Indirect Fracture Reduction: A Technique for Minimizing Surgical Trauma

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Abstract

In recent years, the treatment of fractures has evolved away from the rigid, anatomic internal fixation advocated in the 1960s and 1970s toward stable, "biologically benign" internal fixation, utilizing minimal soft-tissue dissection and retraction. Application of this concept appears to avoid complications that can be produced by additional surgical soft-tissue trauma and bone devascularization. Achieving this goal requires the surgeon to assess the degree of soft-tissue injury so as to be able to optimally time the procedure and plan the surgical dissection. Preoperative planning of the location of the internal fixation enables precise placement of the incisions. The author describes techniques of indirect reduction that enable the surgeon to achieve an adequate reduction without the extensive additional soft-tissue dissection previously required to allow fragment manipulation.

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The trauma of bone fracture often overshadows the concomitant injury to the surrounding soft tissue. Nevertheless, it is imperative that the orthopaedic surgeon study not only the radiographs of the fracture but also the soft-tissue envelope that encloses the fracture, for it is the soft-tissue envelope that provides vascularity and viability to the underlying bone and fracture fragments. Evaluation must also address the mechanism of injury, including the magnitude and direction of the force. With careful soft-tissue examination and handling and appropriate fracture stabilization, a satisfactory outcome can be achieved, while avoiding potential complications, such as skin sloughs, wound infections, and nonunions.

In this article, I will discuss assessment of the injury, the concept of biologic fixation, and the need for preoperative planning. Techniques of surgical exposure will be presented, as well as the use of indirect reduction to limit the need for exposure. Finally, specific objective examples will be given, and some special techniques will be described.

Assessment of the Injury

All wounds are not created equal. A tibial fracture resulting from downhill skiing has an energy input of 300 to 500 ft-lb, while a similar tibial or tibial-plateau fracture due to a bumper injury at 20 mph has an energy input of 100,000 ft-lb.[1] Knowing the type of mechanism that produced the injury can greatly enhance one's ability to evaluate both the soft-tissue trauma and the underlying bone trauma.

When dealing with any fracture, the overlying soft tissues must be inspected not only to see whether there is an open or a closed injury, but also to assess the degree of injury to the soft tissues themselves. This assessment can be partially achieved through direct visualization of the skin, looking carefully for areas of contusion or abrasion, or can be performed indirectly through evaluation of the fracture, which gives an estimate of the gradations of energy delivered during the injury.[1,2] Fractures with minimal displacement, minimal comminution, and certain fracture patterns, such as spiral fractures, are generally produced with low energy. Fractures with moderate displacement of more than 50% of the diameter with butterfly comminution and transverse or oblique fracture patterns tend to be produced with more energy. Fractures with significant displacement, multiple fragments, and comminution are generally produced with a large amount of energy.

Tscherne has developed a useful soft-tissue injury classification for both open and closed fractures.[1,3] In his system, a grade 0 closed fracture has negligible soft-tissue damage. The fracture is caused by indirect violence and has a simple configuration, such as a torsional injury. In grade I closed injuries, there is a

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superficial abrasion or contusion caused by fragment pressure from within. The fracture has a mild to moderately severe configuration (e.g., a midshaft tibia fracture with a butterfly fragment or a pronation fracture-dislocation of the ankle in which the soft-tissue lesion is caused by pressure from the fracture margins). In a grade II closed fracture, there is a deep abrasion associated with localized skin or muscle contusion from direct trauma. Impending compartment syndrome is included in this category. Generally, direct violence has produced a moderately severe to severe fracture configuration (i.e., a comminuted or displaced fracture), as may occur in a proximal tibial fracture due to a bumper injury. In a grade III closed fracture, there is extensive contusion or crush of the skin and muscle. There may be subcutaneous avulsion, a degloving injury, compartment syndrome, or rupture of major blood vessels associated with the closed injury. The fracture is severely comminuted.

In evaluating the soft-tissue injury, the amount of intradermal edema must be assessed, since edema causes hypoxia of the skin, increasing the risk of skin sloughs and wound infection, especially if wounds are closed under tension. Swelling of an extremity, especially around a joint, suggests the presence of a subcutaneous hematoma or hemarthrosis, indicating a need for early fracture stabilization and incision and decompression of the hematoma.

Biologic Fixation

Fracture management objectives should encompass both biologic and mechanical goals. The biologic goal is to maintain viability of the bone by preserving its soft-tissue attachments and blood supply. The mechanical goal is to obtain axial and rotational alignment with stable fixation of the fracture.

In 1965 the Swiss AO group published the first manual on internal fixation. It was their objective at that time to perform anatomic realignment of all fracture fragments with "rigid" stabilization.[2,4] This approach would allow early mobility of the injured extremity and reduce "fracture disease." This principle has evolved over the past three decades. Today the objectives are to obtain stable fixation but to do so with the least possible disturbance of the soft tissues. As Mast states,[5,p1] the "anatomic reduction of each fracture surface is not critical nor should it be the absolute goal in the fracture except in articular fractures, especially if the trade-off for anatomicity is devitalization of the fracture zone."

Currently, the goal for a diaphyseal fracture is to obtain stable fixation with no residual angulation in the frontal or sagittal plane and no rotational malalignment in the horizontal plane. For a metaphyseal fracture, axial alignment is the goal. Only in intra-articular epiphyseal injuries is anatomic reduction required. The implant used varies according to the fracture location and pattern as well as the overlying soft-tissue injury and the surgeon's preference, but the goal of adequate alignment and stability with minimal additional soft-tissue injury remains the same.

Preoperative Planning

Preoperative planning of the operative stabilization is an essential step in achieving the goal of biologic fixation. The necessary equipment and implants of appropriate types and sizes must be available.[5,6] Preplanning each step of the surgery can help reduce operative time. The placement of the implant is predetermined, usually with the use of tracings of the fracture. These steps enable the surgery to be performed precisely with the least amount of soft-tissue dissection.

Surgical Exposure

Surgical exposure should generally be achieved through straight incisions made with sharp scalpel dissection that avoids acute angles. Where two incisions are required, the intervening skin bridges should be at least 7 cm in width. Avoidance of skin contusion or abrasion is very important. Pressure should be used to control subcutaneous bleeding, and electrocautery of larger vessels should be performed. Crushing of soft tissue, especially subcutaneously, will lead to devitalization of that tissue, which then becomes a good nutrient for bacterial growth.

Deep dissection should be performed with blunt dissection through muscle planes. With high-energy injuries, the fracture has often produced tissue planes that can be utilized by the surgeon. It is important to utilize the traumatic wound to evaluate the deep tissues; when possible, the wound should be used to avoid creating new tissue planes, which may in turn devitalize additional soft tissues. It is also important to handle the soft tissues gently, limit retraction when possible, and avoid stretching or pressure on the subcutaneous tissue and skin, which creates periods of anoxia. Soft-tissue attachments to the bone should be removed only where the plate will lie. Bone clamps and retractors should be precisely placed, according to the preoperative plan, through small fascial incisions made for that purpose. Surgical wounds should be kept moist to avoid dehydration necrosis. If these principles are not adhered to, the most precise fracture stabilization may result in a disastrous complication, usually resulting from skin sloughing and infection.

Techniques of Indirect Reduction

The general principle involved in indirect reduction is the use of the soft-tissue envelope to help stabilize and reduce the fracture fragments indirectly through what is commonly referred to as ligamentotaxis. This technique uses the same principles by which closed reduction and intramedullary rodding are performed on diaphyseal fractures of long bones, such as the femur and tibia. By placing the injured extremity on a fracture table during nailing, the fracture can be reduced closed, often just by manipulation and tension on the soft tissues. In nailing procedures, it is well recognized that the comminuted diaphyseal fracture fragments do not need to be precisely reduced, but can be spanned with the intramedullary rod with proximal and distal locking bolts to maintain axial and rotational alignment. Fractures treated by these methods usually go on to rapid consolidation, enveloping the comminuted fragments, which maintain their viability because they are still attached to the soft tissues.

These same principles can be applied to metaphyseal and epiphyseal injuries that require plate stabilization. To achieve indirect reduction, an external fixator, such as the Synthes femoral distractor (Synthes, Philadelphia), is applied to the bone distally and proximally. Varus, valgus, or rotational malalignment is corrected, and the fracture is then distracted, using fluoroscopy to confirm reduction. Only after a good reduction has been achieved is the plate applied to hold the reduction.

These same principles can be utilized without an external device by using a precontoured plate, not only to act as a stabilizer but also to help in reducing an unstable comminuted fracture. In a comminuted distal tibial fracture (Fig. 1, A), for instance, a well-contoured medial plate can be attached to the distal fragment. An articulating tension device is then placed in the distraction mode at the proximal end of the plate. A Verbrugge clamp can be used to attach the plate to the proximal diaphysis, and the comminuted fracture fragments can be teased into place with minimal disruption of their soft-tissue attachments. The articulating tension device is then used in the compression mode, and the fracture is placed under whatever compression the configuration will allow.

The plate is then secured to the diaphysis with as many screws as necessary to achieve stability (Fig. 1, B). At this time, the correct number of screws is still being defined. The use of longer plates without filling every screw hole is common. It has been demonstrated that an eight-hole plate fixed with four screws (in the two end holes and the two center holes) provides as stable a fixation as a six-hole plate with all six screws fixed. Presumably this results in less damage to the bone. Large butterfly fragments may be secured with intrafragmentary lag screws, provisionally stabilized with precisely placed cerclage wires, or left in situ. In the case illustrated in Figure 1, all the holes in the plate were filled, but the butterfly fragment was not captured. One can speculate that the undisturbed blood supply led to rapid union (Fig. 1, C).

Tibial-Plateau Fractures

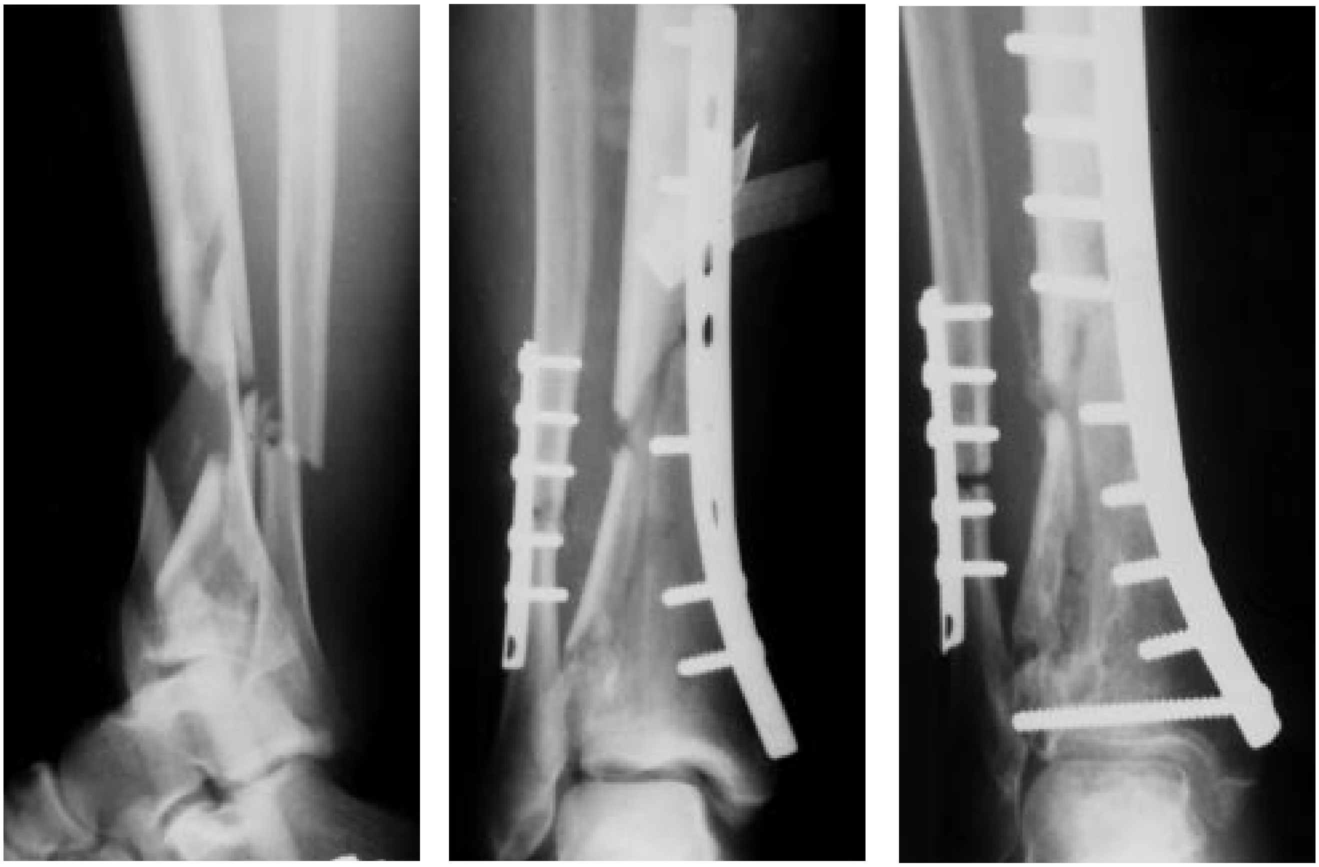
In fractures of the tibial plateau, the femoral distractor or an external fixator, if properly applied, will obtain axial alignment, give stabilization to the injured extremity, and allow surgical reconstruction of the joint surface in a controlled fashion. In a lateral tibial-plateau fracture, the femoral distractor should be placed laterally. The proximal Schantz screw (fixator pin) is placed in the front of the lateral femoral epicondyle, and the distal Schantz screw is placed in the tibial shaft. In a medial tibial-plateau fracture, the reverse configuration would be used with a medially placed distractor. For bicondylar tibial-plateau fractures, two distractors can be used, one medial and one lateral; alternatively, a single anteriorly placed distractor can be used.

The distractor should be placed first, bringing the limb out to length with a little overdistraction of the joint. Radiographs or fluoroscopic images can be obtained to determine whether the proper axial alignment has been obtained. When tension is applied by the distractor in proper alignment, it is not uncommon for many of the displaced fracture fragments to become reduced without any manipulation by the surgeon. In a proximal tibial fracture with intra-articular extension but without depression of the tibial articular surface, it is possible to reduce the fracture by this closed method, allowing the surgical exposure and stabilization to be achieved with minimal disruption of the soft tissues and maximal preservation of blood supply.

In depressed tibial-plateau fractures (Fig. 2), the depressed fragment must be elevated, and the defect must be packed with autogenous bone graft. Much less manipulation of fracture fragments is needed with the distractor technique.

Supracondylar Fractures of the Femur

A severely comminuted intra-articular fracture of the distal femur (Fig. 3, top) is one of the fracture patterns that is most difficult to adequately realign and stabilize. The metaphyseal comminution often is not reducible, nor



A B C

Fig. 1 **A,** Radiograph of a comminuted distal-third tibial-fibular fracture. **B,** Intraoperative radiograph shows reduction with use of a precontoured narrow 4.5-mm dynamic compression plate. Lateral fragment was teased into place without disrupting soft-tissue attachments. **C,** Radiograph obtained 6 months after open reduction and internal fixation shows incorporation of the lateral fragment, which healed without bone grafting.

should an attempt be made to anatomically reconstruct it. With the use of a 95-degree blade plate and cancellous lag screws, the femoral condyles and the intra-articular component of the fracture should be anatomically reconstructed and stabilized (Fig. 3, bottom). Once the blade plate has been properly inserted, a distractor is placed from the femoral condyles (or the tibia) to the proximal third of the femoral shaft on the lateral aspect of the thigh. With distraction, the metaphyseal fragments will usually line up in a relatively anatomic fashion through tension on their soft-tissue attachments. The blade plate is then attached to the lateral aspect of the femoral shaft above the comminution in proper axial and rotational alignment.

By avoiding manipulation of comminuted metaphyseal fractures, the surgeon is creating an “interlocking plate,” as described by Mast.[5] These fractures heal very much like diaphyseal fractures treated with closed reduction and interlocking intramedullary rods (Fig. 3, bottom). The same principle holds true for the proximal femur with comminuted intertrochanteric and subtrochanteric fractures treated with a 95-degree blade plate.

Pilon Fractures

High-energy open and closed pilon fractures (Fig. 4, top) have been reported to have a very high association with wound complications when treated with open reduction and internal fixation.[7,8] Through the use of indirect reduction techniques, these complications can be greatly reduced.[9] Length, alignment, and temporary stabilization can be achieved with a distractor placed perpendicular to the tibia and into the talus on the medial aspect of the lower extremity or by placement of an external fixator with a calcaneal pin connected with medial and lateral bars to an anterior Schantz screw in the midshaft of the tibia (Fig. 4, center). Through this portable traction device, the limb can be brought out to length. The depressed and comminuted metaphyseal fragments of the distal tibia will often align themselves through soft-tissue attachments. This will allow the intra-articular component to be anatomically reduced with greater ease and less soft-tissue dissection. The fragments are then stabilized with the use of lag screws only or lag screws with smaller and thinner neutralization plates (Fig. 4, bottom). The metaphyseal defects should often be grafted with an autogenous bone graft. The use of indirect reduction techniques and ligamentotaxis with an external fixator or femoral distractor has greatly reduced the rate of the complications due to skin sloughing, infection, and loss of reduction of fragments.[9]

Similar techniques can be used on other fractures. For example, when treating a calcaneal fracture, a femoral distractor or an external fixator can be used to obtain height and length of the impacted calcaneus and to improve visualization of the subtalar joint during surgery.

Special Techniques

In addition to the femoral distractor, the external fixator, and

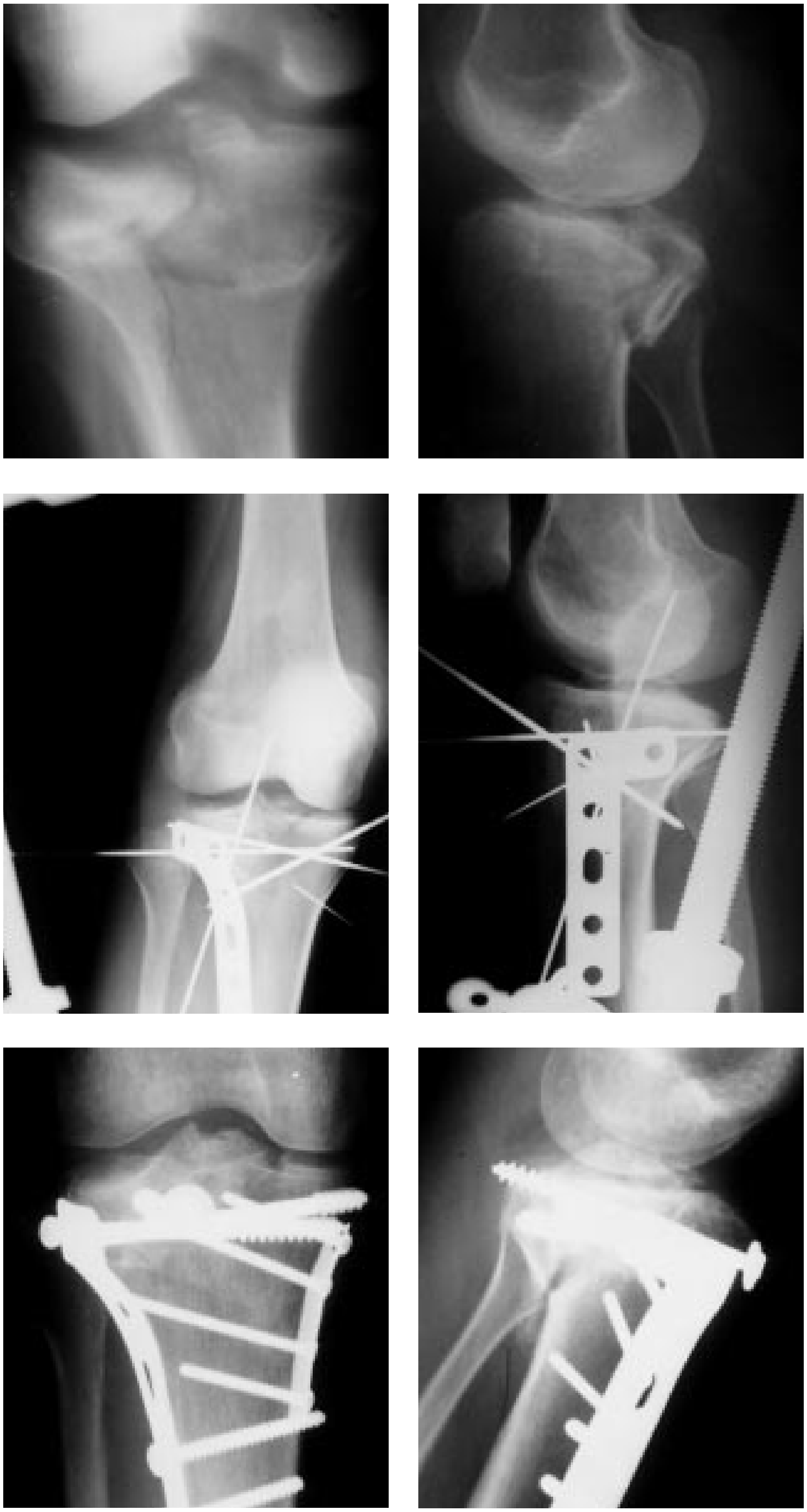


Fig. 2 **Top,** Anteroposterior (AP) **(left)** and lateral **(right)** radiographs of a bicondylar tibial-plateau fracture with depression of the lateral articular surface. **Center,** AP **(left)** and lateral **(right)** radiographs after indirect reduction. Femoral distractor was placed with slight overdistraction of the joint. Lateral buttress plate was then placed, and the fracture fragments were reduced with the use of Steinmann pins. Anatomic restoration was achieved with minimal soft-tissue dissection of the fragments by use of the femoral distractor. **Bottom,** AP **(left)** and lateral **(right)** radiographs of the healed fracture.

Fig. 3 **Top,** AP **(left)** and lateral **(right)** radiographs of a comminuted supracondylar femoral fracture in a 72-year-old woman. **Bottom,** AP **(left)** and lateral **(right)** intraoperative radiographs. An external fixator was used as an indirect reduction device to align the limb. A 95-degree blade plate was secured to the distal fragment, and a Verbrugge clamp was used to hold the plate to the proximal shaft. The comminuted supracondylar fragments were left untouched and attached to their soft tissues.

the plate, other devices can be helpful in obtaining reduction without excessive soft-tissue stripping. If major loose fragments need to be manipulated, a Schantz screw or a threaded Steinmann pin can be placed (percutaneously, if necessary) into the fragment and then attached to a T-handled chuck to enable the surgeon to manipulate the fragment without exposing it. The Schantz screw can be used like a joystick to manipulate the fragment into place.

Judicious use of cerclage wires can aid in manipulating fragments, temporarily stabilizing fragments, and improving bone stability. They should be used only on large fragments with a good deal of soft-tissue attachment because their use necessitates additional soft-tissue stripping during placement. A cerclage wire passer should be placed very gently, while trying to avoid unnecessary additional soft-tissue stripping from the fragment. Precise placement of the fragment is not necessary. The fragment can be teased into place with the use of a small elevator and gentle tightening of the cerclage wire.

The use of small fragments or small, thin buttress plates to augment larger plates as contralateral neutralization plates or the use of an external fixator as a neutralization device, as in a pilon fracture, can obviate the use of two larger plates and the creation of an avascular "bone sandwich."

The use of a small periosteal elevator, a dental pick, or both can help achieve small-fragment reduction without excessive handling. These instruments can be used to elevate the cortex of a depressed fragment or to push on a fragment to tease it into place. The fragments can then be provisionally stabilized with percutaneous placement of a pointed reduction forceps or with Kirschner wires.

Fig. 4 **Top,** AP **(left)** and lateral **(right)** radiographs of a displaced comminuted pilon fracture of the distal tibia and fibula. **Center,** AP **(left)** and lateral **(right)** radiographs show indirect reduction with use of an external fixator with a Schantz screw placed in the midshaft of the tibia and a Steinmann pin placed through the calcaneus. Nearly anatomic reduction of the tibial plafond was achieved without surgical intervention by means of soft-tissue tension with use of the external fixator. **Bottom,** AP **(left)** and lateral **(right)** intraoperative radiographs. A small fragment blade was placed with minimal soft-tissue dissection. Anatomic reduction of the tibial plafond with normal axial alignment was achieved with indirect reduction and minimal manipulation of the fracture fragments.

Paradoxically, longer skin incisions can be important in achieving the goal of protecting the soft tissues. A longer skin incision will allow manipulation of fragments and placement of an internal fixation device without excessive traction on the skin, which can lead to skin necrosis and wound breakdown.

Summary

Indirect reduction techniques, as outlined by Mast et al,[5] have greatly improved our ability to manage high-energy and complex fractures. The evolution away from rigid, anatomic fracture stabilization toward stable, biologically benign fracture fixation has improved the care of high-energy injuries by reducing the complications that are often associated with excessive soft-tissue dissection and handling. With thorough assessment of the soft-tissue injury, careful preoperative planning of the fracture reduction and stabilization, proper soft-tissue handling, and the use of indirect reduction techniques, we can not only reduce complications but also improve healing of the fracture.

References

1. Behrens F: Fractures with soft tissue injuries, in Browner BD, Jupiter JB, Levine AM, et al (eds): *Skeletal Trauma: Fractures, Dislocations, Ligamentous Injuries.* Philadelphia: WB Saunders, 1992, vol 1, p 314.
2. Johner R, Wruhs O: Classification of tibial shaft fractures and correlation with results after rigid internal fixation. *Clin Orthop* 1983;178:7-25.
3. Oestern HJ, Tscherne H: Pathophysiology and classification of soft tissue injuries associated with fractures, in Tscherne H, Gotzen L (eds): *Fractures With Soft Tissue Injuries.* Berlin: Springer-Verlag, 1984, pp 5-7.
4. Müller ME, Allgöwer M, Willenegger H (eds): *Technique of Internal Fixation of Fractures.* Berlin: Springer-Verlag, 1965.
5. Mast J, Jakob R, Ganz R (eds): *Planning and Reduction Technique in Fracture Surgery.* Berlin: Springer-Verlag, 1989.
6. Mast JW: Preoperative planning in the surgical correction of tibial nonunions and malunions. *Clin Orthop* 1983;178:26-30.
7. Ovadia DN, Beals RK: Fractures of the tibial plafond. *J Bone Joint Surg Am* 1986;68:543-551.
8. Pierce RO Jr, Heinrich JH: Comminuted intra-articular fractures of the distal tibia. *J Trauma* 1979;19:828-832.
9. Bone L, Stegemann P, McNamara K, et al: External fixation of severely comminuted and open tibial pilon fractures. *Clin Orthop* 1993;292:101-107.