Motorized internal lengthening nail, anterograde femur technique can correct leg length

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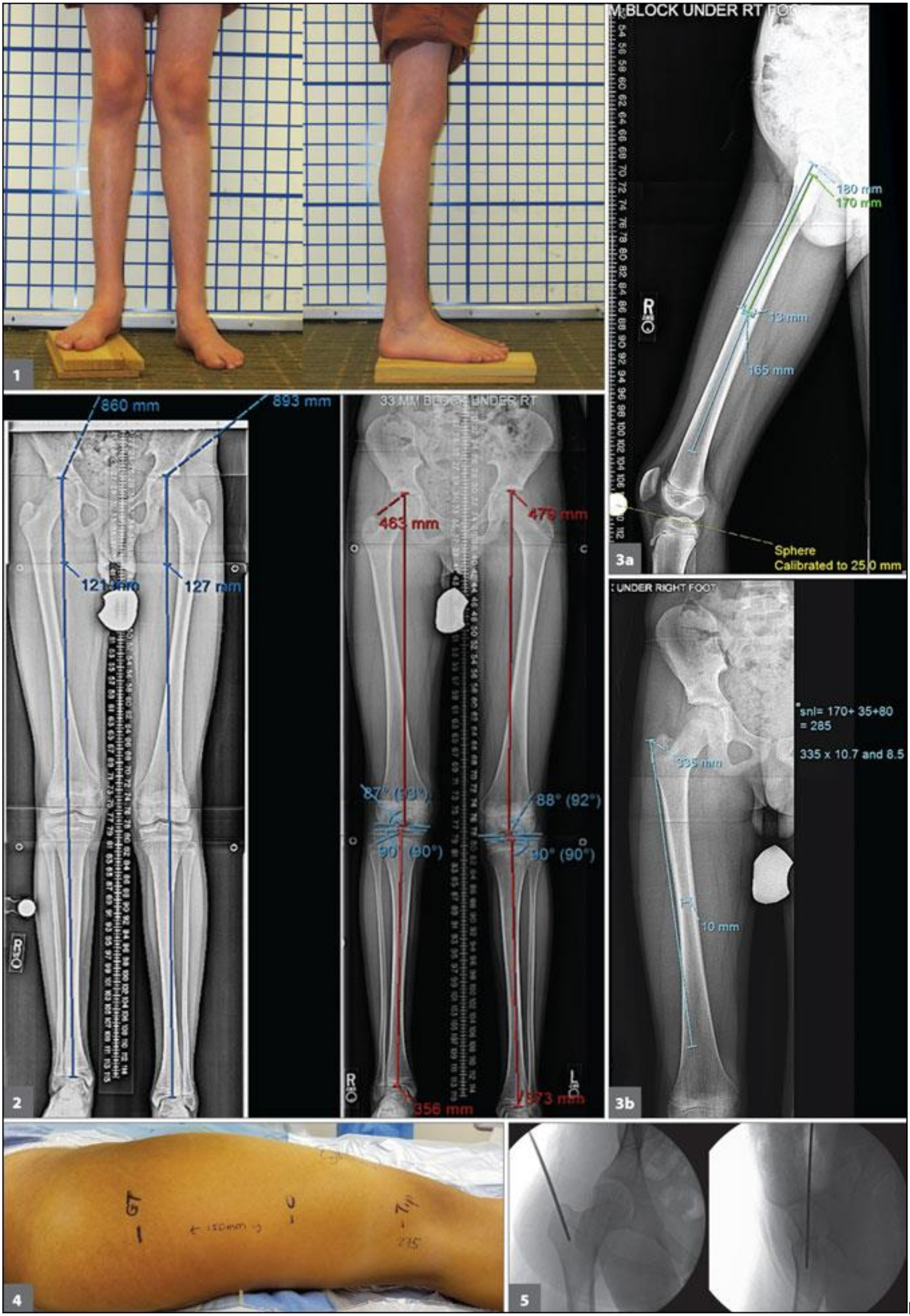
Femoral lengthening with an internal lengthening nail is a recent advance that allows for leg length equalization and deformity correction in a manner that mitigates many challenges associated with external fixation, especially from the patient's perspective.

Preoperative planning

A block test can be useful to determine where a patient feels comfortable with leg length, and can be verified using a shoe lift preoperatively (Figure 1). Both calibrated standing hip-to-ankle radiographs and full-length anteroposterior (AP) and lateral radiographs of the femur are required for planning (Figure 2). Because the nail is straight in the sagittal plane (without an anterior bow like a trauma nail), the osteotomy must be planned at the apex of the femoral bow to allow nail passage. The location of the femoral bow can dictate nail length (Figures 3a and 3b).

We plan nail length using a "shortest nail length" concept. In this method, length is equal to the distance from the tip of the trochanter to the osteotomy level, plus the amount of lengthening needed, plus 8 cm (to account for the initial 3-cm length of the thinner part of the nail, plus a 5-cm "safe zone"). Using this method, when lengthening is complete, there is still a portion of the thick part of the nail across the osteotomy site (now regenerate), which helps with stability and healing. If there is a rotational deformity noted on physical exam, a CT version study is obtained. For most individuals, a piriformis entry nail is used. However, for patients younger than 18 years a trochanteric entry nail is used, which protects the blood supply to the femoral head.


1
860 mm
893 mm
121 mm
127 mm
2
33 MM BLOCK UNDER RT
463 mm
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87° (93°)
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356 mm
373 mm
BLOCK UNDER RT FOOT
180 mm
170 mm
13 mm
165 mm
Sphere
Calibrated to 25.0 mm
3a
UNDER RIGHT FOOT
snl= 170+ 35+80
= 285
335 x 10.7 and 8.5
335 mm
10 mm
3b
GT
Tip
4
5

Figure

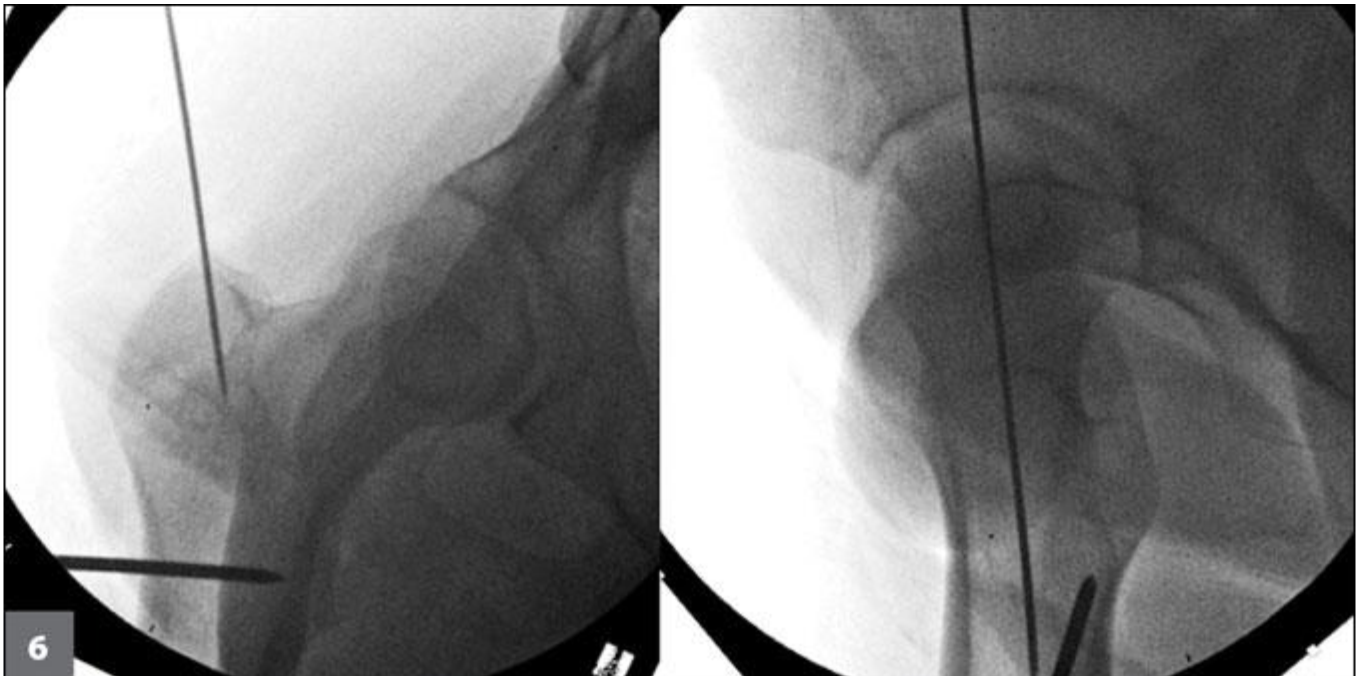
1. Clinical images show a 14-year-old male patient with a 33-mm congenital right leg length discrepancy.**Figure 2.** Hip-to-ankle AP standing radiographs are shown with a 33-mm block placed under the patient's right foot. Leg length discrepancy and distal femur and proximal tibia joint orientation angles are measured for planning purposes.**Figure 3.** The lateral (a) and AP (b) femur radiographs used for nail planning are shown. Note that the lateral radiograph is key because the apex of the femoral bow will determine the osteotomy level; shortest nail length is shortest nail length. It incorporates the distance of the osteotomy from the greater trochanter, the amount of lengthening and 80 mm of "safe zone."**Figure 4.** The greater trochanter, level of the osteotomy and the tip of the nail are marked on the skin using fluoroscopy prior to incision.**Figure 5.** The AP and lateral fluoroscopic views demonstrate the starting point for a trochanteric entry nail used because this patient is an adolescent. A guide wire for the cannulated reamer is used to percutaneously obtain the appropriate starting point.

OR setup

Position the patient supine on a flat radiolucent operating table with a bump under the operative buttock and adduct the arm across the chest (secure the arm with tape or other positioning devices). For supine nailing, keeping the arm out of the way for guide wire passage and reaming is imperative. Bring the C-arm fluoroscopy machine in from the opposite side of the table. When draping, be sure to prepare and drape to the edge of the bump to ensure adequate exposure to the nail entry site.

Osteotomy: Step 1

Use fluoroscopic guidance to mark the distance of the osteotomy from the tip of the greater trochanter (Figure 4). Make a 1-cm incision centered over the femur in the sagittal plane and gently spread soft tissues to bone. Holding the leg adducted during this step (as it will be during osteotomy and nail insertion) will keep the soft tissue path in the appropriate plane. This also avoids unnecessary soft tissue stripping or creating a larger incision. Use a new 4.8-mm drill bit with appropriate drill sleeve to make multiple transverse, bicortical drill holes through the femur. After the first pass, pull the drill tip back almost to the first cortex, and while spinning the drill, redirect it through the hole in the near cortex to place further holes in the far cortex. Use fluoroscopic guidance for placement of the drill holes. After each pass, remove the drill and clean the flutes. Using a new, sharp drill and keeping the flutes clean minimizes generation of heat and prevents bone necrosis. After three to four passes, if the bone allows, make a new drill hole posterior to the first hole, carefully advancing the drill since this hole may be unicortical or may fall into one of the previous holes. This step usually results in five to six holes in the bone.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7

8

Figure 6. AP and lateral fluoroscopic images demonstrate placement of the proximal rotation marking wires. The wire placement is well posterior to the path of the nail as marked by the guide wire. The second wire is placed distal, where the nail will end.**Figure 7.** An alternate method for marking rotation using 6-mm half pins is shown. The half pins can be used to aid in reduction, especially if there is a large deformity to correct prior to nail insertion.**Figure 8.** A 4.8-mm drill (with drill sleeve) is shown, which is used to make multiple transverse holes in the cortex. After the nail is partially inserted, the osteotomy is completed with an osteotome.**Figure 9.** The magnet is marked using fluoroscopic guidance and a skin mark is made. During each lengthening session, the patient aligns the external magnet with the skin mark.

Nail entry and canal preparation

Adduct the leg 20° to 30° while avoiding internal rotation, and insert a 2.4-mm Steinmann pin percutaneously into the piriformis fossa using biplanar fluoroscopic guidance. When the appropriate entry point is confirmed in both planes, drive the pin into the medullary canal, once again using fluoroscopy to guide the position (Figure 5). Make a 2-cm incision around the pin and spread the soft tissue. Use a 12-mm acorn reamer (the smooth shank of the drill obviates need for a soft-tissue protector) to create a path through the soft tissues and open the proximal medullary canal. Remove the reamer, insert a ball-tip guide wire and pass it to the distal femur.

Ream the canal sequentially with flexible reamers to the length of the planned nail and about 2-mm wider than the diameter of the planned nail. Ream to 12.5 mm for the 10.7-mm nail. Resistance and cortical chatter during reaming can help determine the final nail diameter intraoperatively. Although a larger diameter nail does allow increased weight-bearing, excessive reaming to accommodate a larger diameter nail can be detrimental to bone healing. The previously placed drill holes serve as vents for the intact femur, allow reamings to extrude and act as bone graft.

While the bone is still intact, place rotational markers to avoid the introduction of any iatrogenic rotational deformity or to plan rotational correction. Place a 2.8-mm Steinmann pin bicortically at the level of the lesser trochanter, posterior to the canal, and place a parallel 3.2-mm Steinmann pin distal to where the nail will end (Figure 6). If desired, 5-mm or 6-mm half pins may be used for rotational markers instead. These half pins can also serve as a monolateral frame to help with reduction or hold any necessary correction (Figure 7).

Osteotomy: Step 2 and nail insertion

Remove the guide wire and insert the nail into the proximal femur, keeping it about 1 cm proximal to the osteotomy site. This ensures the nail is not blocked by the rotational marker and allows the nail to be used to help with reduction after the osteotomy is complete. Use a 7-mm Stille-type osteotome to expand the hole in the near cortex and “re-trace” the drill holes (Figure 8). A 13-mm wrench can be used to gently rotate the osteotome to free it from the bone and will later help to complete the osteotomy. Work the anterior and posterior cortices with the osteotome. When the osteotomy site has been sufficiently weakened, place the osteotome across the medial cortex (check with fluoroscopy) and turn the handle of the osteotome 90° clockwise and then turn the handle counterclockwise to complete the osteotomy.

Once the osteotomy has been completed, an assistant should pull traction and lift the leg to counter the varus and flexion deformities that occur. Pass the nail across the osteotomy and use fluoroscopy to confirm final positioning of the nail. Rotate through the osteotomy — around the nail — to confirm that it is complete and align the rotational markers.

Insertion of locking screws

The locking screws may be inserted in any order. However, if the distal screws are inserted first, this allows for the insertion handle to rotate the nail to make obtaining perfect circles easier. Additionally, if the osteotomy site is excessively distracted, locking the nail distally first allows compression by "back-slapping" the nail. The two distal screws are interlocked using a freehand technique. The screws are the same diameter as the hole in the nail, so interlocking requires more precision than with a trauma nail. Tapping a drill bit through a nail that is slightly off axis can be helpful. If it is significantly off axis, it may be necessary to use a t-handle chuck to loosen the drill bit in the bone and slightly expand the hole in the near cortex. Insert the proximal screws using the aiming jig after verifying correct rotation using the markers. Because the screws (which are truly pegs) are only threaded proximally, it is imperative that they be bicortical to resist the stresses associated with lengthening.

Figure 10. Excellent hypertrophic regenerate formation is seen in AP and lateral femur radiographs of the 14-year-old male patient near the end of consolidation.

Iliotibial band release, mark magnet

To prevent knee stiffness during lengthening, release the iliotibial (IT) band. Usually the two stab wounds for the distal locking screws can be connected and the IT band exposed after dissecting though the superficial tissues. Make a transverse incision and use curved Mayo scissors to continue to the anterior fascia of the thigh and then posteriorly to the lateral intermuscular septum.

Before closure, use fluoroscopy to mark the center of the magnet in the nail since this is where the remote controller will need to be centered. Mark this spot with the marking pen and later reinforce it with either a permanent marker or a single prolene suture. The outline of the remote controller also can be traced on the leg to make it easier for the patient to properly position the device (Figure 9).

Postoperative care

Our standard protocol for femur lengthening is to begin on postoperative day 4. We begin with adjustments made four times per day at 0.33-mm per session for 4 days and continue at three times per day going forward. The patient is taught how to do the adjustments with the remote control and adjustments are performed by the patient or family at home. Every 2 weeks, radiographs are taken. The patient is examined for nerve function and joint motion. Rate of distraction can be adjusted by changing the number of sessions per day, if necessary. Nail diameter determines weight-bearing during distraction and early consolidation: 30 lbs. for an 8.5-mm nail; 50 lbs. for a 10.7-mm nail; and 70 lbs. for a 12.5-mm nail. Physical therapy focuses on maintaining knee and hip range of motion. Nail removal is recommended after about 9 months to 12 months due to the strong magnet contained in the implant (Figure 10).

References:

Kirane YM, et al. *Clin Orthop Relat Res.* 2014;doi:10.1007/s11999-014-3575-0.
Muthusamy S, et al. *Strategies Trauma Limb Reconstr.* 2016;doi:10.1007/s11751-016-0265-3.
Rozbruch SR, et al. *J Am Acad Orthop Surg.* 2014;doi:10.5435/JAAOS-22-07-403.
Rozbruch SR, et al. *JBJS Essential Surg Tech.* 2016;doi.org/10.2106/JBJS.ST.O.00063.

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Falls reports no relevant financial disclosures. Fragomen reports he is a consultant for Smith & Nephew, NuVasive, and Synthes ATF. Rozbruch reports he is a consultant for Smith & Nephew, NuVasive and Stryker.