

Adult Posttraumatic Reconstruction Using a Magnetic Internal Lengthening Nail

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Summary: A new generation of internal lengthening nail is now available that has reliable remote-controlled mechanisms. This allows accurate and well-controlled distraction rate and rhythm, and early clinical results have been very positive. In this article, 2 posttraumatic cases are presented that illustrate deformity correction and lengthening using the internal lengthening nail. Surgical planning and adjuvant techniques of fixator-assisted nailing and the use of blocking screws are discussed.

Key Words: internal lengthening nail, PRECICE, limb lengthening, femur lengthening, tibia lengthening, malunion

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INTRODUCTION

The primary indications for bone lengthening and deformity correction are congenital and posttraumatic conditions including malunion and growth arrest. Distraction osteogenesis (DO) has been successfully used over the past half century to lengthen bone.^{1,2} Critical to successful DO is an optimal rate and rhythm of distraction for which external fixation has been a reliable tool.^{1,2} However, the disadvantages of frames are well known to include pin tract infections, skin pain, soft tissue tethering, and joint stiffness.^{1–3} Hybrid techniques,^{3–7} such as lengthening over a nail and lengthening and then nailing, were developed to decrease the time needed in the external fixator.

Bone lengthening with a fully implantable device is desirable to avoid external fixation entirely; however, the mechanical integrity and accurate control of distraction are mandatory. Internal lengthening nails (ILNs) are telescopic nails that are inserted into the intramedullary (IM) canal of long bones after performing osteotomy at the desired location. The distal and proximal nail segments are fixed to the respective bone segments using interlocking screws, and thus, distraction of the nail results in lengthening of the bone.

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Previous generations of ILNs did not have accurate control of distraction, resulting in a high complication rate.^{8,9}

New remote controlled internal lengthening IM nails have recently become available and can be used in both the femur and tibia. The inventory available includes antegrade femur (piriformis and trochanteric entries), retrograde femur, and tibial ILNs. The PRECICE (Nuvasive Specialized Orthopedics, Aliso Viejo, CA) remote-controlled magnetic ILN contains a permanent rare earth magnet connected to a gearbox and screw shaft assembly. Distraction of the nail is brought about by the application of a remote-controller unit containing 2 revolving external magnets. The controller unit is applied externally at the exact location of the nail's internal magnet (which is marked on the skin intraoperatively under fluoroscopic guidance). The magnet revolutions within the external controller unit cause reciprocal movement of the internal magnet and consequently the gearbox and screw shaft assembly within the nail. As a result, the nail elongates causing the desired change in bone length. The controller can be custom programmed to adjust the lengthening rate, and the accuracy of distraction has been reported to be 96%.^{10,11}

The ILN may be used for bone lengthening and deformity correction if needed. Adjuvant techniques used include fixator-assisted nailing¹² and the use of blocking screws.¹³ The application of this surgical approach to posttraumatic femur and tibial deformity is illustrated in the following 2 clinical cases.

CASE 1: TIBIAL MALUNION

A 25-year-old man presented with a tibial malunion. Two years prior, he sustained a grade 3 open tibial fracture with segmental bone loss. He was treated with a rotational flap and bone transport using a circular external fixator. His preoperative deformity included 9 degrees of valgus deformity and 25 mm of leg length discrepancy (LLD) (Fig. 1).

Choosing the Nail Length

The apex of the deformity is 180 mm distal to the knee joint line. The thick part of the nail will pull out of the distal moving fragment, and the ideal goal is for there to be 50 mm of thick nail in the distal fragment at the end of distraction. The starting length of the nail has 30 mm of thin protruding nail at the end. The shortest nail length (SNL) that should be used = osteotomy level + desired lengthening + thick nail + protruding nail. In this case, SNL = 180 + 25 + 50 + 30 = 285. Based on nail inventory and analysis of the x-ray, a 305-mm nail was chosen. A longer nail would be difficult to pass across the previous docking site that has mild translation on the lateral x-ray (Fig. 2).

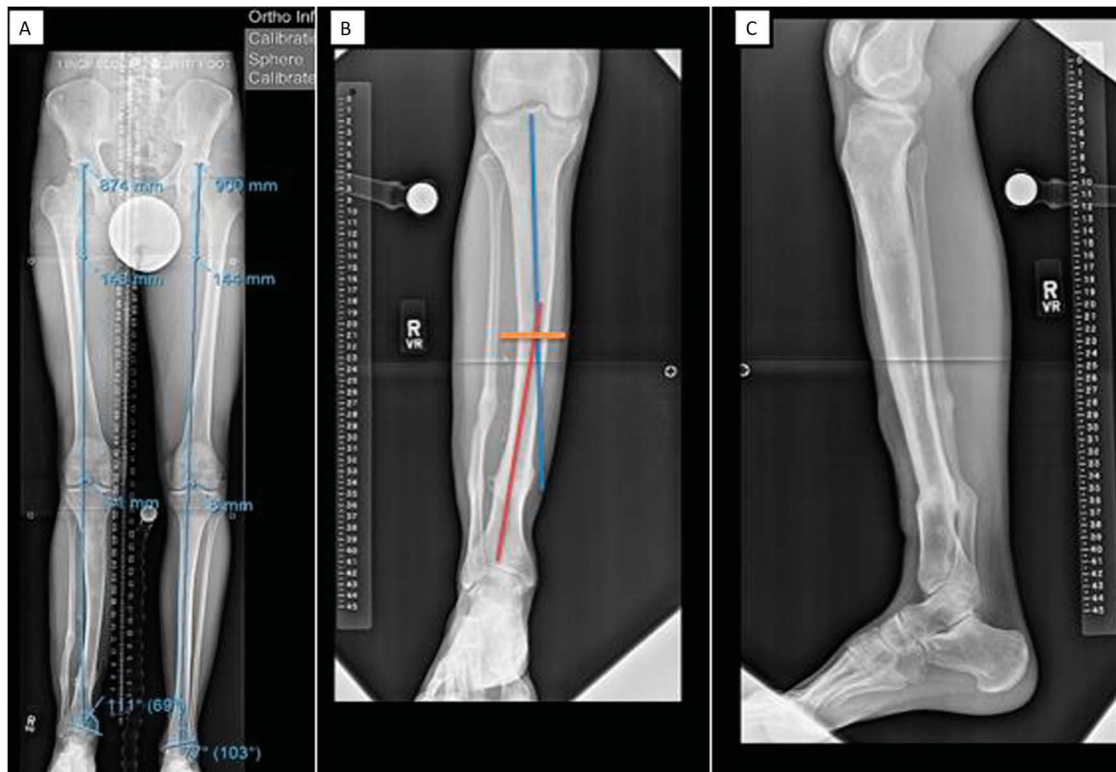


FIGURE 1. Tibial malunion case, preoperative. A, Erect leg x-ray showing LLD of 25 mm and valgus alignment. B, Apex of deformity is 180 mm from joint line. C, Lateral x-ray shows step off at previous distal docking site.

Blocking Screw

When the width of the IM canal is greater than the diameter of the nail, the nail will not automatically correct the angular deformity.¹³ Furthermore, during lengthening, there are typical deformities that ensue during a tibial lengthening—valgus and apex anterior. The blocking screw is typically placed adjacent to the osteotomy site at the apex of the deformity to be corrected and/or prevented. In this case, the lateral blocking screw is needed to achieve correction of the valgus deformity and is placed before the IM canal is reamed (Fig. 3).

Fixator-Assisted Nailing

The 2-pin fixator is placed, so the pins are outside of the tract of the IM nail. Each pin is placed in the respective segment orthogonal to the axis of that segment.¹² This stabilizes the tibia in the corrected position after the osteotomy during the IM canal reaming. The pins also mark the rotational alignment of each segment so that rotational deformity can be prevented or corrected as needed.

Stabilization of the Fibula to the Tibia

The proximal and distal tibia–fibula relationship are stabilized before lengthening of the tibia (Fig. 3). This ensures that the fibula osteotomy will separate and lengthen with the tibia. Omission of this step would result in proximal migration of the distal fibula and distal migration of the proximal fibula despite a fibula osteotomy. Complications of deformity and contracture of the ankle and knee would ensue if this step were omitted.

Soft Tissue Procedures

Acute correction of tibial deformity carries a risk of compartment syndrome and nerve injury. Adjuvant procedures

of prophylactic fasciotomy and peroneal nerve decompression may be appropriate. In this case, anterior and lateral compartment fasciotomies were done through small incisions at the initial surgery. Gastrocnemius recession (GSR) may be needed to prevent or treat equinus contracture¹⁴ during tibial lengthening. In this case, GSR was done 6 weeks after the initial surgery to treat a 20-degree equinus contracture that developed during the lengthening.

Osteotomy

A multiple drill hole osteotomy technique is used. This is a low-energy osteotomy that minimizes thermal necrosis. First, multiple drill holes are made in a transverse fashion at the osteotomy level. A new sharp 4.8-mm drill was used for this purpose. The final step is completion of the transverse osteotomy with a sharp osteotome.

Reaming of IM Canal

A tourniquet is not used. The canal is sequentially reamed 2 mm larger than the nail to be inserted.

Surgical Steps

1. Drill holes at the osteotomy level
2. Anterior compartment fasciotomy
3. Insertion of lateral blocking screw 1 cm proximal to osteotomy line
4. Lateral compartment fasciotomy
5. Fibula osteotomy
6. Entry into the IM canal of the proximal tibia
7. Insertion of external fixator pins

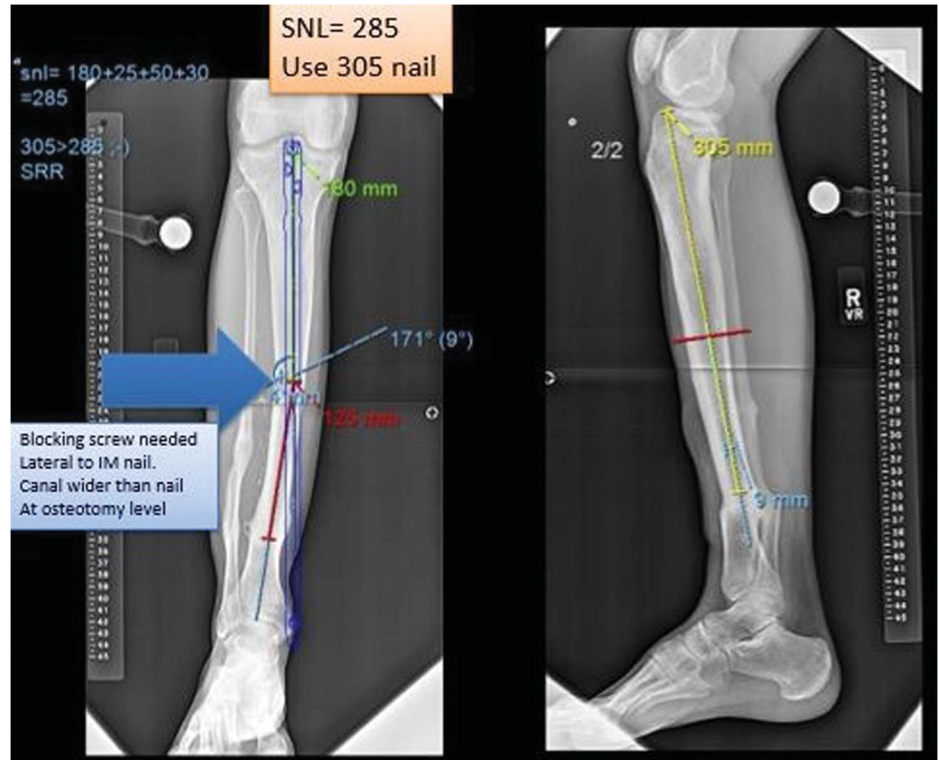


FIGURE 2. Surgical planning for ILN length and need for lateral blocking screw.

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| <ul style="list-style-type: none"> 8. Completion of tibial osteotomy and correction of valgus 9. Stabilization of tibia with 2-pin external fixator 10. Insertion of guide wire and sequential reaming of IM canal 11. Insertion of ILN | <ul style="list-style-type: none"> 12. Removal of external fixator 13. Insertion of proximal locking screws 14. Rotation of distal segment around the ILN to confirm complete osteotomy |
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FIGURE 3. A, At the end of distraction showing utility of blocking screw to correct valgus deformity. B, Anteroposterior x-ray showing consolidation and the proximal and distal fibula tibia screws. C, Lateral x-ray showing consolidation. D, Erect leg x-ray showing correction of LLD and deformity.

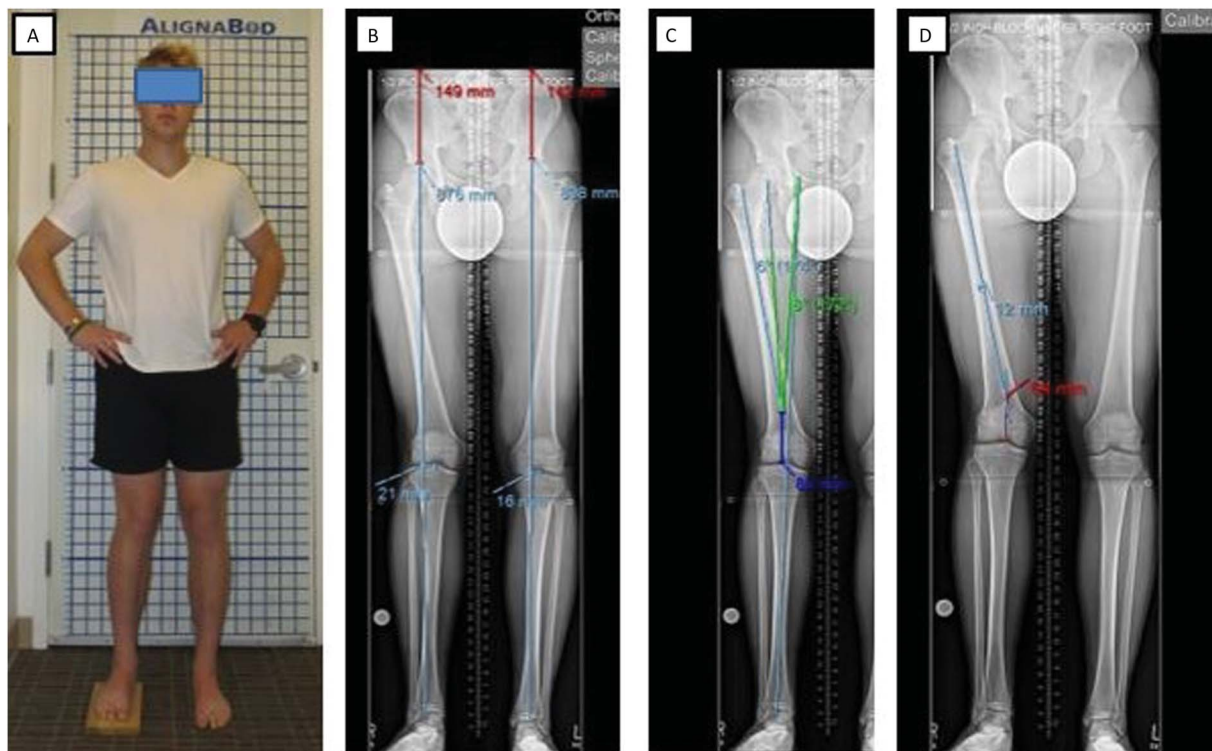


FIGURE 4. Distal femur traumatic growth arrest case, preoperative. A, Clinical photograph. B, Erect leg showing LLD of 21 mm and valgus alignment. C, Mechanical axis surgical planning. D, Anatomic axis surgical planning.

15. Insertion of distal interlocking screws
16. Secure fibula to tibia proximally and distally
17. Marking magnet location on skin and foot print for the remote control device.

Distraction of the tibia¹⁵ was started on postoperative day (POD) 7 and was 0.25 mm 4 times a day for 4 days and then was slowed to 3 times per day. X-rays were obtained every 2 weeks during the distraction and monthly thereafter. Knee and ankle range

of motion (ROM) exercises were prescribed.^{16,17} Weight bearing was limited to 50 lbs for this 10.7-mm ILN.

Distraction was completed on POD 39. A GSR was performed 6 weeks after the surgery to treat a 20-degree equinus contracture. Acute correction of equinus was not done, and the patient was not casted. Consolidation progressed and full weight bearing was allowed at 4 months. The fibula tibia screws were removed after 4 months when the fibula was noted to be well

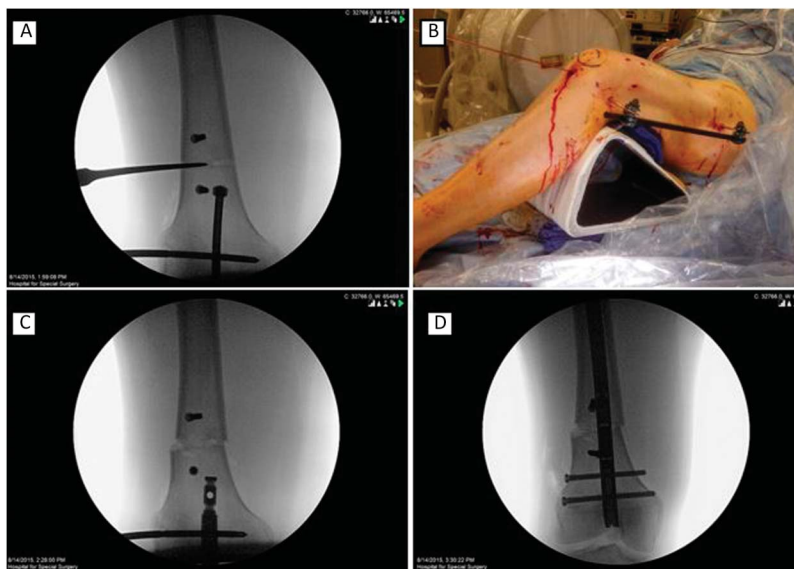


FIGURE 5. Intraoperative images. A, Placement of blocking screws in concavity of deformity; direction of nail path in distal segment; just about to complete osteotomy. B, With fixator in place in preparation for IM canal reaming. C, Insertion of ILN. D, ILN locked distally.

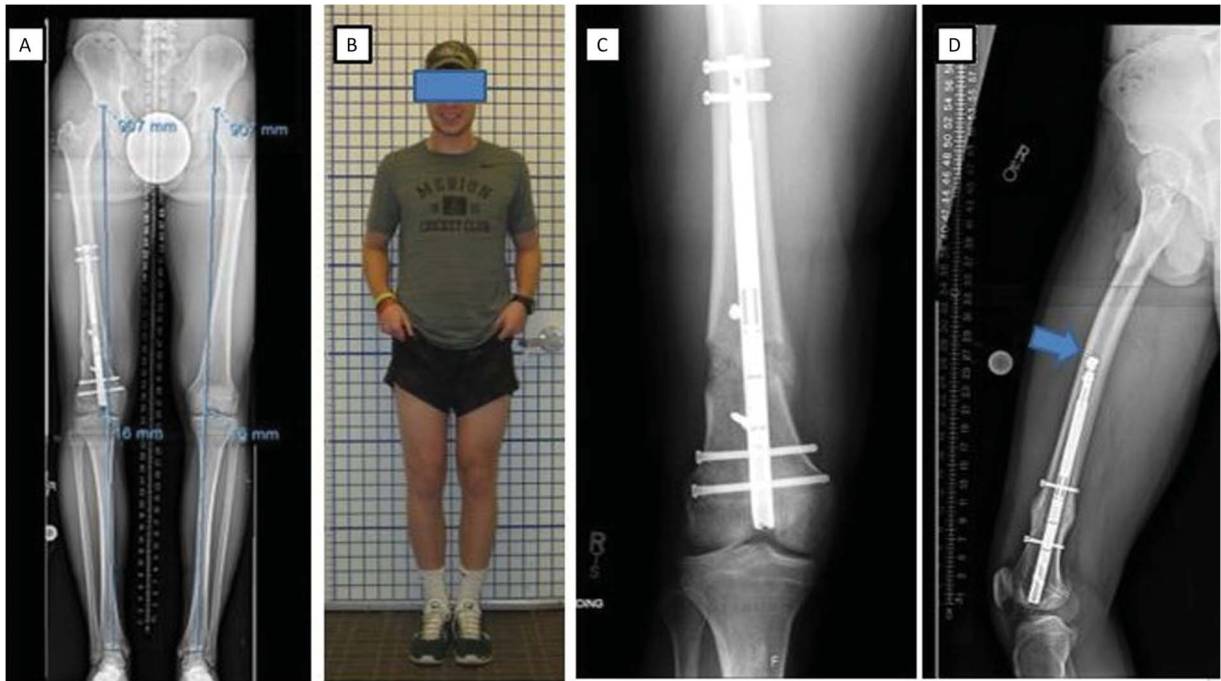


FIGURE 6. After consolidation. A, Erect leg x-ray showing correction of valgus and LLD. B, Clinical photograph. C, Anteroposterior x-ray showing consolidation of osteotomy. D, Lateral x-ray showing consolidation of osteotomy. Note the proximal bow of the femur and the inability to use a longer ILN.

healed. The tibial nail was removed 12 months after the initial surgery. The patient is fully functional and has normal ROM of the knee and the ankle (Fig. 3).

CASE 2: POSTTRAUMATIC GROWTH ARREST OF FEMUR

A 22-year-old man presented with right lower extremity LLD and valgus deformity. At age 14, he sustained a traumatic distal femur growth plate fracture that was treated with cast. Over time, this developed into a LLD of 21 mm and 8 degrees of valgus deformity (Figs. 4A, B).

Choosing the Nail Length

The apex of the deformity was noted to be in the distal femur. Mechanical axis planning (Fig. 4C) was followed by anatomic axis planning (Fig. 4D) and the osteotomy site planned was 80 mm proximal to the joint line. The SNL analysis was done as was explained earlier.

$SNL = 80 + 21 + 50 + 30 = 191$ mm. A 215 mm nail was chosen based on inventory and the SNL analysis. A longer nail was not desirable since it would not be able to pass the proximal sagittal bow of the femur.

Blocking Screw

To achieve correction of the valgus deformity, blocking screws were needed in the concavity of the valgus deformity. Since the IM canal was wider than the nail diameter on both sides of the osteotomy, blocking screws were placed both proximal and distal to the osteotomy site. The entry point in the distal femur and the direction of the nail in the distal segment was derived from the surgical planning and was critical to achieve correction of the deformity (Fig. 5A).

Fixator-Assisted Nailing

A 2-pin fixator was applied out of the path of the ILN¹⁸ orthogonal to each segment axis. After the osteotomy and deformity correction, the external fixator was used to stabilize the femur in the optimal orientation for IM reaming (Fig. 5B). The fixator pins were placed to mark the axial rotation.

Soft Tissue Procedures

Iliotibial band tenotomy was performed and is routinely done for femur lengthenings.¹⁹ Peroneal nerve decompression should always be considered when doing acute correction of valgus but was not done in this case because the valgus was not large.

Osteotomy

A multiple drill hole osteotomy technique was used.¹⁵ This is a low-energy osteotomy that minimizes thermal necrosis. First, multiple drill holes are made in a transverse fashion at the osteotomy level. A new sharp 4.8-mm drill was used for this purpose. The final step is completion of the transverse osteotomy with a sharp osteotome.

Reaming of IM Canal

A tourniquet is not used. The canal was sequentially reamed 2 mm larger than the nail to be inserted.

Surgical Steps

1. Drill holes at osteotomy level
2. Blocking screws
3. Insertion of external fixator pins
4. Entry point in distal femur IM canal and establish direction of nail in distal segment
5. Complete osteotomy with osteotome

6. Acute correction of valgus deformity
7. Stabilization with 2-pin external fixator
8. Insert guide wire and ream IM canal
9. Insert ILN (Fig. 5C)
10. Distal interlocking screw insertion with jig (Fig. 5D)
11. Remove external fixator but leave pins for rotational marking
12. Rotate proximal segment around ILN to confirm complete osteotomy
13. Proximal interlocking screw insertion with free-hand technique
14. Mark location of magnet and footprint for remote control on skin
15. Iliotibial band tenotomy.

Distraction was started on POD 4 at a rate of 0.33 mm 4 times per day for the first 4 days. Then the rate was slowed to 0.33 mm 3 times per day. X-rays are obtained every 2 weeks during the distraction and monthly thereafter. Knee and ankle ROM exercises were prescribed.¹⁷ Weight bearing was limited to 50 lbs for this 10.7 mm ILN.

Distraction was completed on POD 25. At 12 weeks after the surgery, the patient was advanced to full weight bearing. The ILN was removed 12 months after the initial surgery. The patient is fully functional and has normal ROM of the knee and the hip (Fig. 6).

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