Fixator-Assisted Acute Femoral Deformity Correction and Consecutive Lengthening Over an Intramedullary Nail

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Background: External fixators are being used frequently in standard limb-lengthening and deformity-correction procedures. Lengthening over an intramedullary nail has been a successful technique, and fixator-assisted intramedullary nailing has provided satisfactory results for the correction of selected deformities. We report a combined technique for the treatment of femoral deformities associated with shortening.

Methods: Between 1997 and 2005, twenty-eight femora in twenty-five patients with a median age of twenty-seven years underwent reconstruction with an intramedullary nail and a unilateral fixator. The mean amount of shortening was 6.33 cm, and the mean preoperative mechanical axis deviation was 33.86 mm. Deformity correction was performed acutely and secured by the intramedullary nail, which was locked distally, and the same external fixator that was used for the deformity correction was utilized for lengthening. At the end of the distraction period, proximal locking screws were placed in the intramedullary nail and the external fixator was removed. At the time of follow-up, deformity correction and bone healing were assessed clinically and radiographically, complications were noted, and the functional results were assessed.

Results: The mean duration of follow-up was forty months. The mean duration of the external fixation was 83.29 days, and the mean external fixation index was 14.98 days/cm. The mean amount of lengthening was 6.02 cm. The mean amount of mechanical axis deviation at the end of the treatment was 11.29 mm. The mean bone healing index was 36.66 days/cm. A knee flexion contracture developed in one patient and resolved after intensive rehabilitation. One patient underwent two revisions because of Schanz screw displacement secondary to cortical fracture, and four patients with minor pin-track infections were treated successfully with local wound care and oral antibiotics.

Conclusions: While femoral lengthening and deformity correction can be obtained with classic methods for application of an external fixator, the long period of external fixation, patient discomfort, and plastic deformation of the regenerated bone after removal of the fixator are major disadvantages. Two techniques, fixator-assisted nailing and lengthening over an intramedullary nail, were combined in this series. The duration of the external fixation was reduced compared with that required for classic treatment with an external fixator and patient comfort was increased. In addition, the intramedullary nail prevented fracture and deformation of the regenerated bone.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

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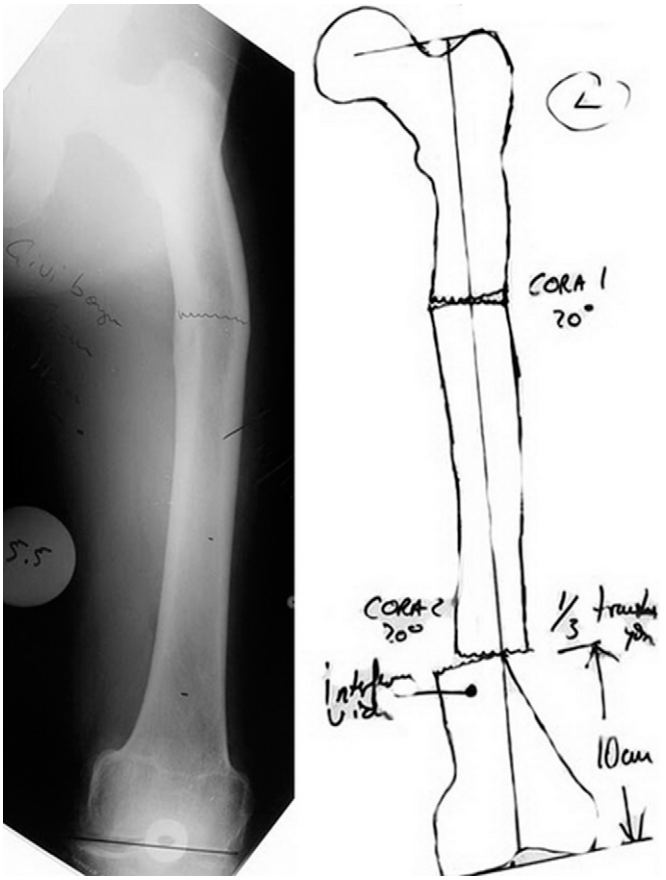

Fig. 1
Radiograph of a left femur with a varus deformity and a paper tracing for simulating the reconstruction preoperatively. CORA = center of rotation of angulation.

Lengthening over an intramedullary nail for the treatment of limb-length discrepancies and fixator-assisted nailing for the treatment of deformities of long bones such as the tibia and femur can provide satisfactory results[1,2]. Both techniques have the advantages of intramedullary nailing, as they prevent fracture of the regenerated bone or loss of correction and/or lengthening. External fixators are commonly used for the treatment of patients with concomitant limb-length discrepancy and deformity[3-5]. We combined fixator-assisted nailing and lengthening over an intramedullary nail for the treatment of this specific group of patients. The purpose of this study was to report our results with this combined technique.

Materials and Methods

We performed the fixator-assisted deformity correction first and then the lengthening over an intramedullary nail in twenty-eight femora of twenty-five patients between 1997 and 2005. Thirteen patients were female and twelve were male. The median age of the patients at the time of surgery was twenty-seven years (range, fourteen to sixty-one years). The etiologic factors were posttraumatic deformity and shortening in eleven patients, deformity and shortening secondary to hypophosphatemic rickets in four, and sequelae of poliomyelitic or congenital deformities in ten (see Appendix).

All patients were evaluated for malalignment and limb-length discrepancy with standing orthoroentgenograms in both the frontal and the sagittal plane. The center of rotation of angulation sites were marked for each femur, and the osteotomy levels were planned accordingly[6]. By using paper tracings, we simulated each procedure preoperatively (Fig. 1). Preoperative planning also included estimation of the diameter and length of the intramedullary nail to be used as well as the location of the interference screws for each case. Extra custom-made holes for locking screws were placed in the nails, if necessary. We used a unilateral fixator (Orthofix LRS; Bussolengo, Verona, Italy) for fixator assistance and an intramedullary nail (Ortopro Retrograde Femoral Nail 4G; Istanbul, Turkey) for intramedullary fixation.

The mean amount of shortening was 6.33 cm (range, 1.5 to 12 cm). The mean angular deformity in the frontal or sagittal plane was 21.89° (range, 5° to 45°). The mean preoperative mechanical axis deviation was 33.86 mm (range, 0 to 123 mm) (Fig. 2). The mean preoperative lateral distal femoral angle was 78.38° in the group with valgus deformity (thirteen femora) and 99.53° in the group with varus deformity including antecurvation (fifteen femora) (Fig. 3).

Twenty-three femora underwent lengthening and deformity correction through the same metaphyseal osteotomy level(s). In five femora, the first osteotomy at the metaphyseal level was used for acute deformity correction, after which an osteotomy was performed at another level for lengthening.

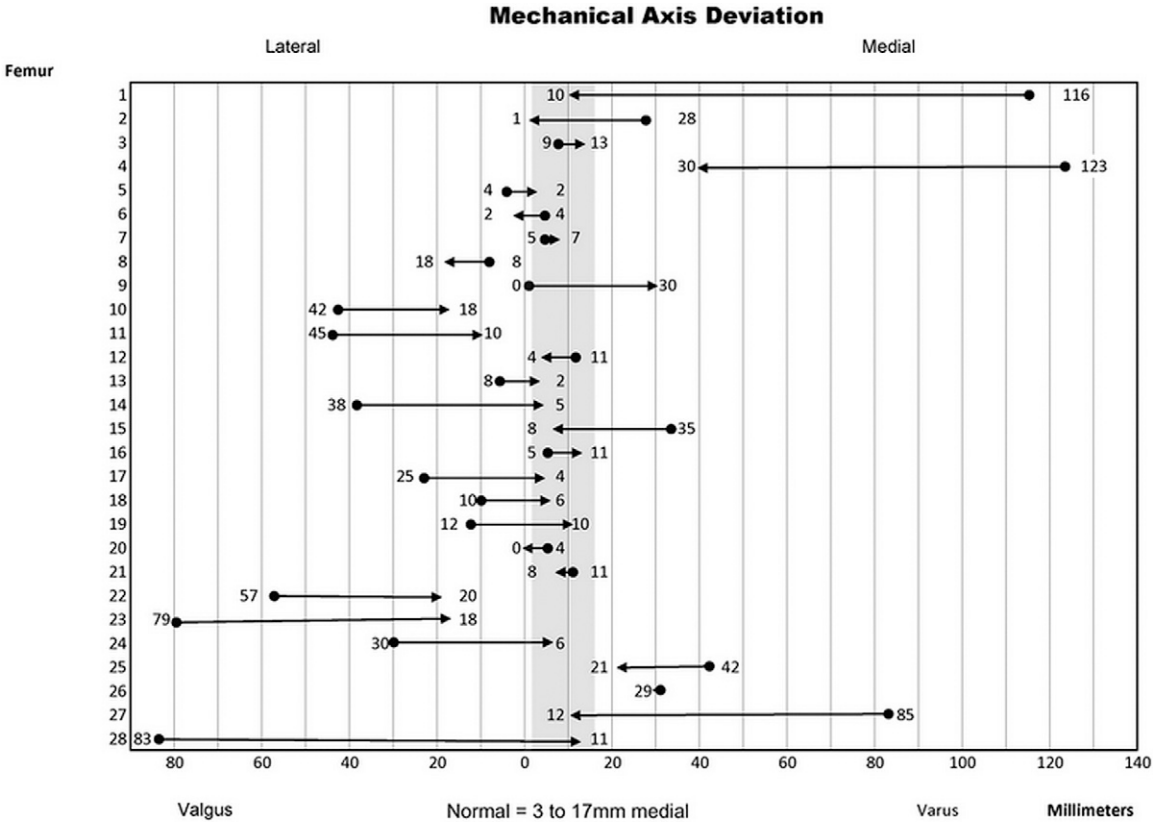

Fig. 2

Mechanical axis deviation. The preoperative deformities are represented by the circles, and the postoperative values are represented by the arrowheads.

The criteria used to evaluate the results in this study were the bone healing index (duration of consolidation per length gained), the external fixation index (duration of external fixation per length gained), and preoperative and postoperative malalignment test values[4]. Consolidation was considered complete when three of four cortices of regenerated bone were noted to be intact on the anteroposterior and lateral radiographs. The functional outcome was assessed with the score described by Paley et al.[1], and complications were classified according to the system proposed by Paley[7].

Operative Technique

The patient is placed supine on a radiolucent table and checked with fluoroscopy from the hip to the ankle in both planes before sterile preparation. Schanz screws are placed perpendicular to the anatomic axis of each segment proximally and distally, with care taken to remain distant from the intramedullary nail to be inserted. Osteotomies are performed with use of a multiple-drill-hole technique at each center of rotation of angulation level. The level of the lengthening osteotomy and the length of the intramedullary nail are chosen to ensure that at least 8 cm of the nail lies above the distraction gap at the end of the lengthening[1]. The deformity is corrected acutely with use of the LRS type of Orthofix external fixator. At this stage, intraoperative radiographs are made in both planes and a malalignment test is done[4]. If the desired correction is not achieved, the external fixator is readjusted and additional radiographs are made. Once satisfactory correction is achieved, an interference screw (a so-called Poller screw) is inserted in the frontal and/or sagittal plane in order to maintain the necessary amount of translation and to narrow the medullary canal, especially in the metaphyseal area (Fig. 4). An intramedullary guide is then inserted through the intercondylar notch percutaneously. The medullary canal is overreamed by 1.5 mm more than the diameter of the intramedullary nail to be used, in order to allow sliding of the nail for lengthening (Fig. 5). The nail is then inserted slowly. Interlocking screws are inserted distally whereas the proximal interlocking screws are not placed until lengthening has been completed. An image intensifier is used to check all Schanz screws to ensure that they are not in contact with the intramedullary nail, and distraction testing is done with the external fixator to confirm that distraction is occurring at the osteotomy level (Figs. 6-A and 6-B). An epidural catheter is inserted for postoperative analgesia.

On the day of the operation, isometric quadriceps and knee range-of-motion exercises are started. On the first postoperative day, full weight-bearing with two crutches is allowed. The patient gradually discontinues use of the crutches during the first month. Distraction begins seven days postoperatively at a rate of 0.25 mm four times a day. During lengthening,

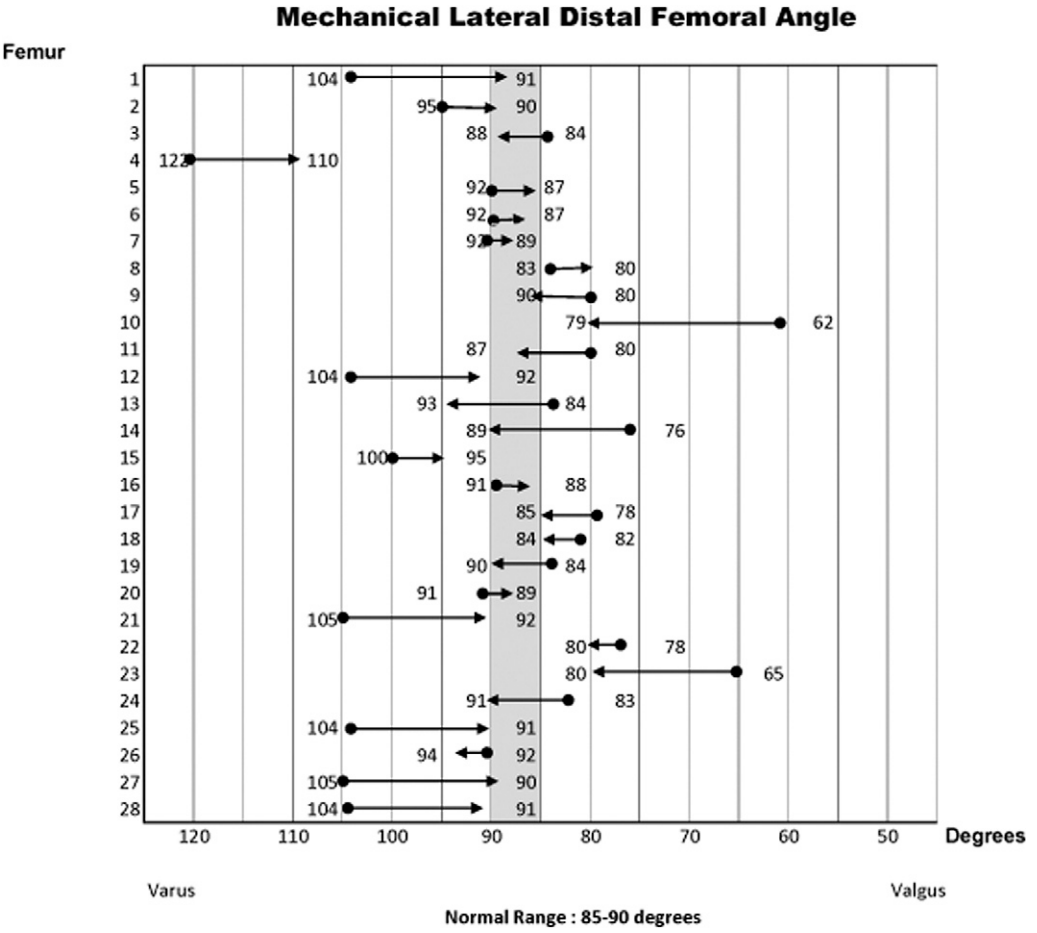

Fig. 3

Mechanical lateral distal femoral angle. The preoperative deformities are represented by the circles, and the postoperative values are represented by the arrowheads.

radiographs are made every two weeks to monitor the distraction progress, and the patient is assessed clinically at each visit.

When the desired amount of lengthening has been achieved, the remaining interlocking screws are inserted and then the external fixator is removed at a second session (Figs. 5, *D,* and 6-C). Following removal of the external fixator, the patient is not allowed to bear full weight until consolidation is established radiographically.

Source of Funding

There was no external source of funding for this study.

Results

The mean duration of follow-up was forty months (range, twenty-eight to 124 months). The mean amount of lengthening was 6.02 cm (range, 2 to 12 cm). The mean mechanical axis deviation of the lower extremity improved from 33.86 mm before the treatment to 11.29 mm (range, 0 to 30 mm) after the treatment. There were no cases of delayed or premature consolidation. The mean duration of external fixation was 83.29 days (range, twenty-eight to 181 days). The mean external fixation index was 14.98 days/cm (range, 8.1 to 30.2 days/cm). The mean bone healing index was 36.66 days/cm (range, 15 to 55 days/cm). The mean postoperative lateral distal femoral angle value was 85.84° in the group with valgus deformity and 91.73° in the group with varus deformity.

The functional score as rated with the system of Paley et al.[1] was excellent for fifteen patients, good for seven, and fair for three. This technique was associated with a total of seven complications, including five problems, two obstacles, and no sequelae according to Paley's classification[7]. Four patients had minor pin-track infections, which responded to local wound care and oral antibiotics. A knee flexion contracture developed in one patient and resolved after intensive rehabilitation. One patient underwent two revisions because of Schanz screw displacement secondary to cortical fracture. This patient did not have any long-term problems as a result of the screw displacement.

Discussion

Femoral deformities are either discrete and angular, or long-bowing (multiapical), deformities. Discrete angular defor-

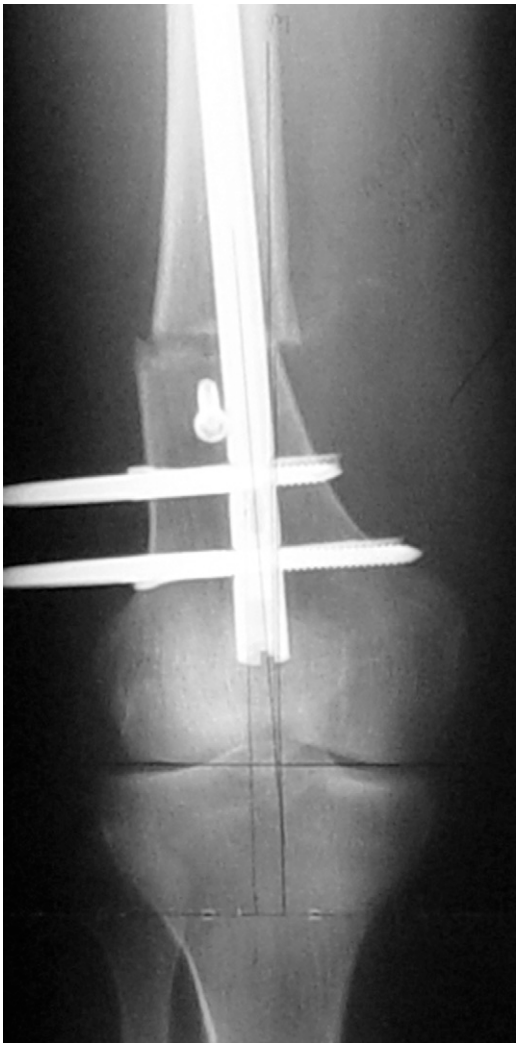

Fig. 4

An interference screw (Poller screw) has been inserted from anterior to posterior to ensure maintenance of the necessary amount of translation and to narrow the medullary canal at the metaphyseal level.

mities originate from or adjacent to the growth plate, and often a single osteotomy is all that is required to correct the deformity. The management of patients with multiapical deformities is complicated, especially if they are associated with a limb-length discrepancy[8,9]. Multiapical deformities are generally due to metabolic bone diseases and usually result in bowing of the entire long bone. More than one osteotomy is often needed to correct the deformity in order to produce a straight bone and avoid creating secondary iatrogenic deformities[8]. Correction of all deformities with an Ilizarov-type external fixator at one operation can cause considerable discomfort[1], but it allows postoperative adjustments and prevents inequality of limb lengths. Ilizarov-type external fixators, however, have disadvantages such as pin-track infections, discomfort, and bulkiness[1]. Internal fixation provides better patient comfort but requires substantial technical skill and expertise[8].

Two techniques, fixator-assisted nailing and lengthening over a nail, have been combined for the treatment of cases of femoral deformity associated with limb-length discrepancy[10]. The standard treatment for this group of patients has been external fixation alone[3,4]. By using the combined technique, we obtained the advantages of both[11]. However, the combination of fixator-assisted acute deformity correction and consecutive lengthening over an intramedullary nail requires careful analysis of the deformity and preoperative preparation[6,7,10]. The surgeon must be familiar with both intramedullary nailing and external fixation techniques, as both techniques have a steep learning curve[8].

Donnan et al. reported their technique of acute correction of lower-extremity deformity and simultaneous lengthening with use of a monolateral fixator[4]. Their patients were mainly children, and they used this technique on both the tibia and the femur. The mean bone healing index in the femoral subgroup in their series, which was equal to the external fixation index in our series because Donnan et al. used a fixator-only technique, was 46.4 days/cm. In our series, the mean external fixation index was substantially lower (14.98 days/cm) and the bone healing index was lower as well (36.66 days/cm).

Paley et al. compared the results of femoral lengthening over an intramedullary nail with those of Ilizarov femoral lengthening[1]. The mean external fixation index for the limbs that were lengthened over an intramedullary nail was 0.5 mo/cm (15 days/cm), which is similar to our result (14.98 days/cm). The mean radiographic consolidation index (the bone healing index) was 1.4 mo/cm (42 days/cm) in their group treated with lengthening over an intramedullary nail and 1.7 mo/cm (51 days/cm) in their group treated with Ilizarov femoral lengthening. In our study, the bone healing index was 36.66 days/cm, which was similar to the value in their group treated with lengthening over an intramedullary nail but shorter than that in their group treated with Ilizarov femoral lengthening.

Tetsworth and Paley reported on the accuracy of correction of complex lower-extremity deformities with use of the Ilizarov method[12]. Postoperatively, their patients had a mean limb-length discrepancy of 6.1 mm, a mean residual distal femoral deformity of 5.4°, and a mean mechanical axis deviation of 8.6 mm. Their results suggested that the accuracy of correction increased with surgical experience. We obtained a mean postoperative femoral length discrepancy of 5.1 mm and a mean postoperative mechanical axis deviation of 11.29 mm. The mean postoperative lateral distal femoral angle in our series was 85.84° in the group with valgus deformity and 91.73° in the group with varus deformity.

Gugenheim and Brinker reported on a group of patients in whom fixator-assisted nailing was used without lengthening for the correction of distal femoral deformities[11]. In that series, the mean postoperative lateral distal femoral angle was 89° for both patients with a distal femoral varus deformity and those with a distal femoral valgus deformity.

When metaphyseal-level osteotomies are used for deformity correction, there is a risk of progression of the de-

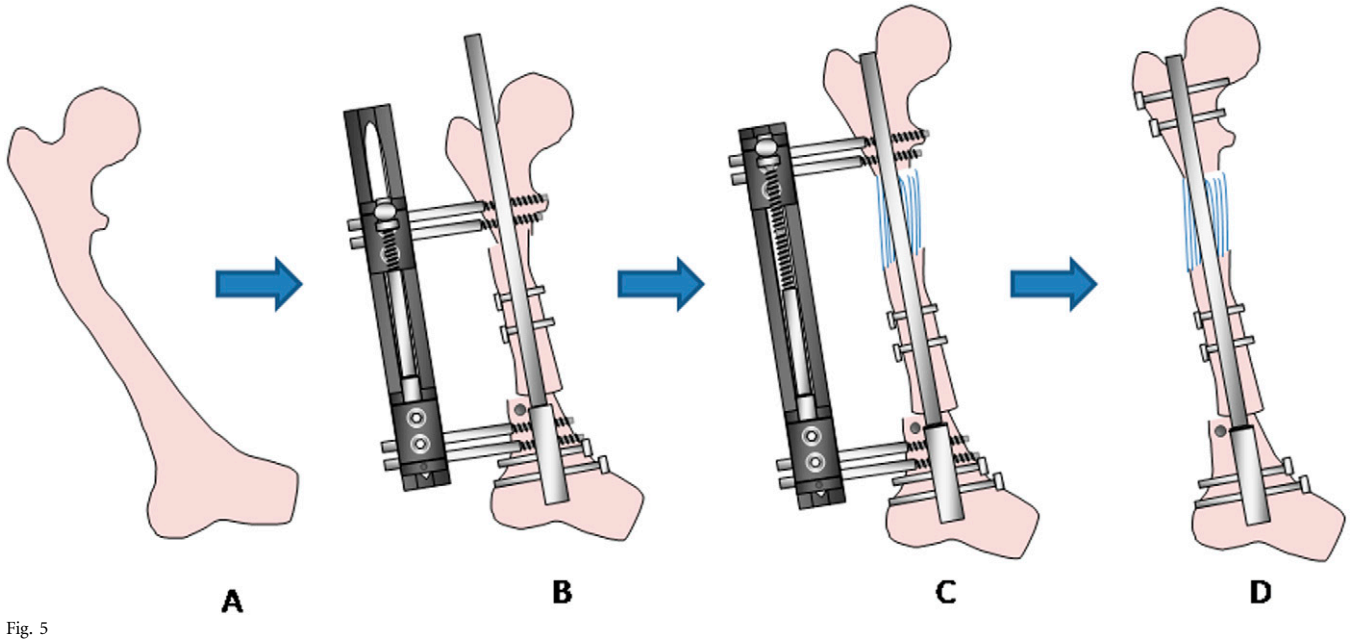

Fig. 5

Schematic drawing of fixator-assisted deformity correction and simultaneous lengthening over an intramedullary nail. *A:* A right femur with a deformity. *B:* Acute deformity correction through two osteotomy levels with fixator assistance. The intramedullary nail has been locked at the distal and middle fragments. The interference screw holds the distal fragment in the desired amount of translation and narrows the medullary canal. *C:* Lengthening over the nail with use of the external fixator. *D:* The intramedullary nail is locked proximally, and the fixator is removed at the end of lengthening.

formity as well as loss of deformity correction during lengthening, especially in patients with metabolic bone disease[9]. To avoid this, we have statically locked the intramedullary nail at the metaphyseal osteotomy levels in both the frontal and the sagittal plane and performed osteotomies at another level for lengthening.

When a patient is treated with fixator-assisted nailing and lengthening over an intramedullary nail, the external fixator remains in place only during the distraction phase and not during the consolidation phase; thus, patient tolerance and mobility are better than they are with classic external fixator techniques, with which the device is used throughout the distraction and consolidation phases. Furthermore, the risk of complications related to prolonged use of an external fixator, such as pin-track infections and joint stiffness, is decreased as a result of the shortened duration of external fixation. Paley et al. found a significant decrease ($p < 0.001$) in the duration of external fixation in their patients treated with femoral lengthening over an intramedullary nail as compared with the duration in the group treated with external fixation only, and the latter group had twice as many pin-track infections[1].

The use of an intramedullary nail also provides numerous advantages. On completion of lengthening, there is no external fixator in place during the consolidation period. Therefore, the duration of external fixation and the external fixation index are significantly decreased ($p < 0.001$) compared with the values associated with treatment with an external fixator alone[1]. As a result of the increased stability provided by the intramedullary nail, the risks of fracture of the regenerated bone and loss of deformity correction are very low. These issues are of maximum importance, especially for patients with metabolic bone disease[1,8,13]. Paley et al. reported fracture of the regenerated bone after limb lengthening[1]. Song et al.[13] demonstrated refractures after deformity correction when an intramedullary nail had not been used and no fractures when an intramedullary nail had been used. They also found no progressive recurrence of the deformity in the diaphysis. We did not encounter any refractures or any recurrences of the deformities in our series. Another advantage of the intramedullary nail is that it allows early and intensive rehabilitation. Paley et al. found a significant difference ($p < 0.001$) in the knee range of motion at the end of the consolidation phase between the fixator-only group and the group treated with lengthening over an intramedullary nail in their series[1]. Only one patient in our series had a knee flexion contracture at the end of the consolidation phase, and that resolved completely with intensive rehabilitation.

Another alternative for the treatment of patients with deformity and concomitant shortening in the same extremity segment is use of a fully implantable lengthening nail[14]. Baumgart et al. reported on a patient with Ollier disease who had a satisfactory result after treatment with such a device[14]. This technique eliminates the need for an external fixator for lengthening and thus provides much more patient comfort than lengthening techniques that involve use of an external fixator. This device currently is limited to lengthening of up to 6 cm. In our series, twelve of the twenty-eight femora were lengthened >6 cm.

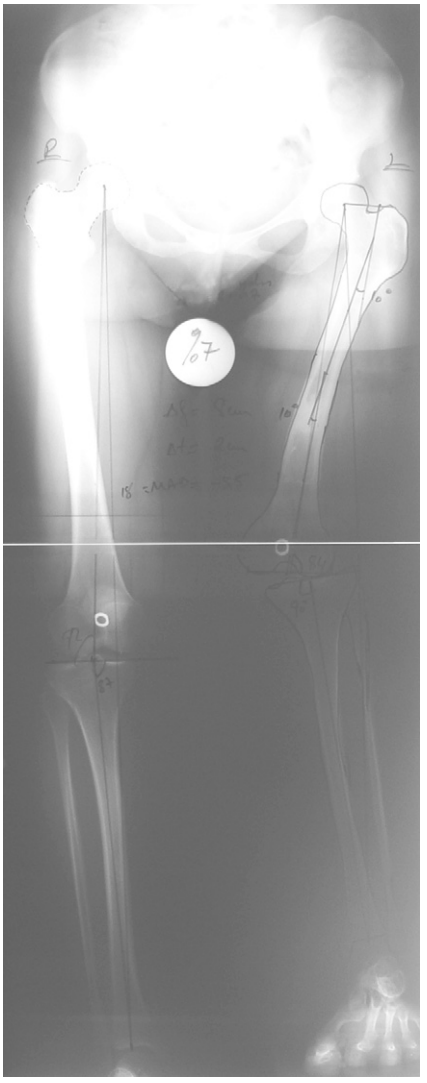

Fig. 6-A

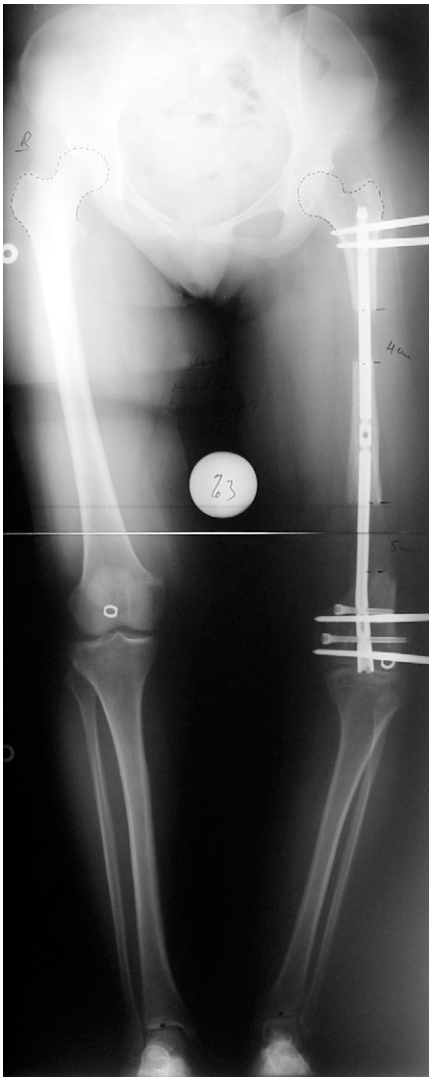

Fig. 6-B

Fig. 6-C

Fig. 6-A Anteroposterior radiograph of the left femur with a valgus deformity and shortening. **Fig. 6-B** Acute correction was achieved through two osteotomies and fixator-assisted nailing. Lengthening was performed with the external fixator. **Fig. 6-C** After lengthening, the intramedullary nail was locked and the fixator was removed, allowing progression of the consolidation phase.

None of our patients had a documented fat embolism. We attribute the lack of this complication to the performance of the osteotomies prior to the intramedullary nailing. We took great care to ensure that there was no contact between the nail and the external fixation pins, as recommended by Paley et al.[1], and no intramedullary infections related to the Schanz screws developed in our patients.

Immediate correction of angular deformities raises concern regarding neurovascular compromise[9]. There is an especially increased risk of peroneal nerve injury when an acute correction of a valgus knee deformity is carried out[9]. To prevent this complication, either prophylactic peroneal nerve release or a closing-wedge osteotomy can be performed[2,9]. The latter procedure is associated with loss of limb length and thus is not applicable when lengthening is needed. There were no neurovascular complications in our series. We attributed this to the compliant soft-tissue envelope of the thigh reducing the risk of compartment syndrome or neurapraxia[9].

In conclusion, this technique of external fixator-assisted acute deformity correction and consecutive lengthening over an intramedullary nail allows the surgeon to address two pathological entities at the same time. Although the combination of intramedullary nailing and monolateral external fixation is technically more demanding than is external fixation alone, it has the advantages of a decreased duration of external fixation, protection against fracture of the regenerated bone, prevention of the loss of deformity correction, and earlier rehabilitation. Compared with classic external fixator techniques, the combined method is associated with fewer pin-track infections, increased patient comfort, fewer problems with patient compliance, and increased safety.

Appendix

eA A table showing details on all study patients is available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD). ■

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