is placed over the leg, two reference wires are placed at the levels of the most proximal and distal rings. Next the frame is centralized and the reference wires tensioned. When placing the wires on the two intermediate rings, any axial deformity is corrected. Following this the frame stabilization is completed with the usual wires and half pins configuration. When the bone loss is a result of resection, it is also possible to

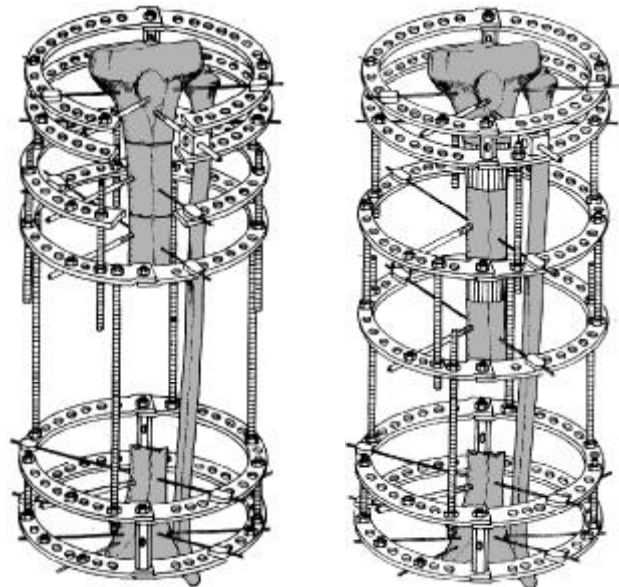


insert an intramedullary guide wire. Two osteotomies are created, one at the level of the proximal metaphysis and one at the level of the distal metaphysis. After a latency period, internal lengthening can be initiated at the two osteotomy sites. Therefore, with this maneuver, the bone ends are approximated in one half the time and each respective regenerate segment half as long as compared to bifocal treatment. Because the time to consolidation of a segment of regenerate bone is inversely proportional to the length of the regenerate segment, it is intuitively obvious that two shorter segments will consolidate more rapidly than one long segment.

### Tandem Trifocal Technique



The tandem variant of trifocal technique is most useful when one of the bone segments is much shorter than the other. In the examples, the preconstructed frame consists of a distal block with one ring 1 to 2 cm proximal to the tibio-tarsal joint and the other ring located 2.5 cm distal to the area of bone loss. Proximally, an epiphyseal block is placed as previously described. The two intermediate rings are placed such that the distal intermediate ring is placed 2.5 cm proximal to the site of bone loss and the second



intermediate ring is placed midway between the proximal epiphyseal block and the distal intermediate ring. The preassembled frame is placed over the leg, reference wires placed, the leg centralized within the frame, and the reference wires tensioned. Taking care to correct the axial alignment of the tibia, the remaining wires and half pins are placed to complete the stabilization of the frame. Two osteotomies are created, one metaphyseal osteotomy distal to the proximal epiphyseal

block and one midway between the two intermediate rings. After a latency period, internal lengthening is initiated at a rate of 1/2 to 1 mm per day at each osteotomy site. This results in a rate of approximation at the nonunion site equal to the sum of the rates of internal lengthening at the osteotomies sites, effectively halving the time required for closing the bone gap. The final result is similar to that achieved using the diverging variant, except that the two intermediate rings will be traveling in tandem.

