J Orthop Sci (2006) 11:657–669
DOI 10.1007/s00776-006-1061-6

JOURNAL OF
ORTHOPAEDIC SCIENCE

Instructional lecture

Intramedullary nailing of femoral and tibial shaft fractures

George W. Wood II

Department of Orthopaedic Surgery, University of Tennessee — Campbell Clinic, 1211 Union Avenue, Suite 510, Education Office, Memphis 38104-3403, TN, USA
Elvis Presley Memorial Trauma Center, Memphis, TN, USA

Introduction

Intramedullary nail fixation has become the standard of treatment for both femoral and tibial shaft fractures, with reported union rates for the femur approaching 97%.[1,2] Because of this success and the ease of intramedullary nailing, the indications for this procedure have been expanded to include the periarticular portions of the long bones. Compared to diaphyseal fractures, periarticular long-bone lower extremity fractures are associated with more frequent complications and poorer outcomes. Intramedullary nail fixation of these fractures, although technically demanding, may be less traumatic than conventional techniques, especially in critically ill patients, and can obtain similar outcomes.[3]

Patient evaluation

In any patient with multiple trauma, the general medical status is of paramount importance. An adequate determination of the patient's previous and present medical problems is essential to determine the appropriate fracture treatment. Medical problems such as cardiopulmonary disease, vascular disease, and immune disorders need to be considered as well as social factors such as addiction and homelessness. Factors that have been shown to affect the outcome of fracture treatment include multiple medical problems. Cardiopulmonary problems may delay mobilization, metabolic problems such as diabetes affect healing and increase the risk of infection,[4] and vascular disease in the extremities slows healing of bone and soft tissue. Osteoporotic bone is associated with implant failures. Altered immune states and poor nutrition can lead to wound breakdown and secondary infection.[5] Neurologic problems such as paralysis slow ambulation, an aid to healing. Psychiatric diseases may result in decreased patient compliance.[6]

Social factors also affect outcome. Use of tobacco slows fracture healing.[7,8] Addictions to alcohol and street drugs impair patient compliance and increase the risk of complications. Poor family support also may limit patient compliance and the ability to participate in physical therapy or comply with weight-bearing restrictions. Nonsteroidal antiinflammatory medications have been shown to delay bone healing. Ibuprofen blocks the bone healing process, which does not recover after stopping the medication.[9]

We currently are evaluating a classification of patients' "host status" as a predictor of the outcome of complicated fractures. Host status categories include three levels, designated "A," "B," and "C." Host status "A" indicates no negative findings. "B" status indicates at least one medical or social factor negatively affecting outcome, such as smoking, bipolar disease, or incarceration. "C" host status indicates more than one negative factor. An example of a "C" host is a patient with bipolar disease who smokes or has hepatitis C. This determination may help when choosing the proper therapy for complicated fractures (Table 1).

We believe that "A" host patients who are medically stable should have the most definitive fixation regardless of the situation. "B" hosts are more prone to problems and may require more attention to avoid complications. "C" hosts are the most complication prone and tend to have wound and fixation problems. This is especially true with regard to leg and ankle injuries. We tend to avoid extensive lower extremity surgery in these patients. Percutaneously locked intramedullary nail fixation is a good option in this difficult patient group.

The initial evaluation of the patient is essential for appropriate planning of fixation with intramedullary nails. In accordance with the Advanced Trauma Life

Offprint requests to: G.W. Wood
Received: March 23, 2006

Table 1. Host status

Definition	Action	Expected outcome
Host A		
No medical problems	Aggressive fixation and early motion	Rapid healing
No social problems		Minimal complications
Nonsmoker		Maximal outcome
No drug abuse		
Compliant		
Host B		
One significant medical or social problem controlled *or*	Percutaneous procedure preferred	Slower healing (1.5–2.0 times normal)
Smoker *or*	Early mobilization	Higher risk of complications
Noncompliant		Less favorable outcome
Host C		
More than one significant medical or social problem *and*	Percutaneous procedure	Very slow healing (1.5–2.0 times normal)
Smoker	Early mobilization	Early bone graft in C type (tibia)
	Frequent follow-up	Complications expected

Table 2. AO-OTA fracture classification

Type	Mechanism	Fracture pattern	Comminution	Complication potential
A	Low-energy	Transverse oblique	Minimal	Low
B	Intermediate energy (low-speed MVA)	Butterfly	Moderate	Intermediate
C	High-energy (high-speed MVA, fall from height, pedestrian MVA)	Segmental	Severe	High

AO-OTA, AO-Orthopaedic Trauma Association; MVA, Motor vehicle accident

Support (ATLS) protocols, cardiovascular and respiratory systems function must be stabilized before fixation of fractures can be considered. The ATLS secondary survey involves the neurologic, musculoskeletal, and integumentary systems. Although these usually are not life-threatening injuries, they frequently result in significant late physical disability.

High-risk patients should not be subjected to extremely lengthy or complicated surgeries. Severely injured patients do not tolerate excessive blood loss or lengthy procedures, so rapid resuscitation and stabilization may be the best initial option. Neurologic problems may delay surgery, as may transient hematologic disorders.[1,10] In these situations, we prefer to delay definitive fixation and apply spanning external fixation if the patient is stable enough to go to the operating room;[11] if not, we use standard skeletal traction or quick external fixation that is applied in the emergency room.

After the primary and secondary surveys, radiographs and computed tomography (CT) scans are obtained to determine the severity of the skeletal injury. Usually the mechanism of injury determined in the initial evaluation gives a hint of what to expect. The AO/OTA fracture classification (Table 2) is useful for quantifying the severity of the injury and to help with the proper selection of treatment options and operative techniques.[12]

At our trauma center, 75% or more of periarticular fractures are AO/OTA type C injuries. This means that great care and planning are needed to avoid complications. These periarticular fractures are treated initially with spanning external fixation so plans can be made for definitive treatment. Measurement, direct or electronic, of the bony canal, the length of the bone, and, most important, the length of the lateral cortex where the locking screws will attach is an essential part of the analysis and preparation. Most fractures require at least 3–5 cm of lateral cortex for locking purposes.

Additionally, radiographs should be reviewed carefully to look for extension of the fracture. If there is any question that this may be present, CT scanning of the joint is necessary. Ideally, it shows a tubular structure that can be easily reconstructed. Anterior and posterior defects in the cortex may allow nail motion and make the use of blocking screws difficult if not impossible. CT scanning of the joints after external fixation has been applied can identify these problems more accurately.[13]

If a ligamentous injury is suspected, a magnetic resonance (MRI) scan can be obtained.[14] Waiting until after

Table 3. End-of-procedure checklist after femoral or tibial nailing

Check for	Method	Risk
Compartment syndrome	Manual measurement	Thigh, leg
Knee ligament injury	Manual — femur	30%
	Comparison — tibia	20%–60%
	MRI	
Shortening	Manual	Femur > tibia
Rotation	Manual	Femur > tibia
	Radiography	
Occult femoral neck fracture	Radiography	Up to 10%
	Fluoroscopy	

definitive treatment and intraoperative knee examination before determining whether an MRI is necessary eliminates the problems associated with external fixators and MRI (Table 3). Ligamentous injuries usually can be repaired after fracture healing.

Bone and cartilage healing

Bone healing requires blood supply and muscle attachment. In the femur, the medial and lateral circumflex arteries ringing the femoral neck can be injured by fractures at the femoral neck or by instrumentation that wanders into the region of the circumflex. Although this is important in pediatric patients, in adult patients with both femoral neck and shaft fractures the incidence of osteonecrosis of the femoral head is far less than the more than 30% reported after isolated femoral neck fractures in elderly patients.[15]

The femur has a rich blood supply from perforators and the profunda extending down the leg. At the level of the femoral condyles, the medial and lateral superior geniculate vessels supply blood to the region of the knee and the skin above it. Damage to both of these vessels may result in skin loss anteriorly and significant muscle damage and may contribute to the skin, bone, and wound problems that occur with double plating of the distal femur.

Rhinelander and colleagues[16,17] showed that the interosseous vessels supply two-thirds of the inner blood supply, and the outer third is supplied by the periosteum. Injury to the femur usually disrupts the interosseous supply because the main perforator enters the femur approximately 2 cm distal to the lesser trochanter. Bone healing studies have shown that even though the interosseous blood supply is lost with intramedullary nailing there is more than adequate blood supply for periosteal healing provided the periosteum is kept intact.

Revascularization is associated with muscular attachment. The same mesenchymal cells that differentiate into vascular tissue also have been shown to differentiate into osteocytes. These cells have been traced to the muscle near the damaged bone.

The pioneering work by O'Driscoll and colleagues,[18–20] using continuous passive motion, demonstrated that primary healing of cartilage is possible. Joint fixation that is as anatomic and as rigid as possible allows immediate continuous passive motion to maximize both joint motion and cartilage healing. Scarring of muscle, tendon, and joints also should be minimized with this technique.

In the tibia, the inferior geniculars supply the plateau area. Loss of these vessels is unlikely to cause skin slough, but the interosseous supply is much more important. The tibial periosteum does not have as rich a supply as in the femur, especially in the distal third of the leg and over the anterior shin, where the blood supply is more from the interosseous supply or the skin supply.[21,22]

Primary bone healing usually requires a minimally comminuted fracture and rigid fixation. Most if not all bone healing in fractures fixed with locked intramedullary nails is osteochondral. Intramedullary nailing allows a degree of motion, compression, and shear for development of callus (Table 4). Acceptable levels of these types of stress actually improve the healing environment.

Fracture fixation devices vary in their biomechanics. Intramedullary nails are load-sharing devices that can also be used in a bridging mode, but this puts significant stress on the proximal and distal locking screws. Plates, on the other hand, are tension band devices that also can be used for bridging, and this puts significant stress on the screw–plate interface unless very long plates are used. External fixators are the classic bridging devices. When they are used to "span joints" without individual segmental fixation, they allow bone and tissue to sag. More rigid fixation usually is not desirable with most temporary constructs because internal fixation is done within a short time and there is a risk of early pin track infection. When spanning external fixation is used, we

Table 4. Bone healing and fixation

Fixation	Primary healing	Osteochondral healing
Plate (rigid compression)	Yes (AO type A and some B fractures)	Less prominent callus (does not apply to bridging)
Intramedullary nail	No	Usual prominent callus
External fixation	Unlikely	More likely Regenerates bone Dynamization

Table 5. Complications of intramedullary nailing of femoral neck-shaft fractures

Technique	Osteonecrosis (6%)	Nonunion (18%)	Malunion (0%–30%)
Antegrade with pins	0/19	3/19	0/19
Retrograde with pins	2/13	4/13	2/13
Reconstruction nail		2/14	

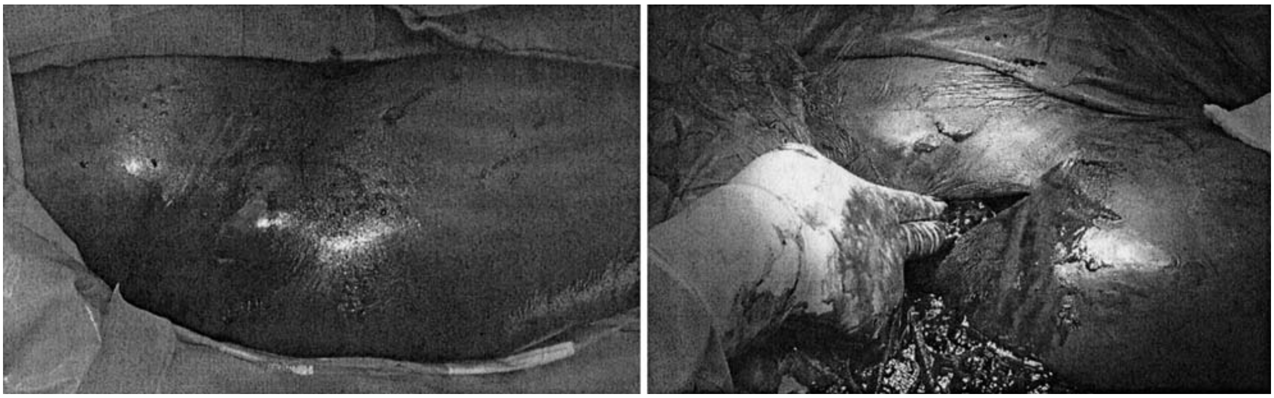


Fig. 1. Morel-Lavelle lesions are frequent with acetabular fractures and they have a more than 50% infection rate. They are not, however, an absolute contraindication to antegrade intramedullary nailing

recommend additional tissue support with a posterior splint.[23]

Specific Joints

Hip

Among periarticular fractures, the proximal femur is an area of definite controversy. Pipkin fractures and acetabular fractures are important because they necessitate retrograde femoral nailing of an ipsilateral femoral fracture to avoid incisions that may compromise the incisions used for the approach to the hip or acetabulum. This is especially true for posterior approaches to the acetabulum and Pipkin fractures.

Acetabular fractures also are highly prone to closed Morel-Lavelle lesions (Fig. 1), which have a more than 50% infection rate. Although these lesions must be considered in fracture treatment decisions, they are not an absolute contraindication to antegrade nailing. We prefer to use retrograde nailing if feasible when these lesions are identified before surgery. If identified at the time of antegrade nailing, the entire lesion should be débrided and treated as an open wound and later closed. Antegrade nailing can still be done in this situation.

The primary area of controversy about fracture in the hip region concerns ipsilateral femoral neck and shaft fractures. Methods for treating these fractures include standard antegrade nailing with screws into the femoral head, reconstruction nails, and retrograde nails with additional screws above the nail (Table 5).

Overall, this fracture combination has an osteonecrosis rate of approximately 6% and a nonunion rate of 18%. Henry and Seligson[24] reported a loss of reduction and malunion rate of up to 30%. The primary problem appears to be a loss of reduction during surgery (Fig. 2). A comparison of the outcomes of various techniques by

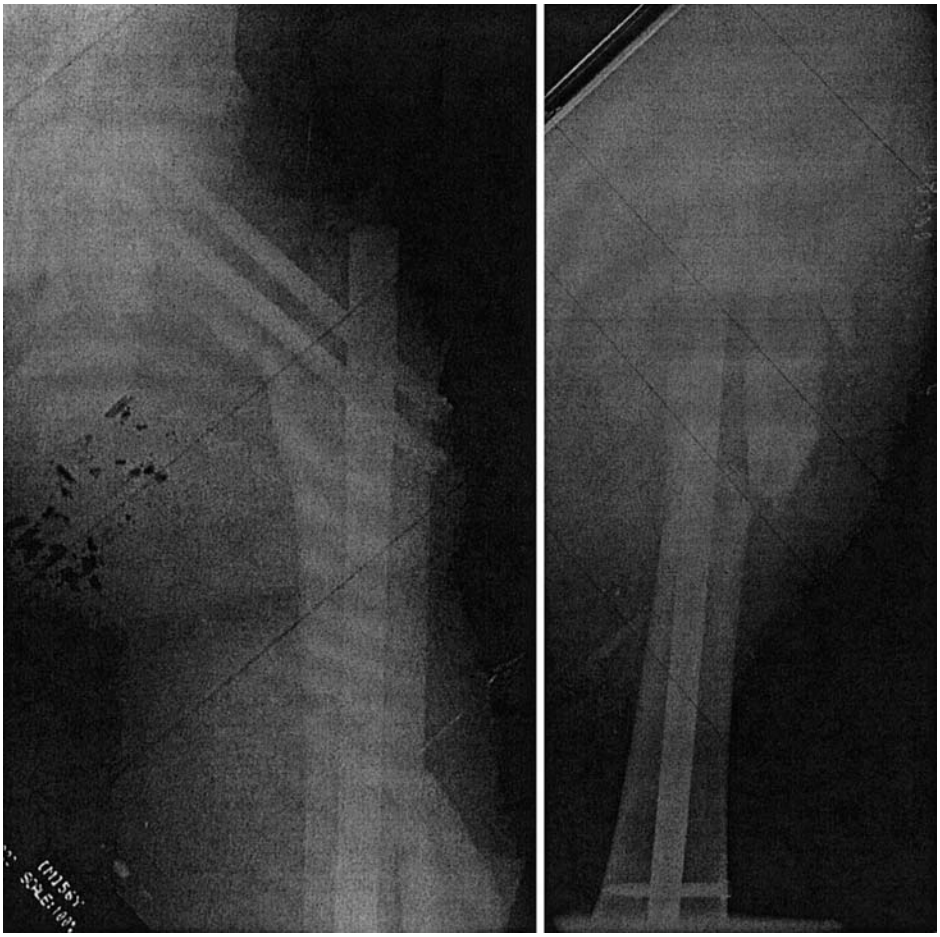


Fig. 2. Early displacement during surgery can occur with use of reconstruction nails. Anatomic reduction of the neck to the shaft is required before placing the nail in the femur

Wiss et al.[25] revealed that retrograde nailing with pins had the greatest number of complications: 2 of 13 patients with osteonecrosis, 4 of 13 with nonunion, and 2 of 13 with malunion. The safest technique appears to be antegrade nailing with screws around the nail into the femoral head, as determined by the studies of Wiss et al.[25] Wu and Shih,[26] and Bennett et al.[27] They noted no osteonecrosis or malunion and only three nonunions in 19 patients. This technique is required for 20%–30% of occult femoral neck fractures that are not identified until placement of the nail or until after the hip is moved through a range of motion at the end of surgery.

Additionally, when reduction of a hip fracture is obtained and maintained, union is more likely and osteonecrosis less likely. Reconstruction nails have more problems with early displacement during surgery. They require anatomic reduction of the neck to the shaft before placement of the nail in the femur. We prefer to reduce the femoral neck first, either open or closed. Occasionally, we use a Schantz pin in the trochanter to help with reduction (Fig. 3). Threaded guide pins placed above the proposed nail track or above and below the nail track are then used to hold the reduction. The entry hole for the reconstruction nail is made, and the guidewire is directed underneath or between the guidewires. Reaming and nail insertion are then done in the usual fashion while the guide pins hold the femoral neck reduction.

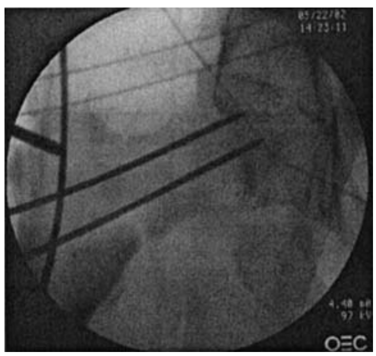


Fig. 3. A Schantz pin can be used as a “joy stick” to assist with reduction. Note the two pins holding the femoral neck reduction

The reconstruction screws are then placed up the femoral neck. Traction is released, and the guide pins are withdrawn before final tightening of the femoral neck screws to maximize femoral neck compression (Fig. 4). The primary technical problems appear to be loss of the neck-shaft reduction or a varus reduction, which has a high correlation with nonunion, as noted by Wiss et al.,[25] Bose et al.,[28] and Henry and Seligson.[24]

The following protocol is recommended for ipsilateral femoral neck and shaft fractures (Algorithm 1). A medically unstable patient should be placed in skeletal traction until he is stabilized for surgery because any procedure for fixation of the ipsilateral femoral neck and shaft fractures are time-consuming and technically demanding, with the potential for significant blood loss. Retrograde nailing with pins should be reserved for obese patients and patients with potentially operative pelvic fractures. Antegrade nailing with pins around the nail should be used in patients with unrecognized femoral neck fractures. In all other patients, the surgeon's preference and experience should be the determining factors. We prefer to use a reconstruction nail in these situations, but it is a more technically demanding and complication-prone procedure than standard intramedullary nailing. Regardless of the fixation used, emphasis should be on reduction of the femoral neck by open or closed methods and maintaining that reduction during the procedure.

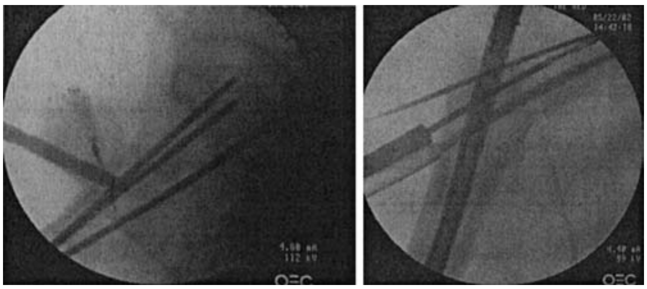


Fig. 4. Reduction must be maintained while reconstruction screws are inserted through the nail into the femoral neck to avoid loss of neck-shaft alignment. To maximize compression, remove the reduction pins and release the traction before the last four to six turns of the reconstruction screws are completed

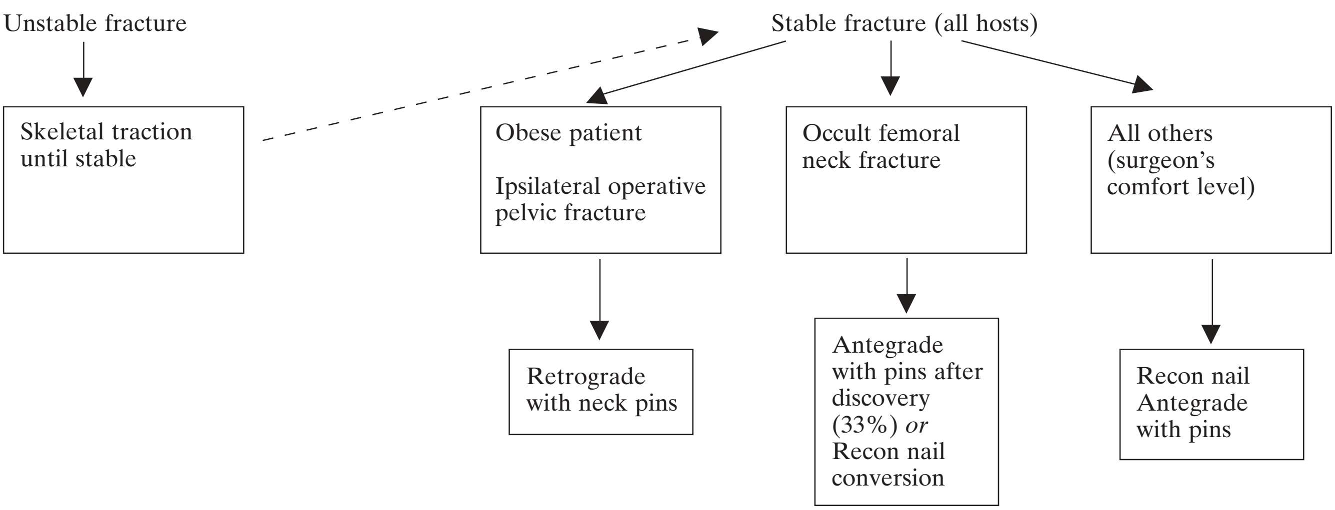
Supracondylar femur and knee

At the other end of the femur, in the supracondylar region, there is a sizable amount of cancellous bone. The gastrocnemius pulls the distal fragment posteriorly. The nerves and vessels are close to the posterior edge of the bone and can be damaged at the time of injury. Treatment of supracondylar femoral fractures requires a dual plane reduction in poor bone stock.

Implants that can be used for this fracture include both antegrade and retrograde nails. Numerous plates have been used, including blade plates, dynamic compression plates, periarticular plates, locked periarticular plates, and dual plates. Regardless of the implant used, fixation of these fractures is difficult and technically demanding. External fixation can be used, either as initial spanning fixation or long-term fixation.

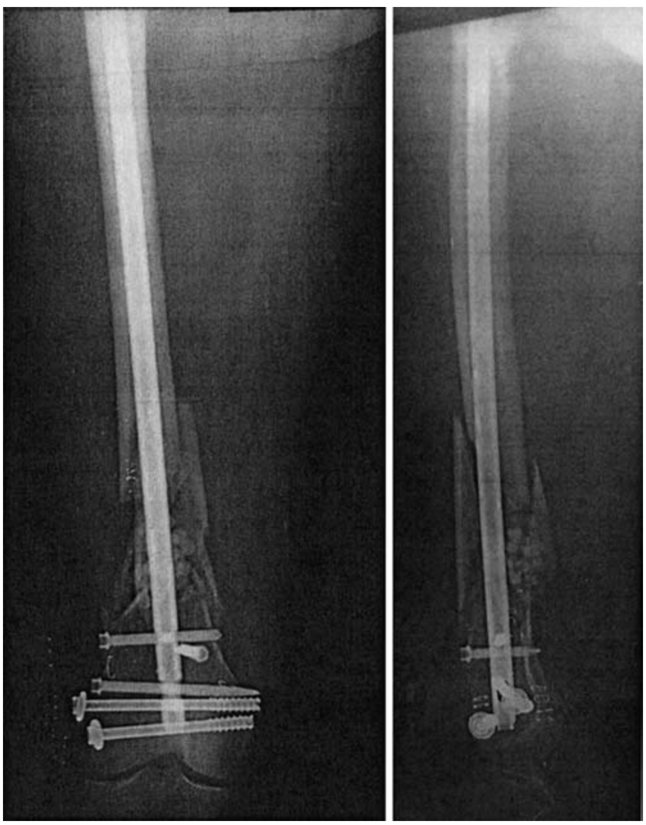
Intertrochanteric and comminuted supracondylar fractures with joint extension can be treated with the patient in traction. The intertrochanteric portion of the

Algorithm 1. Recommended protocol for femoral neck and shaft fractures



Reconstruction nail is personal preference, but it is more technically demanding and time-consuming fracture is provisionally fixed, and the nail is inserted down to the level of the distal femoral fracture. Reaming is continued to the level of the supracondylar fracture. The condyles themselves are then fixed with cannulated screws with the least amount of dissection possible. The nail is positioned as close to a central point of the femoral condyles as possible, and the fracture is reduced with the help of "joy sticks." The maintenance of reduction may require two anterior-to-posterior blocking screws and one posterior blocking screw as the nail is advanced. If careful attention is given to the length of the nail, it can be advanced directly to the subcortical bone of the joint. At each fracture, a test reduction is done before reaming or advancing the nail.

Blocking screws are used to align nails in long-bone fractures when the normal cortical canal does not aid in centralizing the nail (Fig. 5). Blocking or Poller screws were first described by Krettek et al. in 1999.[29] Biewener et al.[30] described a "palisade method" using Kirschner wires in a similar fashion. We prefer to use screws rather than wires because late migration of the nail is less likely when the screws are left in. The goal of blocking screws is to obtain three-point fixation by creating a narrow, rigid canal to centralize the nail in both anteroposterior and, if needed, lateral dimensions.



A,B

Fig. 5. Blocking screws can be used in the proximal and distal femur. **A** Anteroposterior and lateral (**B**) views

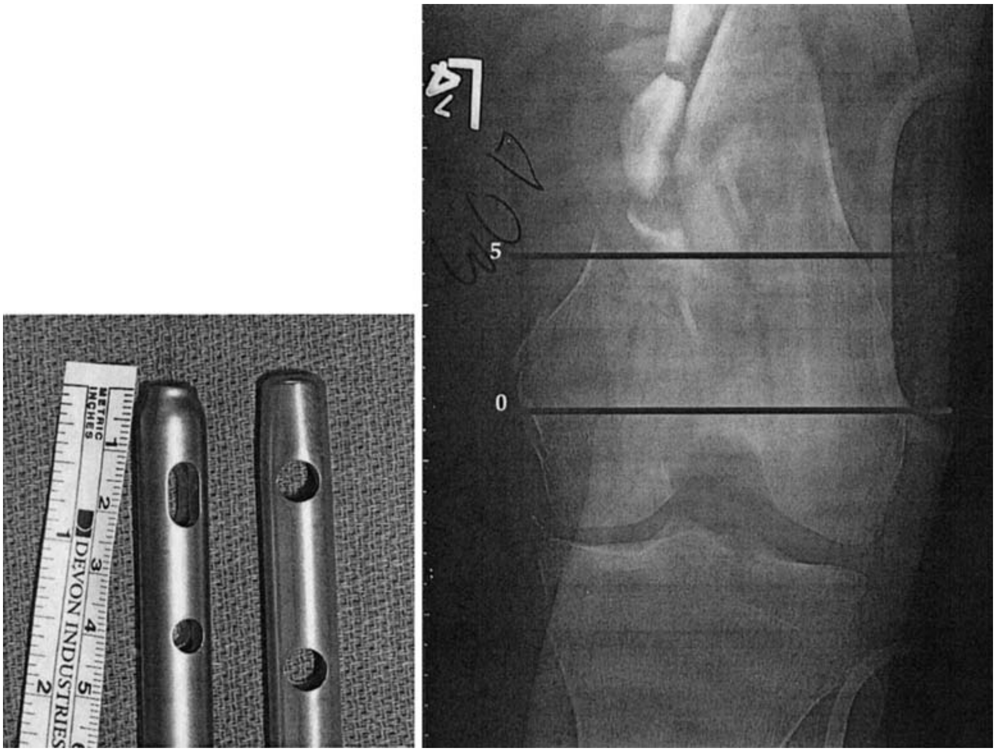
In the femur, blocking screws can be used in the distal femur in both the anteroposterior and lateral planes. They have even been reported in the proximal femur to keep the nail from exiting inferiorly in the shaft. In the tibia, they are used to direct the nail down the shaft by placement in the lateral plane near the insertion hole. Distally in the tibia they are used in the anteroposterior and lateral planes to centralize the nail in the distal tibia.[31]

The use of blocking screws requires careful monitoring of the reduction with nail placement. If the nail begins to migrate from side to side, anteroposterior blocking screws can be placed either by first using a threaded guide pin and then converting to a regular blocking screw or by using the blocking screw itself. The nail should then be advanced while the reduction is maintained by the screw. Blocking screws should not be used after the nail is placed because correcting the deformity is then much more difficult. Therefore, any loss of reduction should be countered with an appropriate blocking screw after removing the malaligned nail from the fragment in question.

After a decision to use a locked intramedullary device is made, the choice of implant is determined by the amount of bone available for fixation (Fig. 6). Antegrade nails and retrograde nails require at least 3–5 cm of lateral wall attached to the distal joint for fixation. Other indications include mild comminution with minimal anterior or posterior comminution in the distal segment. Femoral condyle involvement in a sagittal or coronal plane can be present as long as the screw fixation of the condyles does not interfere with the nail or the locking screws. Locked intramedullary nails are preferred for patients in whom less blood loss is desired and where small incisions are preferred. Locked intramedullary nails can even be used to bridge gaps where there is a significant amount of bone loss.

Contraindications to antegrade nailing include patients who are so sick they cannot undergo a 2- to 3-hour procedure, severe comminution extending 5 cm above the femoral notch, coronal fractures, and fractures in the line of the locking or blocking screws.

Moed and Watson[32] outlined the indications and contraindications for retrograde femoral nailing in their review in 1999. These indications have not changed since that time. They noted that the best uses for this technique include periprosthetic fractures in patients with total knee arthroplasty (provided the nail will pass through the prosthetic device) and fixation with proximal compression hip screws. Another important area for the use of these nails is in floating knee injuries. This is especially true in patients who are in poor medical condition, as it allows potentially rapid reduction and



A B

Fig. 6. Antegrade and retrograde femoral nailings require at least 3–5 cm of lateral wall to allow distal fixation (**A**). This measurement is to the femoral notch on the computed tomography (CT) scan or lateral radiograph (**B**)

fixation of both the femur and tibia through the same incision. We use this nail in patients who have acetabular or Pipkin fractures that require a posterior approach at a later date to avoid the risk of infection from the previous wound for antegrade nail placement. We also have found it helpful for fractures with ipsilateral vascular injury, as the procedure can be done either before or after vascular repair without significant risk of vascular repair damage. It also is helpful in pregnant women when radiation exposure of the child should be kept at an absolute minimum.

Other special situations for the use of a retrograde femoral nail are obesity, periprosthetic fractures, and bone loss, where retrograde nails can be used to bridge large gaps while preparing for an intercalary allograft (Fig. 7).[33]

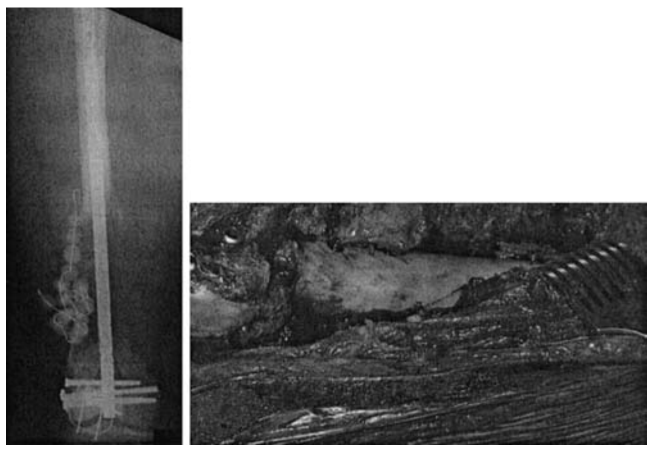


Fig. 7. Retrograde nailing can be used to bridge large bone gaps in preparation for intercalary allografting

Contraindications to retrograde nailing include marked distal comminution, within 4–5 cm of the joint, fractures of the proximal femur 5 cm or less from the lesser trochanter, skeletal immaturity, knee sepsis or marked contamination from an open wound, and knee flexion of less than 45°, which makes placement through the knee difficult. The nail needs at least two screws for placement, and they require at least 4 cm of lateral bone wall above the femoral notch. Blocking screws are helpful to avoid posterior angulation of the distal fragment. Additional blocking screws also can be used to help align the nail as it is placed to avoid a varus or valgus tilt, but adequate anterior and posterior bone is required to hold the screws.

The reported complications of retrograde nailing include a malunion rate of 16% or more. The most common type of malunion is shortening in AO type C fractures. The rate of nonunion is 5%–14%, and knee stiffness is reported in 0%–10% of patients. Joint penetration (Fig. 8) is a technically avoidable problem.

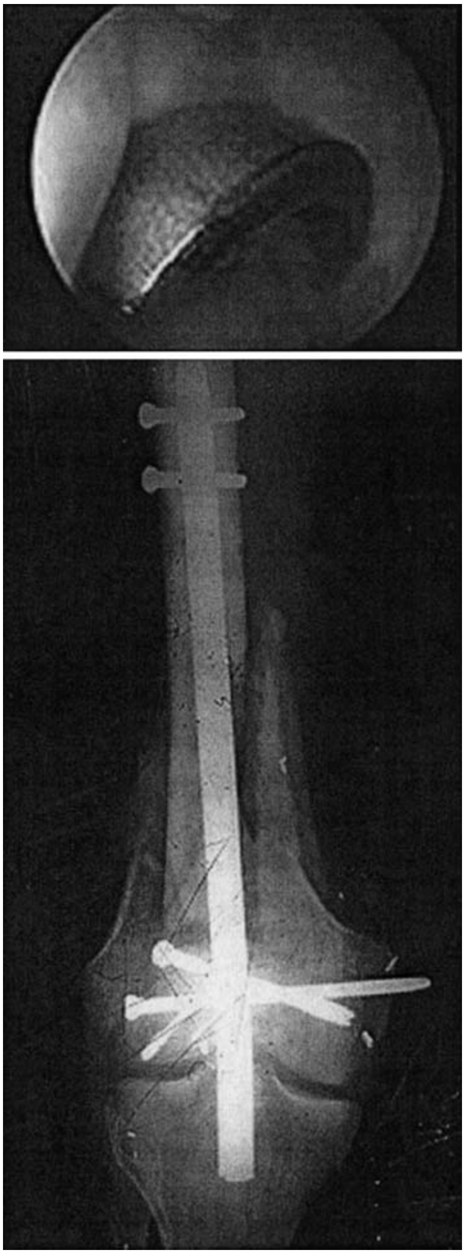


Fig. 8. Joint penetration. This complication can be avoided by preoperative measurements on the CT scan of the knee. Most retrograde or antegrade nails require 4–6 cm of medial and lateral bone proximal to the femoral notch

Nerve and vascular injury, deep venous thrombosis, pulmonary emboli, and infection also have been reported at lower rates and probably are not implant-related.

This procedure probably should not be done if adequate fixation cannot be obtained to allow early continuous passive motion. There is a potential for nerve and vascular injury during the procedure. The nails themselves may penetrate the knee by settling or if the

Fig. 9. For retrograde nailing with the patient supine, the leg is placed over a horizontal bar, and tibial skeletal traction is used to maintain length and rotational control. This technique uses a minimum number of assistants. Conversion to plate fixation can be done without a change of position

patient bears weight, which may result in grooving at the patella or even locking of the patella once the knee reaches 110° of flexion.[32]

The retrograde technique can be done with the patient in or out of traction. Whenever the patient is not in traction, care must be taken and additional help must be obtained to maintain length and rotation. It has been our experience that once a retrograde nail has been placed it is impossible to pull the leg out to length; instead, the nail must be withdrawn, the fracture held at length, and the nail reinserted.

Because nail insertion is done with the patient supine, rotational malalignment is another problem that must be carefully avoided. Similarly, varus and valgus malalignment may develop because of improper placement of the nail. All of these potential problems can be avoided with careful attention to detail. This procedure is best done over a triangle or with the patient in traction over a horizontal bar (Fig. 9). We prefer to use tibial skeletal traction over a transverse bar for AO type C fractures. This allows alignment and reduction to be checked before draping. The open portion of the procedure is minimized when the fracture is held reduced in this manner. This also makes the proximal locking easy because the leg is fixed. If it is discovered that a nail cannot be inserted, it is easy to convert to a locked lateral plate without changing the patient's position or draping.

Complications with either antegrade or retrograde fixation can be avoided by applying skeletal traction to the femur or tibia using a femoral distractor or external fixator to maintain the femur at the length, minimizing the incision to avoid bleeding and scar formation, positioning the leg to allow for the easiest reduction with the fewest people, and using joy sticks consisting of threaded guidewires or screws to aid in the reduction of the fragments.

T-condylar fractures require reduction of the joint with cannulated screws first. Medial, lateral, and transpatellar approaches have all been described. I prefer a transpatellar tendon approach, rather than a medial or lateral approach (Fig. 10), because it can be done with a smaller incision, and less force is required to maintain central alignment of the nail. The choice of approach for both femoral and tibial nails is controversial. A recent article by Toivanen et al.[34] comparing both methods in tibial fractures indicated no difference in knee pain with either technique.

The entry hole is made at the junction of the femoral condyles and the femoral notch. This places the hole at a point that should affect the patella only with 100°–120° of flexion. When the nail is embedded in the bone, the hole covers with fibrous tissue. Only when the nail is left proud is there a problem. This is evident with knee pain and locking when the knee is flexed more than 120°. The patient may even note that he or she has to "hit" the knee to release it.

Locking screws can be used if a medial or lateral approach is necessary to help align the nail during insertion. The nail should be advanced to the level of the lesser trochanter, and the locking screw should be placed at this area. This has been shown by Riina al. to be the safest position to avoid axial damage to the femoral or sciatic nerves and the femoral artery.[35] The proximal or distal position has a greater risk of damage to these structures. We prefer to expose the femur completely for the proximal locking screw rather than using a percutaneous technique because of the risk of wrapping the branches of the femoral nerve in the drill at the time of locking.

As in all femoral nailings, at the end of the procedure we check for alignment, primarily length, and rotation. We obtain a full-length radiograph to make sure that the fracture has been completely reduced and we have not been deceived by the small image view. We then externally rotate the hip and obtain either a standard film or image intensifier view of the femoral neck under live rotation to check for occult fractures. The knee is stressed to check for ligament damage. The tension of muscle is felt or measured to check for compartment pressure elevation. This same protocol is followed for all tibial nailing procedures.

Markmiller et al.[36] compared the outcome of supracondylar fractures treated with LISS plates and retrograde femoral nails and found no significant difference. This was a prospective study of multiple trauma patients, 20 of whom were treated with LISS plates and 19 with nails. There were no significant differences in outcome with regard to range of motion, nonunion, malunion, time to union, or Lysholm-Gillquist knee score at 12 months. Because this study was limited to 1 year, the rate of hardware removal was not noted, and there was no note of the operating time.

Proximal tibia

Proximal tibial fractures also can be treated with locked intramedullary nailing. A retrograde or knee nail can be used provided there is at least 3–4 cm of lateral bone below the tibial tubercle and minimal plateau involvement. This fixation also is helpful for treating segmental fractures where plating may be difficult.

Nailing of proximal tibial fractures was initially reported to have an 84% malunion rate by Lang et al.[37] and Schmidt et al.[38] To avoid these malunion problems, the knee should be maximally flexed; the blocking screws placed posteriorly should be used to direct the nail; and the approach should be as straight as possible (Fig. 11).[39,40] Hernigou and Cohen[39] recommended a transpatellar tendon approach, whereas Tornetta et al.[40,41] recommended a lateral approach that may even involve complete arthrotomy. The position of the guidewire should be at the level of the down-slope of the lateral tibial eminence, as described by Tornetta et al.[41] As with supracondylar femoral fractures, we prefer

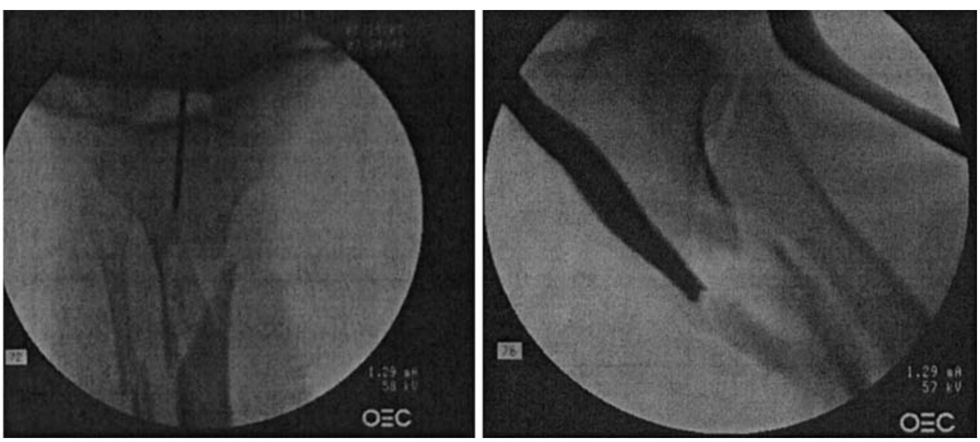


Fig. 10. With the knee in maximal flexion, a transpatellar tendon approach provides direct access to the fracture and avoids malpositioning the nail due to pressure of the tendon against the guide, reamers, and nail. Toivanen et al.[38] showed that this does not increase the incidence of knee pain

Algorithm 2. Recommended protocol for proximal tibial fractures

Unstable patient ⟶ External fixation

Stable patient ⟶ Locked intramedullary nail
- Longger time to do
- Multiple trauma
- Host B or C
- Wound near insertion point

Stable patient ⟶ Locked percutaneous plate
- Isolated trauma
- Host A
- No wounds near plate
- Minimal swelling
- Faster operating time

A,B  C

Fig. 11. Extremely proximal tibial frature for which a blocking screw was needed. **A** Blocking screw is placed behind the reduction tool, leaving room for the nail. **B** Screw is placed in a hole before final reduction and nail placement. **C** Nail is placed as superficial as possible in the proximal fragment to maximize locking screw placement

a transpatellar tendon approach to avoid malpositioning the nail.[34]

Unfortunately, this technique requires a considerable length of time. Unstable patients are better treated with rapid application of an external fixator. Stable patients with an isolated proximal tibial fracture, host B or C status, or wounds where a plate will be placed may be better treated with a locked nail. Stable patients meeting criteria for intramedullary nailing but with multiple trauma. host A status, and no wounds near the plate are best treated with a percutaneous plate. A locked plate may be more appropriate for proximal tibial fractures if time is of the essence (Algorithm 2).

Distal tibia

Finally, distal tibial fractures can be nailed provided there is only simple extension into the joint that can be fixed with a percutaneous screw (Fig. 12). Because this is a wide metaphyseal area, blocking screws are also needed to guide the nail to the center of the fracture fragment. The lateral wall, in most cases, needs to be 2–5 cm long to allow adequate fixation with one or two screws.[38] Special nails are available for these fractures.

The incidence of union in nailed distal tibial fractures has been reported to be 96%–100%. Malalignment also is absent with combined plate fixation of the fibula and still very low without plating. The use of blocking screws also ensures proper alignment. These fractures do heal more slowly than fractures in the tibial shaft and may require additional procedures, such as dynamization and or bone grafting.[42–44]

A distal tibial fracture that meets the criteria for intramedullary nailing in an unstable patient still requires

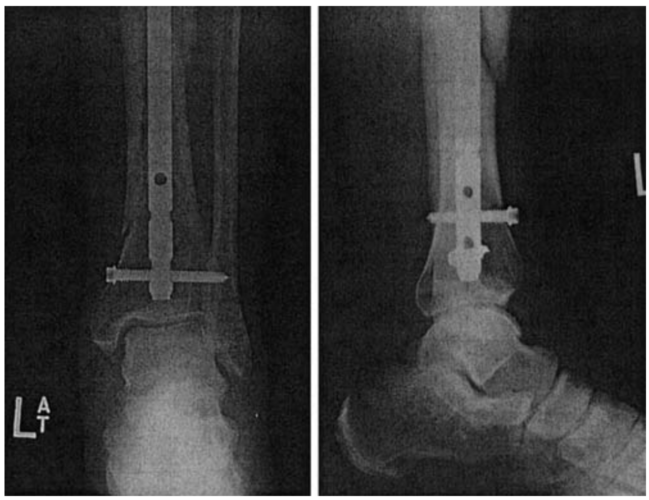


Fig. 12. Intramedullary nailing of a distal tibial fracture with simple extension into the joint; a percutaneous screw is used for distal locking. Blocking screws may be necessary to maintain alignment

immediate external fixation. The use of locked nails in this fracture can be done rapidly even with blocking screws, so it is easily applied to multiple trauma patients, host B and C patients, and those with wounds near the insertion point.

Plating in this situation should be limited to patients with host A status, good skin without local wounds, minimal swelling, and isolated trauma.

Postoperative care

The postoperative care of these fractures requires non-weight bearing and early range-of-motion (ROM) exercises with a continuous passive motion machine followed by active ROM exercise once a range of 90°C is obtained. Neck-shaft fractures usually require 6 weeks of non-weight-bearing or touch-down weight-bearing with progressive weight-bearing thereafter. Supracondylar fractures, on the other hand, require a minimum of 8–12 weeks of non-weight-bearing but aggressive active and continuous passive knee ROM exercise that usually is begun on the second or third postoperative day. Patients with proximal or distal tibial fractures without joint extension may bear weight a little earlier, at 6–8 weeks, with progressive weight-bearing thereafter. The use of active knee ROM exercise and ankle motion should also be encouraged in patients with these fractures (Table 6).

Conclusion

The use of locked intramedullary nails for the treatment of periarticular fractures of the femur and tibia is safe provided there is a careful evaluation of the patient and the fractures. If the patient requires a rapid procedure, we prefer to use external fixation first and then, once he has improved, proceed with the internal fixation. Preoperative planning after a fracture has been fixed with external fixation allows accurate measurements to determine the appropriate implant for the fracture configuration and allows consideration of various options for fixation.

Meticulous attention to detail in the operating room with regard to proper implant selection and developing a surgical plan (including patient positioning, selection of entry portals, the use of blocking screws, and reduction with joysticks or other manual means) should minimize the surgical complications of these more difficult intramedullary nailing procedures. Finally, aggressive postoperative therapy for joint motion is essential provided there has been adequate fixation of the damaged joints.

Table 6. General postoperative care after intramedullary nailing of femoral and tibial fractures

Non-weight-bearing
Femoral neck-shaft fracture: 6 weeks
Supracondylar fracture: 12 weeks
Proximal tibial fracture: 6–8 weeks
Distal tibial fracture: 6–8 weeks
Range of motion
Within 1–2 days
Continuous passive motion — all fractures involving the knee joint

The author did not receive grants or outside funding in support of his research or preparation of this article. He did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No benefits were paid in connection with this work to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the author is affiliated or associated.

References

1. Bhandari M, Guyatt G, Khera V, Kulkamai A, Sprague S, Schemitsch E. Operative management of lower extremity fractures in patients with head injuries. Clin Orthop 2003;407:187–98.
2. Nowotarski PJ, Turen CH, Brumback RJ, Scarboro JM. Conversion of external fixation to intramedullary nailing for fractures of the shaft of the femur in multiply injured patients. J Bone Joint Surg Am 2000;82:781–8.
3. Christodoulou A, Terzidis I, Ploumis A, Metsovitisi S, Koukoulidiis A, Toptsis C. Supracondylar femoral fractures in elderly patients treated with the dynamic condylar screw and the retrograde intramedullary nail: a comparative study of the two methods. Arch Orthop Trauma Surg 2005;125:73–9.
4. Kwon PT, Rahman SS, Kim DM, Kopman JA, Karimbux NY, Fiorellini JP. Maintenance of osseointegration utilizing insulin therapy in a diabetic rat model. J Peridontol 2005;76:621–6.
5. Patel GK. The role of nutrition in the management of lower extremity wounds. Int J Low Extrem Wounds 2005;4:12–22.
6. Karlstrom G, Olerud S. The management of tibial fractures in alcoholics and mentally disturbed patients. J Bone Joint Surg Br 1974;56:730–4.
7. Castillo R, Bose M, MacKenzie E, Patterson B. The impact of smoking on fracture healing and risk of complications in limb-threatening open tibial fractures. J Orthop Trauma 2005;19:151–7.
8. Gullihorn L, Karpman R, Lippiello L. Differential effects of nicotine and smoke condensate on bone cell metabolic activity. J Orthop Trauma 2005;19:17–22.
9. Altman RD, Latta LL, Keer R, Renfree K, Hornicek FJ, Banovac K. Effect of nonsteroidal anti-inflammatory drugs on fracture healing: a laboratory study in rats. J Orthop Trauma 1995;9:392–400.
10. O'Brien PJ. Fracture fixation in patients having multiple injuries. Can J Surg 2003;46:124–8.
11. El-Shazly M, Dalby-Ball J, Burton M, Saleh M. The use of trans-articular and extra-articular external fixation for management of distal tibial intra-articular fractures. Injury 2001;32(Suppl 4): SD99–106.

12. Orthopaedic Trauma Association Committee for Coding and Classification. Fracture and dislocation compendium. J Orthop Trauma 1996;10(Suppl 1):1–154.
13. Nork S, Segina D, Aflatoon K, Barei DP, Henley MB, Holt S, et al. The association between supracondylar-intracondylar distal femoral fractures and coronal plane fractures. J Bone Joint Surg Am 2005;87:564–9.
14. Dickson KF, Galland MW, Barrack RL, Neitzschman JR, Harris MB, Myers L, et al. Magnetic resonance imaging of the knee after ipsilateral femur fracture. J Orthop Trauma 2002;16:567–71.
15. Lu-Yao G, Keller R, Littenberg B, Wernberg J. Outcomes after displaced fractures of the femoral neck: a meta-analysis of one hundred and six published reports. J Bone Joint Surg Am 1994;76:12–25.
16. Rhinelander FW. The normal microcirculation of diaphyseal cortex and its response to fracture. J Bone Joint Surg Am 1968;50: 784–800.
17. Rhinelander FW, Phillips RS, Steel WM, Beer JC. Microangiography in bone healing. II. Displaced closed fractures. J Bone Joint Surg Am 1968;50:643–62.
18. O'Driscoll S, Keeley F, Salter R. Durability of regenerated articular cartilage produced by free autogenous periosteal grafts in major full-thickness defects in joint surfaces under the influence of continuous passive motion: a follow-up report at one year. J Bone Joint Surg Am 1980;62:1232–51.
19. O'Driscoll S, Keeley F, Salter R. The chondrogenic potential of free autogenous periosteal grafts for biological resurfacing of major full-thickness defects in joint surfaces under the influence of continuous passive motion: an experimental investigation in the rabbit. J Bone Joint Surg Am 1986;68:1017–35.
20. O'Driscoll S, Salter R. The induction of neochondrogenesis in free intra-articular periosteal autografts under the influence of continuous passive motion: an experimental investigation in the rabbit. J Bone Joint Surg Am 1984;66:1248–57.
21. Rhinelander FW. Tibial blood supply in relation to fracture healing. Clin Orthop 1974;105:34–81.
22. Trueta J. Blood supply and the rate of healing of tibial fractures. Clin Orthop 1974;105:11–26.
23. Perren S, Claes L. Biology and biomechanics in fracture management. In: AO principles of fracture management. New York: Thieme; 2000. p. 7–30.
24. Henry S, Seligson D. Ipsilateral femoral neck-shaft fractures: a comparison of therapeutic devices. Orthop Trans 1990;14:269.
25. Wiss D, Sima W, Brien W. Ipsilateral fractures of the femoral neck and shaft. J Orthop Trauma 1984;6:159–66.
26. Wu CC, Shih C. Ipsilateral femoral neck and shaft fractures: retrospective study of 33 cases. Acta Orthop Scand 1991;62:346–51.
27. Bennett F, Zinar D, Kilgus D. Ipsilateral hip and femoral shaft fractures. Clin Orthop 1993;296:168–77.
28. Bose W, Corces A, Anderson L. A preliminary experience with the Russell-Taylor reconstruction nail for complex femoral fractures. J Trauma 1992;32:71–6.
29. Krettek C, Micaiu T, Schandelmaier P, Mohlmann U, Tscherne H. The mechanical effect of blocking screws ("Poller screws") in stabilizing tibia fractures with short proximal or distal fragments after insertion of small diameter intramedullary nails. J Orthop Trauma 1999;13:350–3.
30. Biewener A, Grass R, Zwipp H, Rammelt S. Precise positioning of unreamed solid nails in short distal tibial fragments with percutaneous K-wires. Orthopedics 2005;28:263–5.
31. Stedtfeld H, Mittlmeier T, Landgraf P, Ewert A. The logic and clinical applications of blocking screws. J Bone Joint Surg Am 2004;86(Suppl 12):17–25.
32. Moed B, Watson T. Retrograde nailing of the femoral shaft. J Am Acad Orthop Surg 1999;7:209–16.
33. Dennis D. Periprosthetic fractures following total knee arthroplasty. J Bone Joint Surg Am 2001;83:120–30.
34. Toivanen J, Vaisto O, Kannus P, Latvala K, Honkonen S, Jarvinen M. Anterior knee pain after intramedullary nailing of fractures of the tibial shaft: a prospective, randomized study comparing two different nail-insertion techniques. J Bone Joint Surg Am 2002;84:580–5.
35. Riina J, Tornetta P III, Ritter C, Geller J. Neurologic and vascular structures at risk during anterior-posterior locking of retrograde femoral nails. J Orthop Trauma 1998;12:379–81.
36. Markmiller M, Konrad G, Sudkamp N. Femur-LISS and distal femoral nail for fixation of distal femoral fractures: are there differences in outcome and complications? Clin Orthop 2004;426: 252–7.
37. Lang G, Cohen B, Bosse M, Kellam J. Proximal third tibial shaft fractures: should they be nailed? Clin Orthop 1995;315:64–74.
38. Schmidt A, Finkemeier C, Tornetta P. Treatment of closed tibial fractures. J Bone Joint Surg Am 2003;85:352–68.
39. Hernigou P, Cohen D. Proximal entry for the intramedullary nailing of the tibia: the risk of unrecognized articular damage. J Bone Joint Surg Br 2000;82:33–41.
40. Tornetta P, Collins E. Semiextended position of intramedullary nailing of the proximal tibia. Clin Orthop 1996;328:185–9.
41. Tornetta P, Riina J, Geller J, Purban W. Intraarticular anatomic risks of tibial nailing. J Orthop Trauma 1999;13:247–51.
42. Dogra A, Ruiz A, Thompson N, Nolan P. Dia-metaphyseal distal tibial fractures — treatment with a shortened intramedullary nail: a review of 15 cases. Injury 2000;31:799–804.
43. Moshelff R, Safran O, Segal D, Liebergall M. The unreamed tibial nail in the treatment of distal metaphyseal fractures. Injury 1999;30:83–90.
44. Tyllianakis M, Megas P, Giannlkas D, Lambiris E. Interlocking intramedullary nailing in distal tibial fractures. Orthopedics 2000;23:805–8.