Tibial shaft fractures are the most common of all long bone fractures. The National Center for Health Statistics has reported that >490,000 fractures of the tibia occur each year in the United States. Although many tibial fractures can be managed conservatively, the current treatment of unstable fractures, open fractures, fractures associated with compartment syndrome, and high-energy fractures is operative stabilization.

Early and late onset infections during the management of tibial fractures are known complications. The overall incidence of deep infection following intramedullary nailing for closed fractures ranges from 0%-1% and 0%-11% for open fractures, depending on the severity of the soft-tissue injury, contamination, and fixation. Treatment of infection is still a major problem. With the advent of better antibiotics and techniques such as the antibiotic bead pouch, the rate of infection has been reduced significantly.

The current management of infected tibial nails consists of two main objectives. Infection control, which usually is achieved by hardware removal with debridement and local delivery of antibiotics by antibiotic beads or an irrigation-perfusion technique, and fracture union, which usually is accomplished by providing alternative fixation, mostly external fixation.

In most cases, the local delivery of antibiotics in intramedullary infections can be difficult because of limited ability to introduce antibiotic beads in the medullary canal. This article presents an alternative treatment to solve this problem. We have extended the concept of polymethylmethacrylate.
late (PMMA) sticks introduced by Klaus Klemm and developed the antibiotic-impregnated cement nail. Seven patients with infected tibial nails and chronic osteomyelitis of the tibia have been treated successfully using the antibiotic-impregnated acrylic cement nail. This article focuses on the technique of antibiotic nail placement.

**SURGICAL TECHNIQUE**

**Materials**

The materials necessary to prepare the cement nail include (Figure 1):

- Two packs of bone cement. The authors prefer Simplex cement (Stryker Orthopaedics, Rutherford, NJ) along with a vacuum cement mixer and cement gun.
- Chest tube 40 French (Atrium Medical Corp, Hudson, NH) cut to the appropriate length, which usually is the same as the nail. The authors use the 40 French chest tube as the inner diameter corresponds to 10 mm.
- Ender nails with a 3.5-mm diameter, which allow adequate cement mantle around the nail and provide strength. The length of the Ender nail should be 1 cm longer than the chest tube to allow the eye of the Ender nail to be used for extraction (Figures 2 and 3). The Ender nail was chosen because of its curve, which allows insertion into the medullary canal.
- Tobramycin powder 1.2-g vials. The authors use 1.2 g of tobramycin to every 40 g packet of bone cement.

**Antibiotic Nail Preparation**

The chest tube is cut to the appropriate length. Tobramycin powder, 2.4 g, is added to the two packs of bone cement powder and mixed. Liquid polymer is added and mixed using the vacuum mixer. While the cement is in a highly viscous stage, it is transferred to the cement gun. It is important to do this in the high viscous state, as injection of the cement into the chest tube is easier.

The Ender nail is gently inserted into the chest tube, allowing the cement to envelope the nail. The eye of the Ender nail is left proud outside the chest tube to facilitate cement nail removal (Figure 3).

Once the bone cement hardens, the chest tube is cut with a scalpel and gently stripped of the antibiotic nail (Figures 4 and 5). The polyethylene tube peels away from the hardened bone cement as both materials have smooth surfaces (Figure 6). (In one case where the Ender nail did not extend the full length of the bone cement cylinder, the last small portion of the bone cement broke away and remained in the canal after the nail was removed. This piece

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**Infection after intramedullary nail fixation...spreads along the length of the nail and involves the entire length of bone.**
was removed by making an incision over the anteromedial distal tibia, cutting a small bone window, and taking out the piece with a pituitary rongeur.

The antibiotic nail usually is prepared on the back operating table while the surgeon is removing the infected nail and generally fitted with a patellar tendon bearing brace to provide rotational stability. Weight bearing up to 40 lbs is allowed based on fracture healing. Follow-up includes complete blood cell count, erythrocyte sedimentation rate, and C-reactive protein for activity of infection.

The antibiotic nail is not only used for the delivery of antibiotics but to provide some stability to the fracture.

debriding the sinus and wound. After nail removal, the canal is reamed at least 1-2 mm larger than the nail to remove the slimy endosteal layer. Reaming is an important part of debridement. Intraoperative reamings and tissue are sent for routine culture and sensitivity. In most cases, the canal is reamed to a minimum of 11 mm to place a 10-mm antibiotic cement nail.

Once the bony preparation is done, the antibiotic nail is inserted in the medullary canal with the eye of the Ender nail proximal. The nail is inserted with a gentle tap. If resistance is encountered, re-reaming before nail insertion is recommended. The antibiotic nail is inserted flush or slightly proud from the anterior cortex of the tibia to facilitate its removal.

**Postoperative Management**

Postoperatively, the patient is kept on appropriate intravenous antibiotics based on the culture reports for 1 week, followed by oral antibiotics for 6 weeks. The patient is

**Antibiotic Nail Removal**

Once the infection is controlled, based on the laboratory parameters and clinical findings, the antibiotic nail is removed at approximately 6 weeks and exchanged to a standard tibial intramedullary nail with proximal and distal interlocking. Antibiotic nail removal is accomplished by exposing the eye of the Ender nail. The Ender nail extractor hook is used for extraction. At antibiotic nail removal, the canal is reamed again and the material sent for culture. If the material is significantly culture-positive, the procedure is repeated or a different treatment approach is tried.

**CASE REPORT**

A 58-year-old man presented with septic nonunion of a right distal tibia fracture. Symptoms included discharging sinus, persistent pain on weight bearing, and swelling. AP and lateral radiographs were obtained. Nine months prior to presentation, the patient had a closed fracture of the distal tibia that was managed with open reduction and internal fixation, which subsequently became infected. Multiple procedures were performed including hardware removal, external fixator placement, bone graft procedures, and intramedullary nailing.

The intramedullary nail was removed and an antibiotic rod was placed (Figure 7). Cultures showed methicillin-resistant *Staphylococcus aureus* susceptible to vancomycin and bactrim. He was initially placed on vancomycin for 3 days and was discharged home on bactrim. Once the infection was under control, the antibiotic rod was exchanged to a standard interlocking tibial nail. At latest follow-up, the fracture had healed.

**DISCUSSION**

Antibiotic-impregnated cement was first used to treat infection associated with hip arthroplasty in the early 1970s. Antibiotic bead chains were subsequently introduced by Klemm in 1974 and have been widely used in established bony and soft-tissue infection. Their proposed use as a prophylaxis against infection in open fractures has been more recent.

The introduction of the antibiotic bead pouch technique has reduced the incidence of infection in the management of open fractures. The pathomechanics of infection after plating are different from those of infection after intramedullary nailing. Infection after plate osteosynthesis usually involves the fracture site and causes local sequestration. The infection is primarily extramedullary and the medullary cavity involvement is limited to the segment...
where the plate was. The intramedullary canal proximal and distal to the infection usually is not involved. Placement of antibiotic beads delivers the antibiotics locally and helps control the infection. Infection after intramedullary nail fixation usually involves the entire medullary canal. Infection spreads along the length of the nail and involves the entire length of the bone. Infection is primarily intramedullary. This is the rationale of placement of intramedullary antibiotic bead chains.

Placement of an intramedullary antibiotic bead chain from the nail insertion site, after nail removal, poses some practical problems. Antibiotic bead chains are difficult to place in the medullary canal. They are incompatible with external fixators, as the chain cannot be introduced after pin placement. If placed before the pins, the chains cannot be removed easily. To overcome this, Klemm introduced the PMMA stick, which was fabricated by extruding antibiotic-laden PMMA on a continuous monofilament wire. This was easy to introduce and remove. It could be passed around the fixator pins and, if necessary, could be exchanged as a minor procedure. The main disadvantages of the PMMA stick are the fact that it does not provide any stability to the fracture, requires external fixation, and has not been evaluated in a prospective trial.

The antibiotic-impregnated cement nail is an extension of the antibiotic PMMA stick used by Klemm. The antibiotic nail is not only used for the delivery of antibiotics but to provide some stability to the fracture. The antibiotic cement nail has several advantages over antibiotic beads in these situations. It provides more intimate contact with the medullary canal and hence more elution of antibiotic to the endosteal surface. It can be inserted through the same portal of entry as the original nail. The nail traverses the entire medullary cavity and enables a more effective delivery of the antibiotics. It is easy to remove and subsequent exchange nailing is technically easier than bead chain.

Based on our experience and the report by Ohtsuka et al., we believe the antibiotic-impregnated acrylic cement nail is an effective means of treating post intramedullary nail infection. Although our experience is limited to a small group of patients, future controlled prospective trials with large numbers of patients will help validate this technique. Future indications may include infections of other long bone fractures and the treatment of chronic osteomyelitis of long bones.

**REFERENCES**