Plate-Assisted Bone Segment Transport With a Remote-Controlled Magnetic Intramedullary Nail

John D. Wyrick, MD

Summary: Several techniques are available in the treatment of large segmental bone defects. Bone transport is a very reliable method of reconstruction but is usually performed with the use of an external fixator, which can have significant drawbacks. This article describes a new method of bone transport using a magnetic internal lengthening nail combined with a plate to reconstruct a segmental bone defect in a distal femur. It is promising to be able to perform bone transport using an all-internal technique while avoiding an external fixator. The surgical technique and methods to avoid pitfalls are described.

Key Words: bone transport, internal lengthening nail, bone defect, segmental bone defect, femur reconstruction, plate-assisted segmental bone transport

INTRODUCTION

Segmental bone defects remain a challenging problem in reconstructive limb surgery. Often these defects are the result of high-energy open injuries, which can be devastating to the patient. Large bone defects of greater than 5–7 cm present even greater challenges because these have been shown to have unreliable healing with autologous bone grafting alone. Options for reconstruction of these large defects include bone transport, massive bone graft with an induced membrane (Masquelet), and vascularized bone grafts.

Bone transport has historically been performed with external fixators either alone or in combination with an internal device such as an intramedullary nail or plate. External fixators are associated with significant complications, including pin tract infections, pain, and joint stiffness, and not infrequently are poorly tolerated. With the development of internal lengthening nails, it is now possible to perform bone transport with a completely internal system. The rate and amount of lengthening or transport can be controlled with magnetic energy from an external remote control device. This technique offers the potential to avoid the complications associated with external fixators and the near ubiquitous pin tract problems that accompany their use.

This article presents a patient who had a femoral bone transport performed with an internal lengthening nail combined with a plate, which is used to maintain the length of the bone while the nail moves the transport segment. The technique has been referred to as plate-assisted bone segment transport (PABST).

PATIENT INFORMATION

Patient

A 46-year-old man was involved in a motorcycle crash and presented as a severe polytrauma patient with multiple system injuries including a closed head injury, hemopneumothorax, grade III A open left distal femur fracture, closed right femur fracture, and right radius fracture. After initial resuscitation and stabilization of his nonorthopedic injuries, he was taken to surgery to address his orthopedic injuries. His left distal femur was debrided, an antibiotic spacer was placed, his 18 cm laceration could be closed, and a spanning external fixator could be applied for stabilization (Fig. 1). His right femur fracture was treated with a retrograde nail, and then postoperatively, a CT scan was obtained to evaluate the left distal femur fracture. After 1 week, he returned to surgery for definitive open reduction and internal fixation of his left distal femur intercondylar fractures and stabilization with a long distal

Accepted for publication August 29, 2018.

From the University of Cincinnati, Cincinnati, OH.

J. D. Wyrick is a Consultant for Stryker, Speakers bureau for Smith & Nephew.

Reprints: John D. Wyrick, MD, University of Cincinnati, 231 Albert Sabin Way, ML 0212, Cincinnati, OH 45267 (wyrickjd@ucmail.uc.edu).

The views and opinions expressed in this case report are those of the authors and do not necessarily reflect the views of the editors of Journal of Orthopaedic Trauma or NuVasive Specialized Orthopedics, Inc.

Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.

DOI: 10.1097/BOT.0000000000001336
femoral locking plate. He was left with a 10 cm bone defect, which also included the anterior portion of his lateral distal femoral condyle (Fig. 2). Once his other injuries had further stabilized, plans were made for reconstruction of his segmental bone defect with PABST and insertion of an internal lengthening nail.

**Surgical Technique**

Initially, a unilateral external fixator is used to stabilize the fracture, while the soft tissues are addressed. It is also important to maintain the original length of the bone during this time, so early on the opposite femur was measured to equalize the lengths. A cylindrical antibiotic spacer was used to manage the dead space and to provide some stability as well. These cases have been managed in a staged fashion with plate stabilization first, and then performing the osteotomy and insertion of the nail at the next stage. The plate was a distal femoral locking plate long enough to span the length of the femur. The locking screws in the distal part of the plate are placed anterior and posterior to the path of the retrograde nail. It is helpful to use a plate that has the option for variable angle locking for the distal screws. Proximally, the screws in the plate are all proximal to the planned level of the osteotomy for the transport segment.

It is important to have very accurate measurements from the radiographs at this stage because the planning for the level of the osteotomy and position of the nail with the interlocking screws is critical. It is recommended to take radiographs with a radiographic marker or ruler (Fig. 3).

The PRECICE nail (Nuvasive Specialized Orthopaedics, San Diego, CA) has been used for the transports. This lengthening nail telescopes and the amount that it lengthens is called the stroke. The maximum stroke possible is 80 mm. Therefore, for defects greater than 80 mm, the surgeon must plan to return the patient to surgery to extend or retract the nail, so additional transport can be performed. Although considered off-label, this process has been called “recharging” the nail and consists of removing the interlocking screws in the transport segment, extending or retracting the nail, and then reinserting the interlocking screws. Also a screw needs to be placed through the plate into the transport segment to prevent the segment from rebounding and losing transport length during the recharging process. Preoperative planning is critical. One needs to take into consideration the length of the nail, position of the osteotomy, and position of the interlocking screws in the transport segment. If the nail needs to be recharged, which is necessary whenever a defect of more than 8 cm is being treated, the transport segment must be large enough to reposition the nail and then get fixation with at least one...
interlocking screw. The shortest length of nail that has 80 mm of stroke is 245 mm in length, and using the shortest length, nail has worked out best in regards to the surgical planning. If less than 5 cm of stroke is needed, shorter lengths of nail are available. A retrograde nail was used in this case, which means the nail was fully distracted the 80 mm before inserting and then the transport performed by retracting or shortening the nail. The nail can also be placed in an antegrade fashion in which the nail pushes the transport segment rather than pulling it.

The surgery was performed in the lateral position on a radiolucent table and standard retrograde nailing technique performed. The level of the osteotomy needs to be planned accurately. (Fig. 4). It is performed with multiple drill hole technique with the holes created before reaming, so the reamings can be deposited at the osteotomy site. The magnetic lengthening nail, which is not cannulated, is inserted after the osteotomy is completed. Another consideration is the direction of the interlocking screw holes. The retrograde nail has screw holes that are 90 degrees offset between the distal and proximal interlocks. This works well with the laterally positioned plate. The distal screws are placed from medial to lateral using the interlocking drill guide. The proximal interlocking screws in the transport segment are placed in the anterior to posterior direction. For this case, an additional proximal interlocking hole was created in the moving segment of the nail. This is off-label and not recommended by the engineers. It was placed distal to the standard interlocking holes to essentially shorten the nail. It was felt that the 245 mm nail was going to require a very long transport segment to recharge the nail and still have the nail interlocking holes within the transport segment. A long transport segment also reduces the length of the proximal segment, which is needed for adequate fixation of the plate. The nail was inserted, and so the proximal end actually protruded a little past the level of the osteotomy, and another screw hole option was felt necessary. (Fig. 5).

The antegrade versions of the nail have interlocking holes that are all lateral to medial, except for one anterior to posterior distal hole. When using an antegrade nail, the piriformis nail can be used and rotated 90 degrees, so the screws are all placed anterior to posterior to avoid the laterally positioned plate. Once the nail is placed, it is critical to mark the position of the magnet using the
C-arm and then make a line on the skin with a permanent marker. The nail is then tested by distracting it a millimeter or so to confirm the external remote controller and nail are operating properly. (Fig. 6).

Postoperatively, the patients are kept toe-touch weight bearing, and knee range of motion is initiated as soon as the incisions are dry. The transport is started between 5 and 7 days at 1.0 mm/d. I have not been more aggressive in weight bearing because the plates tend to deform into some varus, which can be corrected after the segment is docked.

Patients are seen for radiographs every other week and adjustments made to the rate of distraction depending on the regenerate. The femur tends to make very good regenerate, and it was necessary to increase this patient’s distraction rate up to 1.5 mm/d. After 7 cm of transport was obtained, the patient was returned to surgery to revise the proximal interlocking screws. A screw needs to be placed temporarily in the transport segment through the plate to prevent the segment from rebounding while the interlocking screws are changed. The interlocking screws were removed, the nail was recharged by advancing it until the interlocking hole just cleared the proximal edge of the transport segment, and then a single interlocking screw was replaced. (Fig. 7).

Once the transport segment had docked, which was noted when the segment stopped moving and radiographically was in contact with the distal segment, the patient was brought back to surgery, the distal interlocking screws removed, and the transport segment impacted into the distal segment by back slapping the nail (Fig. 8).

FIGURE 5. Postoperative AP (A) and lateral (B) radiographs after osteotomy and retrograde insertion of the expanded magnetic lengthening nail. AP, anteroposterior.

FIGURE 6. Intraoperative fluoroscopic view of a different patient demonstrating the magnet of the lengthening nail. The position of the magnet needs to be marked on the skin to show the patient where to place the remote controller during treatments.
FIGURE 7. AP radiographs at the time of proximal screw revision. Before recharging and revision of screws (A). The interlocking screws were removed, and the nail expanded 10 mm, then a single screw replaced (B). AP, anteroposterior.

FIGURE 8. AP radiographs of distal (A) and proximal femur (B) at the time of docking and before nail exchange. Note the mild varus deformity at the regenerate site in the proximal femur. AP, anteroposterior.
A screw is then placed from the plate into the transport segment that maintains the compression of the transport segment at the docking site. The lengthening nail was then removed and exchanged for a stronger retrograde trauma nail (Fig. 9). This serves the purpose of depositing reamings at the docking site as well as increasing the strength and stiffness of the fixation construct protecting the regenerate and the docking site. After the nail exchange, the patient was advanced to full weight bearing.

Outcome

The patient healed the osteotomy site and docking site without any complications and was full weight bearing 5 months after his initial surgery (Fig. 9). His follow-up radiographs demonstrated limb lengths within 1 cm and very slight valgus of the left femur (Fig. 10). He struggled trying to regain knee motion during the transport process, and it was felt he would need a quadricepsplasty and knee release. Once he was full weight bearing and with aggressive therapy, he was able to obtain 5–100 degrees of knee motion, so he is satisfied and has returned to work.

Complications

There were no complications in this patient. His knee motion is reduced but felt to be appropriate and actually quite good with the severity of his injury.

DISCUSSION

This article presents an early experience of plate-assisted segmental bone transport with a magnetic internal lengthening nail. There are multiple options currently available for managing bone defects, each with their advantages and drawbacks. The 2 most common methods in current practice for large bone defects include the induced membrane technique with massive bone grafting and bone transport. Successful bone grafting of segmental bone defects has improved with the development of the induced membrane technique. Obtaining sufficient bone graft to fill these large defects can be a problem in multiple injured patients, as was the case with this patient. Other problems encountered with the technique include infection, refracture, and persistent nonunion.

Bone transport using the principle of distraction osteogenesis is a proven method with international acceptance. It is typically performed with an external fixator used as a motor to move the transport segment. If the transport is performed solely with an external fixator, the patient may be in the fixator for a very extended length of time when the defect is large. External fixators can be associated with significant complications, most notably pin tract infections, pain, and joint contractures. Modifications of the original Ilizarov technique have been developed to decrease the time spent in the fixator including transport over a nail, transport and then nailing, or transport and then plating, as well as cable transport and then nailing. These have all been significant advances, but the eventual goal would be to have a completely internal system. With the development of internal lengthening nails, it is now possible to perform bone transport without using an external fixator.

This article describes a newly developed technique using the magnetic internal lengthening nail with a plate to reconstruct a 10 cm defect in a distal femur. Using external fixators for bone transport in the femur is associated with pin problems because of the large amount of soft tissue, the pins must cut through. Having an all-internal system avoids this. It also avoids having to harvest...
There are some difficulties to overcome with PABST technique. One limitation is the soft-tissue distance, which the external remote controller can penetrate and still connect with the magnet in the nail. This patient was thin, and with the retrograde technique, there was not a problem with them connecting. A previous patient, with a body mass index of 40, had the nail inserted antegrade in the femur and then had difficulty linking the nail with the external remote controller resulting in premature consolidation of the osteotomy. Because there is more muscle mass in the proximal thigh compared with the distal thigh, there is a larger distance between the controller and the magnet with an antegrade nail. The author elected to remove the nail, and then reinserted it in a retrograde direction, so there was less soft-tissue distance. The nail worked successfully afterward with the transport progressing at a normal rate. Consideration must be given to using a larger diameter nail in heavier patients because a larger nail has a stronger magnet, which can penetrate more soft tissue.

Other technical considerations relate to the length of the nail, where to make the osteotomy and length of the transport segment. This is simpler with an antegrade approach in which the transport segment is pushed rather than pulled. Care must be taken in both techniques to keep the screws from the plate out of the path of the nail. Also, the maximum stroke of the nail is 80 mm, so for defects larger than that, a plan must be made preoperatively how to recharge the nail and where the interlocking screws will be replaced in the transport segment. The patient will need to be brought back to surgery, a screw placed through the plate to hold the transport segment in place, and the nail either expanded or retracted depending on the direction it is placed. The external remote controller takes about 6 minutes to move the nail 1 mm. This would be a very expensive procedure to perform while the patient is under anesthesia. Options to manage this include (1) the patient could recharge the nail either after admission to the hospital or in the postanesthesia area or (2) discharged to home and return to surgery later to replace the interlocking screws.

The regenerate has formed well, as is typical in the femur, and needed to be monitored closely during transport because the rate needed to be increased to a faster rate of 1.5 mm/d to prevent premature consolidation. Another problem, which was mild in this case but has been more significant in other cases, is the femur deforming into varus during the transport. This is caused by the plate deforming but is corrected by exchanging the transport nail for a trauma nail once the segment is docked. Plus, the patient can be progressed to full weight bearing after the nail exchange.

In conclusion, PABST has been shown to be a successful all-internal method of bone transport in the management of large segmental bone defects. There are some technical challenges that need to be improved to make it a widely accepted technique, but it certainly shows enough promise to pursue.

REFERENCES


---

Read the rest of the **JOT Case Reports** online on www.jorthotrauma.com. It’s the Grand Rounds series from the *Journal of Orthopaedic Trauma*, the official journal of the Orthopaedic Trauma Association.