Compression of Nonunions With the PRECICE Magnetic Intramedullary Compression Nail

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Summary: The magnetic intramedullary lengthening nail can be predistracted and used to compress bony interfaces to assist in the healing of nonunions of long bones and to accelerate union at difficult to heal fractures and osteotomy sites. This requires no special implant apart from the lengthening nail. Technical considerations include predistraction of the nail on the back table, overreaming of the canal, shortening at the defect site, and applying compression over several days.

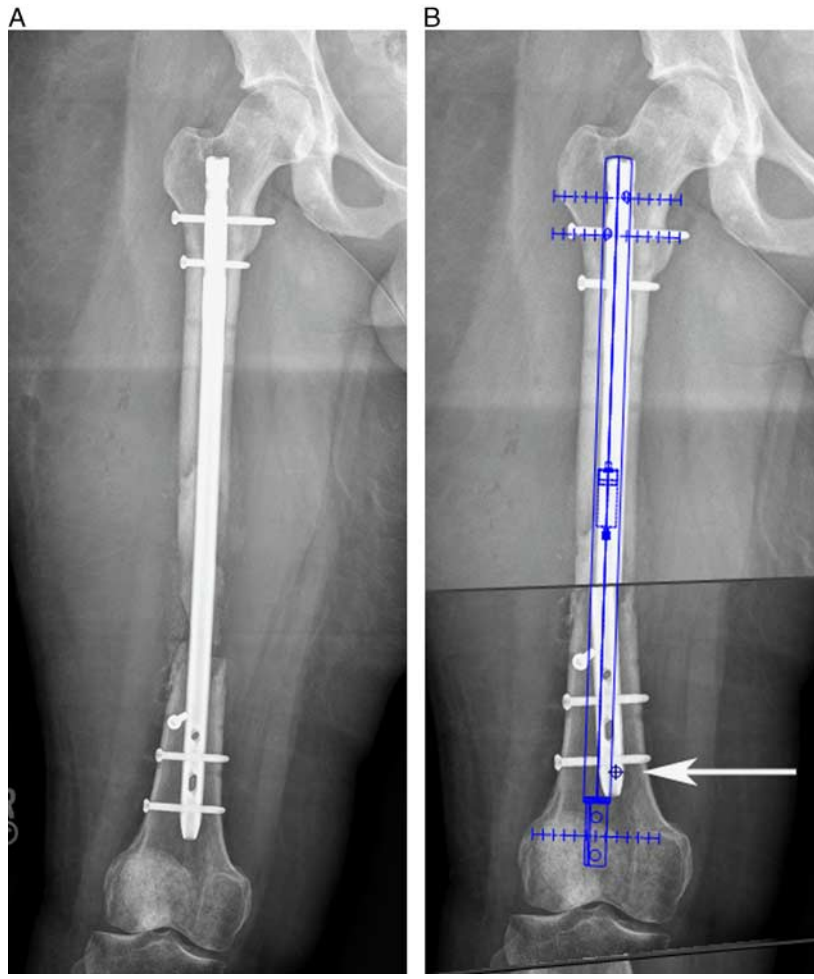

FIGURE 1. This patient sustained a high energy open femur fracture fixed with an intramedullary nail that was complicated by deep infection. Staged exchange intramedullary nailing with local antibiotics resulted in chronic osteomyelitis and nonunion. A large area of necrotic bone is seen on this radiograph (A). There is a contaminated implant and valgus angulation despite the use of a blocking screw. Preoperative planning included a 10 cm bone resection, limb shortening, and insertion of a PRECICE magnetic intramedullary compression nail predistracted 15 mm with an additional blocking screw (arrow) (B).

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A.T.F.: Outside of this work potential conflicts include consultant for Smith and Nephew, NuVasive, and Depuy Synthes (J&J).

For reprint requests, or additional information and guidance on the techniques described in the article, please contact Austin T. Fragomen, MD, at fragomena@hss.edu or by mail at Clinical Orthopaedics, Weill Medical College of Cornell University, The Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021. You may inquire whether the author(s) will agree to phone conferences and/or visits regarding these techniques.

Patients can weight-bear immediately and often return to work quickly. The same nail can be used for bone lengthening, after union is achieved, by creating an osteotomy around the implant. Results show high union rates with minimal morbidity.

Key Words: PRECICE—nonunion—compression nail—limb lengthening—bone transport—sleeper nail.

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INDICATIONS

The magnetic intramedullary compression nail (MICN) is indicated for diaphyseal nonunions of long bones. The additional expense of this implant may make it better suited for recalcitrant nonunions, however, using this technique earlier in treatment may offset the total cost of care by preventing failures of other methods saving the patient and the medical system the cost of an additional surgery. This savings was observed with the same implant when it was used for long bone lengthening surgery in lieu of the standard lengthening-over-nail technique.[1] Compression is beneficial in many settings where healing is required, and nonunion is not the sole indication for this technique. The PRECICE nail (NuVasive, San Diego, CA) has been used in compression mode for difficult-to-heal, acute humeral fractures[2] and in oncologic surgery to enhance the incorporation of intercalary allografts after tumor resection.[3] This sustained compression method can also useful in deformity correction surgery to accelerate osteosynthesis of an osteotomy created through sclerotic diaphyseal bone or in compromised hosts.

There are no absolute contraindications to compression nailing, but the inability to pass an intramedullary (IM) nail would preclude this method. Metaphyseal nonunions may not provide enough bone stock for the nail to control the articular fragment and may be better managed with circular fixation.[4]

SURGICAL PLANNING

Surgical planning is fundamental to the successful treatment of long bone fracture nonunion. Planning starts with the patient's history and physical examination. A history of infection, current use of antibiotics, wound healing challenges, plastic surgical intervention, unexplained pain, obstructive psychological stress, chronic opioid use, and smoking/comorbidities are examples of variables that can significantly impact the decision of when to intervene surgically, whether to stage surgery, or which reconstruction method best suits the patient. Physical examination will provide valuable input that cannot be gleaned from the radiographs. A sensory examination will provide the baseline neurological status and may indicate further workup for nerve releases or neuroma management. The pulse examination may reveal a single vessel limb which can influence surgical approach and the need for a vascular surgeon on standby. A single vessel limb may also influence the decision to perform acute versus gradual shortening at the nonunion site. Adjacent joint mobility may

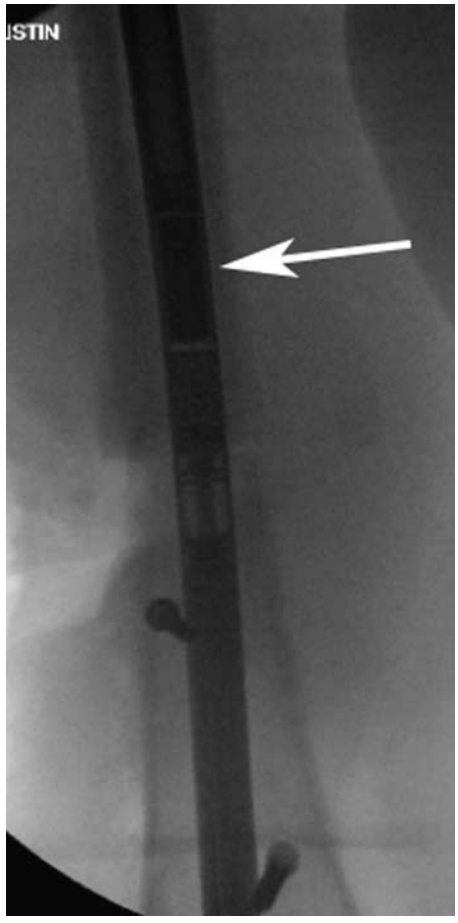

FIGURE 2. The magnet (arrow) can be visualized as a dark rectangle within the magnetic intramedullary compression nail on this intraoperative fluoroscopy film.

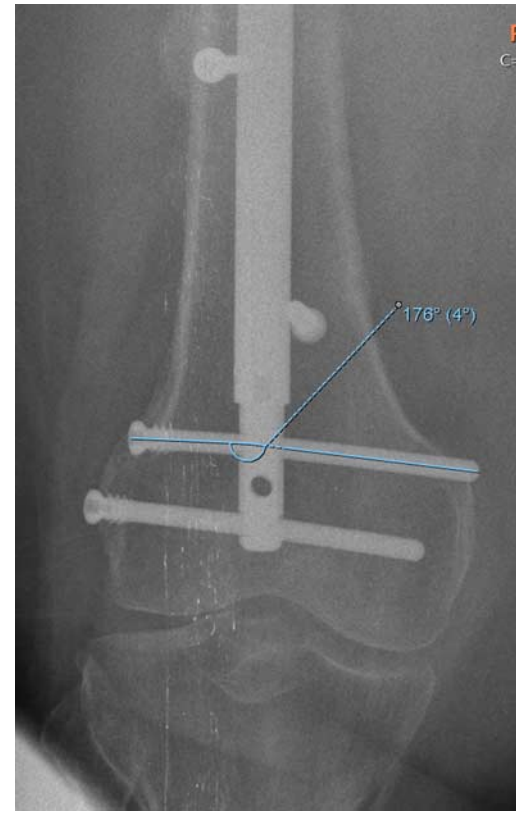

FIGURE 3. This postoperative radiograph shows correction of the diaphyseal valgus and deflection of the distal locking bolts of 4 degrees implying strong compression at the nonunion site.

impact the decision to use internal fixation versus external fixation; a tibia nonunion with an ankle joint contracture may be better addressed with an external fixator for concomitant treatment of both the pseudarthrosis and the articular stiffness. The presence of a free tissue transfer may require the presence of a microvascular surgeon. A visibly draining sinus will confirm the presence of a fracture related infection which could influence the choice of implant, necessitate staging surgery, require advanced soft tissue coverage, or suggest the need for local antibiotic placement in the IM canal. This global analysis will reveal the "personality" of the nonunion.

Infection is always a concern when embarking on nonunion surgery with an intent to implant internal fixation. Even a benign appearing nonunion has a 28% chance of yielding positive cultures; fortunately, few of those require implant removal.[5] Established infection is not an absolute contraindication to magnetic compression nailing but must be approached wisely to mitigate complications. With thorough bony debridement and insertion of antibiotic-impregnated, absorbable (calcium sulfate) cement into the IM canal immediately prior to nail insertion, hardware infection can be prevented in this author's experience.[4,6] Alternatively, a staged approach starting with an antibiotic polymethylmethacrylate-coated static nail can be used[7,8] or a circular external fixator can be used to treat the infected nonunion.[9] Infection management should be worked into the planning.

Radiographic assessment of the involved bone will strongly influence the ability to use an IM implant. Once it is determined that a compression nail is feasible, then the radiograph is studied, anticipating the implant dimensions that will be needed. This requires a calibrated x-ray. Nail length planning must consider any intended resection of bone and subsequent additional shortening. The thick barrel of the nail should cross the nonunion site for optimal stability. One should also foresee the need for future lengthening with the same implant which may require a longer nail than otherwise required for simple compression. The nails require predistraction which should also be considered when deciding nail length. The distraction is performed in the operating room by the surgeon using the rapid distraction tool which moves the nail 7 mm/min. The more the nail is predistracted, the less stroke it has for later lengthening. If there is bone contact after nonunion repair, then predistraction of 13 mm has been shown to be adequate; the average amount the nail will shorten is 6.7 mm with a maximum of 10 mm.[4] If there is a bone defect that will require gradual shortening then the anticipated defect size should be added to the 13 mm to ensure enough room in the nail for docking and compression. Blocking screws may be required to prevent compression-induced deformity or to correct existing deformity.[10] When treating nonunions of the proximal tibia, blocking screws were not able to adequately prevent compression-induced flexion and varus at the nonunion site.[4] Femur nonunions introduce the additional challenge of navigating the femoral bow with a straight IM implant. This must be considered when selecting an antegrade versus retrograde method and when planning the nail length (Fig. 1).

SURGICAL TECHNIQUE

Repair Nonunion

Nonunion surgery begins in a standard fashion. Patients receive tranexamic acid 1 g IV at the start of surgery. A

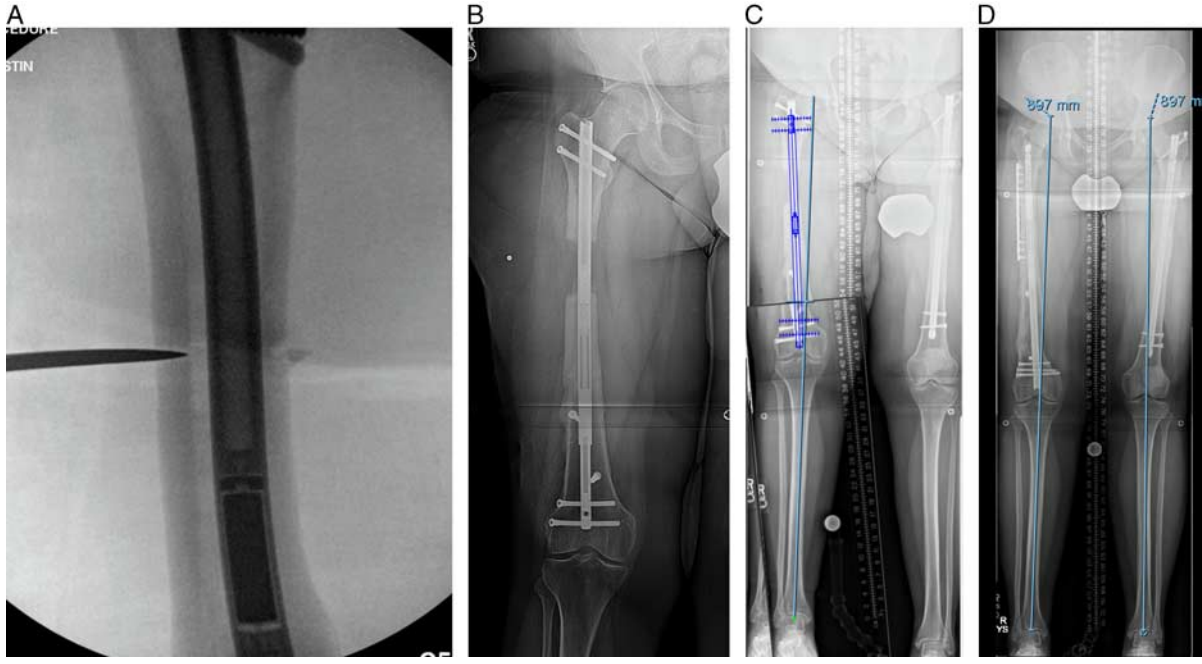

FIGURE 4. Osteotomy around the existing "sleeper" nail was performed and gradual distraction applied using the same nail (A). Regenerate formation was remarkably slow and the lengthening was stopped after 5 cm (B). Preoperative planning for a retrograde PRECICE was conducted using angular measurements and then templated with digital cut outs (C). The mechanical axis is expected to shift 5 mm laterally with a 5 cm lengthening, so the correction aims for an MAD of 5 mm medial in preparation for the anticipated lengthening-induced lateral deviation (C). This exchange nailing was executed by removing the antegrade magnetic intramedullary compression nail, stabilizing the proximal lengthening site with a unicortical plate to prevent shortening or lengthening, creating a corticotomy in the distal metaphysis, adding a critical blocking screw, and inserting a new retrograde lengthening nail; this was followed by gradual distraction to 5 cm (D). Final length and alignment are acceptable, and the nonunion is united with no evidence of infection. MAD indicates mechanical axis deviation.

tourniquet can be used but is removed during reaming. Hardware is removed from the path of the planned IM nail. In cases of atrophic nonunion, the site is approached with an open technique where bone ends are debrided. Tissue specimens are obtained for microbiology and histopathology. The canal is opened to permit passage of a guidewire. When a normotrophic nonunion is present then a percutaneous drilling method can be used to stimulate the site and insert graft material. (A comprehensive review of the proper debridement of nonunions is beyond the scope of this article.)

Reaming

An external fixator can be applied posterior to the IM canal to help reduce the bone ends during reaming. Positioning the Schantz pins outside the path of the IM canal is important to avoid reamer and nail obstruction.[11] If blocking screws are needed then this is an ideal moment to insert them. These screws will greatly assist with directing the reamer. Surgeons can use an awl or Steinman pin to start the path of the nail. A rigid hand-reamer may be needed to create a pathway across the sclerotic nonunion site prior to inserting the ball-tipped guidewire. Once the ball-tipped wire is in the desired position, reaming is performed in the standard fashion. Overreaming by 2 mm has ensured the ability to compress across the nonunion site.[12]

Nail Insertion

The guidewire is removed as this nail is not cannulated. The predistracted nail is inserted gently. Rough impaction or excessive bending of the nail can damage the internal gears and render the nail ineffective. The MICN is straight and more rigid than most trauma nails making tibial nail insertion particularly tricky. Often a posterior blocking screw (if inserted for reaming) will need to be removed if the tip of the nail cannot pass. The shoulder of the nail, at the junction of the telescopic pieces, tends to get stuck on blocking screws and at the nonunion site as well. Recognizing that the nail is not advancing prevents possible damage. The C-arm fluoroscopy can be used to identify the location of the blockage. Manipulation of the fracture site will allow for passage of the thicker barrel of the nail into the distal fragment, and additional reaming or removing the distal blocking screw will permit the nail to reach the distal most point in that circumstance. Blocking screws can typically be reinserted into the same drill path once the nail is seated, pushing the nail back into optimal alignment.

Locking and Augmentation

Locking is performed using the targeting device, and bone graft material can be added at this point if desired. The nonunion is compressed either manually or with the Schantz screws and unilateral external fixator (if already inserted), rotation is checked, and the far end of the nail is locked free-hand. The holes in the nail are the same diameter as the locking bolts. This line-to-line system is unforgiving. Care must be taken if tapping the drill bit through the nail with a mallet as it can get incarcerated. Two locking bolts on either end of the nail have been adequate in the diaphysis.[4]

Marking the Magnet

The C-arm fluoroscopy is used to find the internal magnet and mark its location on the skin (Fig. 2). This landmark will be the site that the patient will need to apply the external remote control magnet postoperatively. The patient will need to reapply the marker periodically at home. The nail can be tested intraoperatively by sterile wrapping the external remote control and shortening the nail 1 mm to ensure that the mechanism is functioning postinsertion.

Postoperative Routine

Although several millimeters of compression can be applied in the operating room, it is time consuming. The latest version of the internal compression-distraction nail has been extremely reliable, and the current protocol does not include intraoperative compression. The nail is shortened 2 mm per day for 5 days. The telltale sign that compression is present is bolt deflection (bending) as seen on radiographs (Fig. 3). The average bolt deflection noted has been 2.5 degrees.[4] If bolt bending is not seen on a postoperative radiograph, then more compression is needed. Overcompression is possible and typically results in no movement of the nail. If the resistance of the bone ends at the nonunion site is greater than the torque the external magnet can deliver to the internal magnet then the gears will not turn. This does not appear to damage the nail mechanism.[4] If compression is applied and a subsequent radiograph shows no additional shortening, despite a lack of bolt bending, then the nail is maximally compressed. Compression beyond visible bolt bending is not recommended.

Patients are placed on venous thromboembolic prophylaxis consisting of either aspirin 325 mg twice daily or rivaroxaban 10 mg. Weight-bearing as tolerated is allowed with both 10.7 and 12.5 mm diameter nails. Patients are followed monthly until consolidation. Additional compression may be applied as indicated particularly if a loss of bolt deflection is seen on x-ray. computed tomography scan can be used to determine bony union and plan additional lengthening surgery. The MICN should be removed once union is complete if not being used for subsequent lengthening surgery employing the same/existing nail. Subsequent osteotomy over the existing nail with distraction is possible, but slow regenerate formation should be expected particularly in the posttrauma setting (Fig. 4).

Tips for success

- Careful preoperative planning will ensure all equipment is available and that the proper reconstruction pathway has been selected
- Be sure to order an extra nail that is shorter than templated in the case that a more aggressive bone resection is needed
- Most PRECICE nails have an 8 cm stroke length: excessive predistraction will reduce the usable nail length for later distraction
- Loss of compression can occur during nonunion healing. Apply additional compression of 1-2 mm at each outpatient visit if there is no sign of active compression
- A loose stitch can be placed at the site where the magnet was marked on the skin as a more permanent indicator of where to place the external remote control

Avoiding Pitfalls

- The compression nail must be predistracted in the operating room prior to insertion. Failure to do this will make compression impossible
- This technique makes no effort to preserve length, and this must be explained to the patient and family prior to surgery. Later lengthening can be performed as part of a staged reconstruction
- Overcompression does not seem to damage the nail, but it is not recommended
- Deep infection of the nail is possible if the patient was previously treated with an external fixator. This is not a contraindication as steps can be taken to prevent this particularly by using absorbable antibiotic carriers during nail insertion[13]
- Do not use this technique in proximal tibial metaphyseal nonunions which tend to deform under IM nail compression
- Patients with implanted magnetic nails may not undergo magnetic resonance imaging examination
- No data exists for the compression technique using the STRYDE nail, and its' harder material may make this method more dangerous particularly in the instance of overcompression

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