COMPLICATIONS

Knee Pain

Anterior knee pain was present in 55%

Affects younger more than older patients

A significant number of the patients with anterior knee pain had pain with kneeling [90%]

They also found no significant correlation between proximal protrusion of the nail and knee pain, but they suggested that there might be an association with a patellar tendon splitting approach as compared to a parapatellar insertion with a higher number of patients (77%) having pain with the patellar tendon splitting approach as compared to the paratendinous approach (50%).

They found that 80% of their patients required nail removal and that the 50% had their pain either completely or partially relieved.

In a prospective randomized trial, Toivanen randomized 50 patients to receive an intramedullary nail through either a paratendinous or transtendinous approach. They then followed these patients for an average of 3 years. They found no significant difference in anterior knee pain between the transtendinous to the paratendinous approach: 67% with the transtendinous approach and 71% with the paratendonous approach.

In a study using ultrasound to assess the patellar tendons of patients who had had an intramedullary nail, Vaisto compared those with anterior knee pain and those without. They found no significant differences in the ultrasonographic appearance of the tendon and specifically found no differences in patellar tendon blood circulation, calcification of the patellar tendon, or granulation tissue. This suggests that the etiology of anterior knee pain following intramedullary nailing is still unclear. A follow-up study by the same authors found that anterior knee pain symptoms in a significant number of patients might disappear between 3 and 8 years.

Neurologic Damage

The most common neurologic injury following intramedullary **tibial** nailing is injury to the peroneal nerve.

The prevalence of neurologic injury to be approximately 30% in a retrospective review of 60 patients treated with a reamed intramedullary nail, but they stated that the majority were minor sensory neurapraxias with 89% of these being transient and resolving within 3 to 6 months.

In a prospective series of 208 patients with a **tibial** shaft **fracture** treated with a reamed intramedullary nail, 5.3% were seen to develop peroneal nerve dysfunction postoperatively. Seen in closed **fracture** caused by a varus force with no evidence of compartment syndrome. The majority showed good recovery after 3 to 4 months. Some patients still had residual symptoms resulting in weakness of their extensor hallucis longus.

Thermal Necrosis

Leunig described thermal necrosis in 3 patients, all of whom had narrow intramedullary canals. They found that after reamed intramedullary nailing, these patients developed pretibial blistering and further went on to develop osteomyelitis. They attributed this to thermal necrosis from tight reaming of the canal. Thermal necrosis has also been implicated in the development of postoperative infection following intramedullary nailing in another series of reamed nails.

To minimize the risk of thermal necrosis, it is suggested that a tourniquet should not be used and reaming should not be forceful.

Compartment Syndrome

50% the **fracture** associated with syndrome is related to fracture of the **tibial** diaphysis. Compartment syndrome was more common in younger men under the age of 35. Incidence of syndrome following **tibial** shaft fractures was 4.3% [McQuen]

Compartment Pressure Monitoring is useful in unconscious patients but not required routinely in a conscious patients.

A good argument can be made for monitoring those patients who are potentially at risk for developing compartment syndrome or who are not able to respond appropriately to pain or clinical examination. The Stryker compartment pressure monitor.

Harris randomized 200 extra-articular **tibial** shaft fractures into monitored and unmonitored groups for compartment pressure measurement. The monitored group received continuous compartment pressure monitoring for 36 hours. They had five cases of compartment syndrome in the nonmonitored group and no cases in the monitored group of patients; however, within the monitored group of patients, there were 18 patients with a ΔP of less than 30 mm Hg.

Compartment Syndrome and Intramedullary Nailing

Experimental evidence has suggested that intramedullary nailing is associated with an increase in compartment pressure. Some surgeons attribute this to the process of reaming. However, clinical evidence suggests that the compartment pressure may be raised by the reduction of the **fracture** and passage of the nail as opposed to differences in reaming.

Nassif conducted a randomized trial comparing the effect of reamed and unreamed intramedullary nailing on intraoperative compartment pressures. They found that highest pressures occurred during reaming in the reamed group and during nail insertion in the unreamed group. However, there was no significant difference in pressures between the two groups.

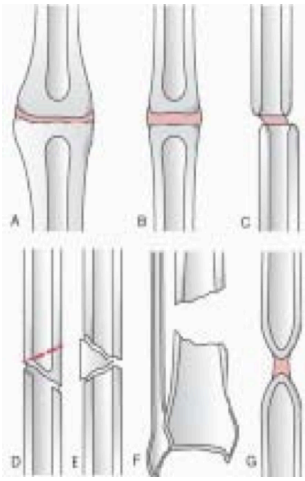
Malunion

There is no good definition as to what constitutes malunion in **tibial** diaphyseal fractures. Boucher defined malunion as greater than 10 degrees of rotation, 5 degrees of varus or valgus, and greater than 10 degrees of antecurvatum or recurvatum. They found no significant correlation between the subject's response to any of the three scores and **tibial** malalignment in any plane at a follow-up time of 5.5 years.
Full-length **tibial** views and standing leg views should be obtained to assess the deformity and the overall alignment of the limb. CT examination to include the knee proximally and the ankle distally may help assess the degree of angular and rotational deformity. There is no good evidence as to the best method of operatively correcting a malunion. The options of using an intramedullary nail, plate, or external fixator should be individualized based mainly on the location and severity of the malunion.
If the malunion is rotational, transverse osteotomies may be necessary to allow for derotation of the tibia. If shortening is present, transverse or step-cut osteotomies using a nail and bone graft or lengthening over a nail or with an Ilizarov type frame may be required. We prefer to correct malunions at the site of the actual malunion rather than correct the angular deformity proximal or distal to the malunion.

In varus or valgus malunions, closing wedge osteotomies have the benefit of providing good bony contact but they do potentially shorten the limb. Opening wedge osteotomies have the benefit of either preserving limb length or lengthening it to

tibial correction. Commonly use locked plate fixation or intramedullary nailing for distal or proximal diametaphyseal malunion fixation and tibial nailing for diaphyseal malunion.

Nonunion

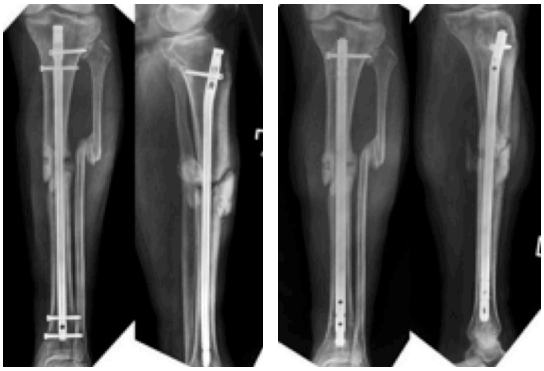


Nonunions have traditionally been classified into three basic types: atrophic, oligotrophic, and hypertrophic nonunions.
Classically hypertrophic or oligotrophic nonunions represent a failure of stability while atrophic nonunions represent both a failure of stability and/or biology.
Nonunions may also be classified as septic or aseptic.

The average elapsed time prior to the establishment of a delayed union was 3.5 +/– 1.4 months, and the average time for a **fracture** to be labelled a nonunion was 6.3 +/– 2.1 months.

Weber's Types:
A. Elephant's foot. **B.** Horse's foot. **C.** Oligotrophic. **D.** Dystrophic (torsional) wedge **fracture**. **E.** Necrotic (avascular segment). **F.** Bone defect. **G.** Atrophic.

Court-Brown reported that the incidence of nonunion for closed **tibial** shaft fractures ranged from 0% to 3.5% depending on the Tscherne grading of injury



c
Nonunion treated by exchange nailing.
a

Clinical and Radiologic Signs

The clinical signs of an established nonunion include pain, motion, and swelling at the **fracture** site.
An examination of the overlying skin and soft tissues should be undertaken looking for any draining sinuses or other clinical signs of infection
The overall alignment of the leg for angular and rotational malalignment and limb-length discrepancies.
Look for contractures.
Radiologically, the nonunion may present as a persistent **fracture** line or with a lack of bridging callus in of three out of the four cortices on the anteroposterior and lateral radiographs.
The radiographs may also show hardware breakage or failure
CT scans or bone scans may also be useful.

Predictors of Nonunion

Mechanism of injury, degree of soft tissue injury, diabetes, alcohol consumption, smoking history, surgical delay, the use of steroids or anti-inflammatory medication, vasculopathy, age, and gender.

Bhandari: used both univariate and multivariate regression modeling: These are low risk, where there are no risk factors and a 4.4% prevalence of nonunion, moderate risk, where there is one risk factor and an 18% prevalence, high risk, with two risk factors and a 47% prevalence, and very high risk, with three risk factors and a 94% prevalence of requiring reoperation to promote bone healing. The only modifiable risk factor suggested in the multivariate analysis was cortical continuity.

Treatment

Aseptic Nonunion.

Intramedullary nailing
The technique of intramedullary nailing of **tibial** nonunions is slightly more demanding as passage of the nail past through fibrous nonunion site may be difficult. The canal may need to be opened at the nonunion site with an awl being passed proximally and distally from the nonunion to allow for the subsequent passage of the power reamers and the nail. It is important that the initial power reamer is an end cutting reamer to facilitate passage through the nonunion. If there is any **tibial** malalignment, a fibular osteotomy will probably be required to permit

Dynamization

Dynamization of an intramedullary nail is the process by which a statically locked intramedullary nail is converted to one that is dynamic. The principle is to increase compression at the **fracture** site with weight bearing. It is a procedure that is associated with low morbidity, and it is used to encourage union. It is, however, limited in its scope and is not recommended in unstable **tibial** nonunions or if there is a segmental defect. Clinical evidence of its usefulness is very limited.

Nonunion with Segmental Tibial Defects

Treatment Algorithm [Keating]

A 6 cm bone is the practical limit for the use of autogenous bone graft techniques.

It has been shown that defects of less than 2 cm associated with less than 50% circumferential bone may heal with exchange nailing.

Defects of less than 4 to 6 cm are amenable to treatment with autogenous bone grafting after the wound has healed, and there

Recent work on osteoinductive proteins, such as bone morphogenetic protein (BMP)-2 or BMP-7, suggests that there may be role for their use as inductive agents.

When defects are larger than 6 cm, individualized treatment plans are necessary. The main treatment choices

1. Repeated bone graft
2. Vascularized bone transport techniques
3. Techniques incorporating the Ilizarov or other subsequent lengthening, or bone transport 4 cm to 12 cm.

Paley assessed their series of 19 patients, with a mean **tibial** defect of 10 cm, treated with Ilizarov bone transport techniques. Union was achieved in all patients, but 10 patients required bone grafting or débridement of the bone ends at the docking site and the average time in the Ilizarov frame was 16 months

Infected Tibial Nonunion

Type A being infected nonunions of the long bone with nondraining or quiescent infection with or without an implant.

Type B cases were an infected nonunion of the long bone with a draining or active infection.

The diagnosis of infected nonunion is often based on clinical grounds.

Current imaging, in the form of nuclear medicine scanning, is usually undertaken. Two scans are often used: the technetium labelled phosphate bone scan and the indium-111-labelled white cell scan.

1. High dose intravenous antibiotics for a week followed by oral antibiotics for 6 to 8 weeks.
2. Treatment with exchange nailing with reaming of the intramedullary canal was undertaken.
3. Extensive débridement as well as reconstruction of the bone and soft tissues.

Two Stage Revision

The first stage is an extensive and thorough débridement. All necrotic and dysvascular bone is removed as well as obviously necrotic and devitalized tissue. If an intramedullary nail has been used, we routinely overream the intramedullary canal and undertake a thorough lavage. Enlarge the locking screw holes to ensure a satisfactory flow of lavage fluid through the medullary canal. Place an antibiotic cement nail in the intramedullary canal as described by Paley

Second stage: Definitive nailing

Plastic surgical team has been using an anterolateral thigh free flap for the reconstruction of soft tissue defects.

Often, infected **tibial** nonunions have some inherent stability, and if this is the case we do not use any internal fixation initially but prefer to immobilize the patient in a functional brace or cast leaving the knee free to allow mobilization. If, however, stability is required, an indwelling cement filled intramedullary nail and cement spacer often imparts adequate stability that can be supplemented with a cast as necessary.

ADJUNCTS TO FRACTURE HEALING

Bone Stimulators

The current options for bone stimulators include low-intensity pulsed ultrasound, electrical stimulation, and extracorporeal shock wave therapy. These bone stimulation devices all purport to accelerate **fracture** healing and to aid in the healing of nonunions.

Electrical Stimulation

Recent studies suggest that electromagnetic stimulation has an impact on many cellular pathways, including growth factor synthesis, proteoglycan and collagen regulation, and cytokine production. These pathways may enable bone to respond to changing environments, ultimately stimulating the calcium/calmodulin pathway thus enhancing bone healing.

A meta-analysis of the effect of electrical stimulation on **fracture** healing identified 10 randomized trials.
Evidence from four trials reporting on 106 delayed or nonunited fractures demonstrated
an overall pooled relative risk in favor of electrical stimulation, but was not statistically significant.

Osteoinductive Proteins

BMPs belong to the transforming growth factor beta superfamily of signalling proteins.
The pooled estimate of effect on the rates of union was in favor of BMP treatment. With regards to functional outcomes, the methodology precluded pooling of the results.

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