Intragrade Intramedullary Nailing of an Open Tibial Shaft Fracture in a Patient With Concomitant Ipsilateral Total Knee Arthroplasty

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Abstract

Open tibial shaft fracture occurring below an ipsilateral total knee arthroplasty (TKA) is a unique injury pattern that presents an additional degree of complexity to an already challenging treatment algorithm. Tibial shaft fracture is a surgical emergency requiring respect for the soft-tissue envelope and consideration of the biomechanical and biologic factors involved in healing. Treatment with an intramedullary nail relative to other types of internal or external fixation methods optimizes these factors and minimizes the risks of nonunion, malunion, infection, soft-tissue compromise, and reoperation, which are prevalent after this fracture. However, tibial shaft fracture associated with an ipsilateral TKA complicates standard treatment principles and increases the risks after surgery. In many instances, this type of injury pattern in a patient with medical comorbidities that would impede fracture and wound healing would make a limb amputation the preferred method of treatment. However, in this case report, we examine treatment options for an open tibial shaft fracture in the setting of an ipsilateral TKA and propose a method of limb salvage in a patient with medical comorbidities sustaining this injury pattern.

Fracture of the tibial shaft below an ipsilateral total knee arthroplasty (TKA) is an infrequently occurring injury pattern that presents a unique treatment scenario. The high predilection for open wounds associated with these diaphyseal fractures further complicates the treatment algorithm.[1,2] The standard principles of treatment for open tibial shaft fractures entail open fracture débridement followed by adequate fracture reduction and stable skeletal fixation in a manner that limits adverse complications of this injury, which include nonunion, malunion, infection, soft-tissue compromise, and reoperation.[3,4]

Antegrade intramedullary (IM) tibial nailing has become standard treatment for tibial shaft fractures.[5-7] This minimally invasive method of fixation limits damage to the soft-tissue envelope, provides superior neutralization of the mechanical forces to provide a template for biologic fracture healing, and allows the best options for revision procedures in the event of inadequate healing. This case report examines treatment options for an open tibial shaft fracture of an ipsilateral TKA, complicating the standard treatment of antegrade tibial nailing. The patient provided written informed consent for print and electronic publication of this case report.

Case Report

A 66-year-old woman became light-headed and fell down a flight of stairs at her home. She was taken to the local emergency room where she presented with left leg pain, deformity, and a skin wound. The wound was dressed with sterile gauze and the extremity immobilized in a temporary plaster splint after which the patient was transferred to our level I trauma center. The accident occurred shortly after dawn, and she received definitive evaluation at the level I trauma center before noon the same day, making the time from injury to evaluation less than 6 hours.

The patient's medical history was significant for depressive and anxiety disorders, fibromyalgia, hypertension, peripheral vascular disease, and lymphedema. Her surgical history was significant for a remote left TKA and remote open reduction with internal fixation of a left lateral malleolus fracture. She was prescribed antidepressant and anti-anxiolytic medications, narcotic medication, and antihypertensive therapy. She smoked 1 pack of cigarettes per day for approximately 20 years and denied alcohol consumption or illicit drug use. Her body mass index was 37.5, and she ambulated independently in the community.

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Upon presentation at our hospital, the patient was hemodynamically stable with no discernable systemic compromise from the extremity injury. An examination of the left lower extremity showed a large longitudinal skin wound over the anteromedial surface of the lower leg measuring roughly 10 cm in length with obvious periosteal stripping and protrusion of the proximal fracture segment. Neurologic motor and sensory function was intact in the lower extremities and pulses were strong. Lower leg compartments were soft. Radiographic imaging confirmed a short oblique fracture of the distal third of the tibial diaphysis. The left TKA was intact with no signs of component loosening or periprosthetic fracture (**Figures 1A, 1B**).

Figure 1. (A) Anteroposterior and (B) lateral tibial radiographs showing the initial injury pattern with ipsilateral total knee arthroplasty.

The patient urgently received broad-spectrum antibiotics with intravenous (IV) cefazolin and IV gentamicin as well as tetanus vaccination. Her fracture was temporarily stabilized in a long-leg splint before she was transported to the operating room. Based upon the characteristics of the patient and the open fracture, we had an extensive discussion with the patient regarding the severity of her injury and treatment options, including nonoperative treatment, operative irrigation and débridement with skeletal stabilization, or below-knee amputation. The patient was adamant that limb salvage be attempted despite adequate understanding that she was exposing herself to risk of multiple reoperations from potential complications, as well as systemic medical compromise. Thus, we considered possible techniques for internal fixation of the tibial shaft fracture and treatment of the open wound.

Two primary technical concerns were addressed in the preoperative planning phase: the first was the need for primary closure of the open wound. This patient had a large wound over the anteromedial surface of the distal third of the tibia with scant soft-tissue coverage. Consequently, skin graft alone would not be adequate. While a muscle flap is another option, it would be prone to failure because of the patient's age and comorbidities, including hypertension, peripheral vascular disease, lymphedema, and tobacco use. Therefore, we hoped to achieve primary closure. Our second major concern was that the method of fixation must be biomechanically sound without impeding our first goal of primary wound closure. In the setting of an ipsilateral TKA, standard antegrade IM nail fixation would not be possible. While we considered plate fixation, it is biomechanically less stable than an IM nail, and we had great concerns about wound complications. External fixation—uniplanar and mutliplanar (eg, Ilizarov)—was limited by issues of long-term fracture stability and risk of pin-site infection. Both methods appeared less desirable compared with IM nail fixation. Thus, we devised an innovative technique to implant an IM nail into the tibial canal.

Figure 2. Limited intramedullary reaming using a cannulated technique into the proximal tibial segment through the original traumatic wound. The same method of reaming was used for the distal fracture segment.

The operative procedure first entailed standard open fracture care comprising débridement of nonviable soft tissue from the traumatic anteromedial tibial wound, curettage of the fractured bone ends, and irrigation with pulse-jet lavage. Then, we turned to reduction and internal fixation of the bony injury. The large traumatic wound was not extended and was used as the primary surgical approach to permit introduction of the IM nail into the canal. Through the traumatic wound, we performed limited reaming of the proximal and distal fracture segments. Using a cannulated technique over guide wires, we reamed to 11 mm (**Figure 2**). The tourniquet was not used during the IM reaming. We determined the

Figure 3. After proximal and distal canal preparation, a short intramedullary nail was completely advanced into the proximal tibial segment.

maximum nail length (approximately 22 cm) by measuring the distance from the fracture to the bone interface with the tibial component. We used a 10×200-mm femoral retrograde Synthes nail (Synthes, Inc, West Chester, Pennsylvania) for the procedure, although we considered an IM humerus nail. Through the traumatic wound, the nail was advanced in its entirety into the proximal tibial segment (**Figure 3**). The fracture was reduced anatomically and held with a bone tenaculum (**Figures 4A, 4B**). A medial cortical window proximal to the proximal extent of the IM nail was created through which the Synthes IM reduction tool (aluminum femoral finger) was advanced to impact the IM nail antegrade through the fracture site into the distal segment (**Figure 5**). After placement of the nail was complete, the excised fragment of bone was reinserted into the cortical window. The Synthes IM reduction tool was chosen for its diameter, length, and, most important, its relative flexibility. While maintaining reduction of the fracture, cross-locking of the nail was performed at the distal and proximal ends with perfect circle technique through stab incisions. Length, alignment, and rotation of the affected tibia were deemed symmetric to the contralateral side based on preoperative clinical measurements. Final fluoroscopic images showed appropriate alignment and proper implant placement.

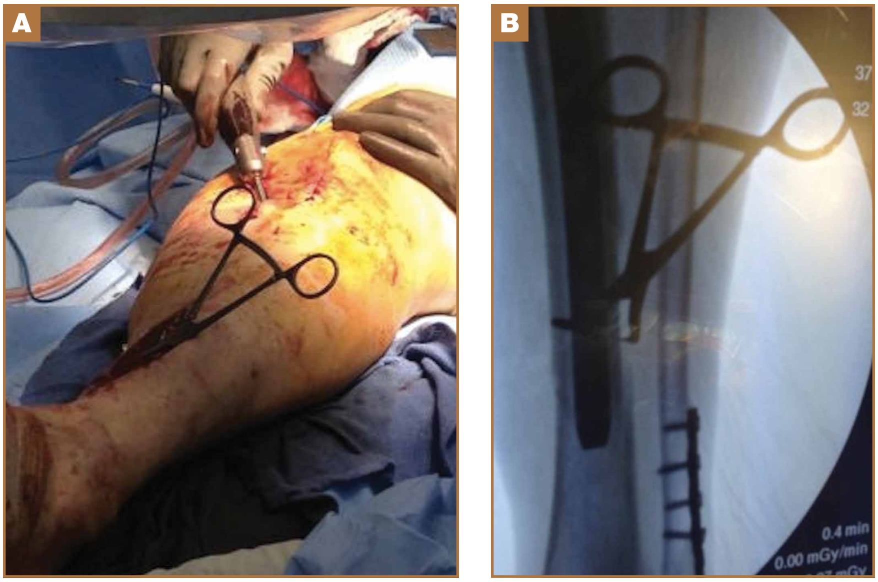

Figure 4. (A) After the intramedullary nail was completely advanced into the proximal segment, the fracture was directly reduced with a bone clamp. (B) Fluoroscopic image showing fracture reduction with a bone clamp.

Following open reduction and internal fixation of the fracture, the traumatic and surgical wounds were closed in a layered fashion. A subcutaneous drain and an incisional vacuum-assisted closure (VAC) device were applied to the closed traumatic wound, and a second subcutaneous drain was placed at the site of the cortical window. The patient tolerated the procedure well without perioperative complications.

In the acute period after surgery, the patient's neurologic and vascular status remained stable. Her muscular compartments remained soft and compressible on physical examination, and her pain was well controlled. The incisional VAC and the 2 Hemovac drains were removed within a few days of the operation. Intravenous cefazolin was continued through her hospital stay and she was transitioned to oral cephalexin at discharge as recommended by our infectious disease colleagues to complete a 10-day course of antibiotic therapy.

Figure 5. A medial cortectomy was created through which the nail was advanced through the distal segment using the Synthes intramedullary reduction tool (Synthes, Inc, West Chester, Pennsylvania).

At the time of discharge—within 1 week of her initial injury—the patient's wounds were dry and she was ambulatory with a walker. She was instructed to remain non-weight-bearing and to keep her wounds clean and dry with follow-up in 2 weeks. Over 6 to 8 weeks after surgery, the patient's weight-bearing status was gradually advanced to full weight-bearing, and she achieved union of the fracture and uneventful healing of the traumatic wound (**Figures 6A, 6B, 7**).

Figure 6. (A) Anteroposterior and (B) lateral tibial radiographs 8 weeks after surgery showing union of the fracture.

Figure 7. Healed traumatic wound 8 weeks after surgery.

Discussion

We have presented a case of an open distal-third tibial shaft fracture in a 66-year-old obese woman with an ipsilateral TKA. Open fracture of the tibial shaft is potentially limb-threatening because of the challenging management of the bone and soft-tissue injury. The presence of an ipsilateral TKA adds a degree of complexity. From a biomechanical standpoint, the lower interdigitation of cortical bone, coupled with weight-bearing of the lower extremity, subjects the tibia diaphysis to issues of rotation, length, and angular control.[8] Due to the diaphyseal nature of the fracture, consisting of cortical bone with comparably lower vascularity and a small soft-tissue envelope, these fractures heal very slowly and often take as many as 6 to 9 months to achieve union.[9,10] Furthermore, as was the case here, short oblique fractures of the tibial shaft often occur under bending stresses that also cause significant damage to the tibial soft-tissue envelope and periosteum, as indicated by the open wound. This disruption deprives the fracture and soft tissues of important vascular supply that is critical to healing and to avoiding infection and soft-tissue necrosis.[11-13] The effects of treatment may magnify these biomechanical and biologic consequences. Ideal fixation serves to minimize potential complications by neutralizing the biomechanical forces to permit fracture healing while also limiting the amount of soft-tissue trauma and tension. Because the challenges associated with treatment of open tibial shaft fractures make it a limb-threatening injury in a patient with poor peripheral circulation, it is appropriate to consider primary amputation.[14]

If circumstances warrant an attempt at limb salvage, IM nailing with static interlocking screws would typically be the standard of care for treatment of an open fracture of the tibia shaft. This provides stable internal fixation that controls tibial alignment in 6° of freedom and neutralizes bending forces with less strain on the implant because of the IM position.[15,16] In addition to superior neutralization of the biomechanical forces, IM nailing is also a minimally invasive approach that limits further trauma to the periosteum and soft-tissue envelope surrounding the fracture site. This optimizes biologic fracture healing and minimizes complications of malunion, infection, and nonunion.[17-19] Moreover, by limiting further damage to the surrounding soft tissue, there is a diminished need for a plastic surgery procedure to reestablish soft-tissue integrity overlying the fracture site. This is particularly advantageous in patients with medical comorbidities that make skin grafts and muscle flaps less likely to succeed. For these reasons, IM nailing was our preferred method of fixation in our patient; however, the presence of an ipsilateral TKA made this standard treatment through an antegrade approach impossible.

Consequently, we considered other methods of fixation, including internal fixation with plate application or external fixation with a multiplanar construct, such as an Ilizarov frame. Some orthopedists consider plate application a superior technique for achieving fracture union because it results in interfragmentary compression, which promotes primary healing. Interestingly, some would argue that the absolute stability provided by the plate may be too rigid a construct to enable optimal fracture healing biology if compression is not achieved.[20] However, to allow primary healing to complete fracture union, absolute stability with rigid and strong fixation must be provided. In the tibial shaft, with large bending forces and rotational moments, this is difficult to achieve with plate fixation alone.[8] Furthermore, plate application often requires relatively extensive soft-tissue dissection and may impede biologic factors in healing of the bone and soft tissue, increasing the likelihood of infection.[21] Finally, adequate plate fixation would significantly increase the soft-tissue volume at this location, further compromising the soft tissues and impeding our goal of primary wound closure.

A uniplanar or mutliplanar external fixator would be an appealing option for definitive fixation because of minimal additional soft-tissue damage that is created during its application. However, it is difficult to achieve adequate stability to encourage either primary, or more commonly, secondary healing in the adult or elderly population.[22] An Ilizarov frame is a multiplanar external construct, which allows reconstructive applications because of multiple points of fixation in bone.[23] However, the multiple fixation points result in burdensome size of the implant for the patient and requires patient compliance to minimize risk of pin-site infection, which is magnified in a patient with multiple medical comorbid conditions. Furthermore, when comparing treatment options that aim to minimize additional soft-tissue trauma at the site of injury, there is little evidence to show a lower risk of infection at the open fracture site compared with IM nailing.[24,25] Thus, in our patient, customary treatment of an open tibial shaft fracture using antegrade IM nailing was not possible, while plate application and external fixation, though potential treatment options, would be relatively contraindicated due to a higher likelihood of failure.

Consequently, primary amputation may be the most appropriate treatment option in a patient with multiple comorbid medical conditions, including peripheral vascular disease. Primary amputation prevents morbidity and mortality associated with complications related to the aforementioned treatment options, as well as limiting risks associated with multiple reoperations.[14,25] Studies illustrate that patient functional outcomes after primary amputation are equal to and, in some cases, superior to those patients undergoing limb salvage procedures for open tibial shaft fractures.[26-28]

Despite the appropriateness of primary amputation in this case, the patient requested limb salvage. Therefore, other innovative treatment options were explored to achieve our goals of primary wound closure and stable internal fixation. Previous case reports have examined retrograde IM nailing as a means of rigidly fixing tibial shaft fractures in the setting of poor soft tissues or ipsilateral knee arthroplasty.[29-31] However, the retrograde approach to IM nailing requires passage of reamers through the subtalar and ankle joints, leading to associated arthritis in these joints or, more commonly, rigidity because the final nail position often crosses these joints in addition to the fracture site. Therefore, a novel approach for IM nailing was performed using the large open-fracture wound. Through the traumatic wound, open-fracture débridement was first performed, followed by placement of a nail into the medullary canal with little additional disruption of the surrounding periosteum or soft tissue.

Possible complications of this novel method for IM nail passage warrant discussion. First, potentially unfavorable aspects associated with IM reaming include impairment of endosteal blood circulation in the subacute postoperative period.[32-34] If the patient develops complications, such as deep infection, nonunion, hardware failure, or periprosthetic fracture, treatment options that require removal of the nail would be very difficult to execute because this nail was passed "intragrade," or through the fracture site, not from the knee or the calcaneus. However, unique to this case of intragrade nailing, complications associated with the proximal cortical window may occur. In particular, unintended cortical fracture may happen during impaction of the nail into the distal segment of the fracture after reduction. However, this complication may be avoided with the use of a 1-cm wide and 2-cm long window and the use of the malleable aluminum femoral finger (Synthes). Furthermore, use of a femoral nail is recommended because the Herzog curve of a tibial nail cannot be inserted in the proximal tibial segment using an "intragrade" nailing technique. However, fracture may occur intraoperatively or during rehabilitation after surgery because the cortical window creates a region of high stress distal to the tibial arthroplasty component. Likewise, the area of bone between the proximal extent of the IM nail and tibial component of the TKA represents an area of high stress susceptible to periprosthetic fracture.

Conclusion

We have presented a case of a high-energy open distal tibial diaphyseal fracture in a 66-year-old woman with medical comorbidities and treatment complicated by the presence of an ipsilateral TKA. Intramedullary nailing has become the standard of care for open fractures of the tibial diaphysis because of the high rate of union with little additional soft-tissue damage at the fracture site. Despite these advantages, the ipsilateral TKA complicated the placement of an antegrade tibial nail. An alternative treatment, such as an external fixation using an Ilizarov frame, would present equally challenging treatment aspects, including patient compliance, with little proven benefit over an IM nail. Application of a plate would be less desirable because of increased risk of infection at the fracture site, soft-tissue and periosteum disruption, and muscle necrosis compared with other treatment options. Primary amputation was an appropriate consideration for this patient given her comorbid medical circumstances, but the patient refused this treatment option. Therefore, we created a novel approach to place an IM nail, using the traumatic wound to achieve access to the medullary canal proximally and distally.

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