Bone Realignment with Use of Temporary External Fixation for Distal Femoral Valgus and Varus Deformities

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Background: Correction of a distal femoral deformity may prevent or delay the onset of osteoarthritis or mitigate its effects. Accurate correction of deformity without production of a secondary deformity depends on precise localization and quantification of the deformity. We report a technique to correct distal femoral deformities in the coronal plane.

Methods: Fourteen femora in thirteen skeletally mature patients with a distal femoral deformity underwent operative reconstruction. The preoperative deviation of the mechanical axis ranged from 90 mm laterally (genu valgus) to 120 mm medially (genu varus). The mechanical lateral distal femoral angle was abnormal in all fourteen knees. The technique consisted of application of an external fixator, performance of a percutaneous distal femoral dome osteotomy, correction of the deformity, and locking of the external fixator. A statically locked retrograde intramedullary nail was inserted following reaming, and the external fixator was removed. The mean duration of follow-up was thirty-three months (range, six to forty-seven months).

Results: The mean time until healing was thirteen weeks (range, six to thirty-nine weeks). Nine of the thirteen patients reported an improvement in walking, and none needed an assistive device. All nine patients with preoperative knee pain were free of tibiofemoral pain at the most recent follow-up evaluation. The mechanical lateral distal femoral angle was within the normal range in twelve of the fourteen knees. The mechanical axis was within the normal range in ten lower extremities. In three of the four remaining limbs, the residual abnormal deviation of the mechanical axis was due to a residual tibial deformity.

Conclusions: Percutaneous dome osteotomy combined with temporary external fixation and insertion of an intramedullary nail can correct distal valgus and varus femoral deformities. We attributed the early mobilization of patients and the rapid bone-healing to the limited soft-tissue dissection, the low-energy corticotomy, and the use of intramedullary fixation in our surgical technique.

Level of Evidence: Therapeutic study, Level IV (case series [no, or historical, control group]). See Instructions to Authors for a complete description of levels of evidence.

Angular deformities of the distal part of the femur are seen in patients with fracture malunion[1], adolescent-onset Blount disease[2], metabolic disorders[3], osteoarthritis[4-8], and idiopathic processes[3]. The development and progression of knee osteoarthritis correlates with coronal plane deformity[9].

If an osteotomy is performed to correct malalignment of the lower extremity, the location and magnitude of the deformity must be determined to avoid producing a secondary deformity. Although authors of previous studies have recommended proximal tibial osteotomy for correction of a genu varus deformity[7,10-13] and distal femoral osteotomy for correction of a genu valgus deformity[4,7,8,14,15], either deformity may be present in the tibia or the femur, or both. Correction of the mechanical axis of the lower extremity can be accomplished by an osteotomy of either the distal part of the femur or the proximal part of the tibia, but an osteotomy of the incorrect bone can correct the mechanical axis only by increasing the malorientation of the knee joint, which may result in excessive shear at the joint[6,10] (Fig. 1). Accurate correction of a femoral deformity depends on correction of the deviation of the mechanical axis (alignment) and the lateral distal femoral angle

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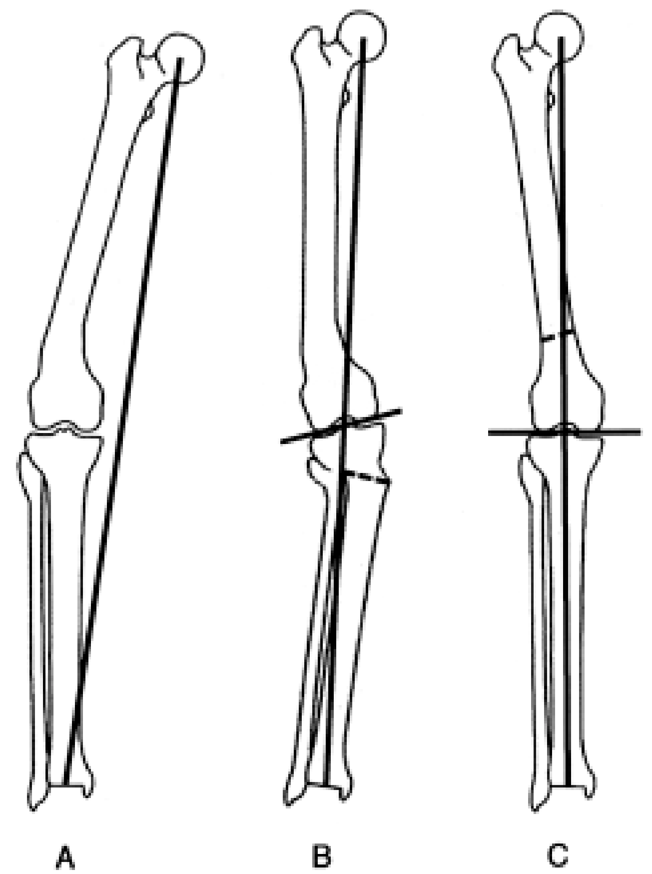

Fig. 1
An osteotomy performed at the incorrect level causes joint obliquity. *A:* Deviation of the mechanical axis due to a distal femoral deformity. *B:* Angular correction through the tibia corrects deviation of the mechanical axis but causes joint obliquity. *C:* Accurate correction at the distal part of the femur corrects deviation of the mechanical axis without causing joint obliquity. Both the mechanical axis and the joint orientation angles are now normal.

(joint orientation)[16,17].

The purpose of this report is to describe techniques for locating and quantifying distal femoral deformities in the coronal plane, to describe a surgical technique for correction of these deformities, and to describe our results with this technique.

Materials and Methods

Characteristics of the Patients

Fourteen femora in thirteen patients underwent correction of a distal femoral deformity in the coronal plane by one or both of us between 1996 and 1999 (see Appendix). The indications for the procedure were a distal femoral valgus or varus deformity as quantified by deviation of the mechanical axis of >15 mm and a mechanical lateral distal femoral angle greater than one standard deviation from the normal value. We selected these criteria because the range of values for these radiographic parameters in older adults with no symptoms of osteoarthritis is very narrow[18] and because angulation of >2° from normal has been associated with progressive osteoarthritic changes in the knee joint[9]. Three knees (Cases 1, 3, and 11 [see Appendix]) had mild joint-space narrowing on a preoperative standing anteroposterior radiograph of the knee, and one knee (Case 2) had lateral osteophyte formation. The average age of our patients at the time of surgery was twenty-six years (range, thirteen to seventy-two years), and there were seven male patients and six female patients. The distal femoral physis was closed in all patients.

The etiology of the distal femoral deformities was Blount disease (four femora), idiopathic (four), fracture malunion (two), partial physeal arrest (one), congenital hypoplastic femur (one), multiple osteochondromas (one), and poliomyelitis (one). One patient with Blount disease involving both lower ex-

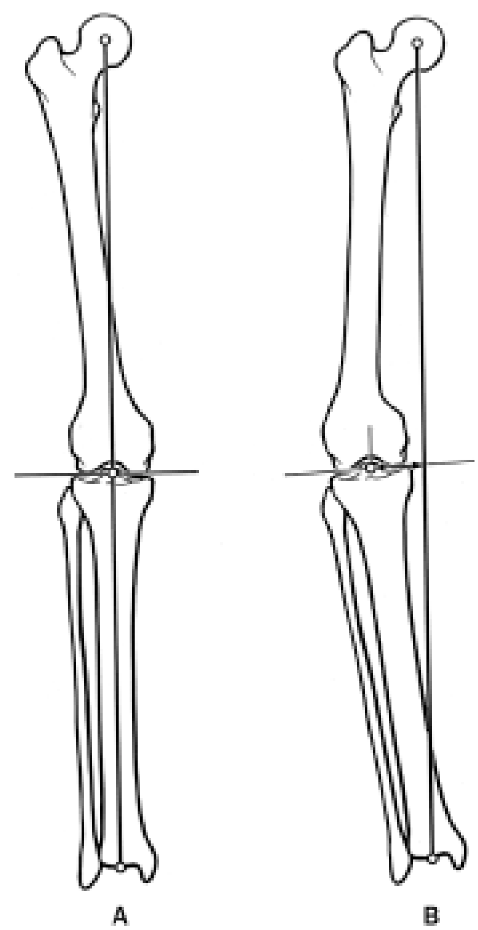

Fig. 2
Quantification of malalignment. *A:* The normal mechanical axis of the lower extremity is a straight line extending from the center of the femoral head to near the center of the knee to the center of the ankle. *B:* Deviation of the mechanical axis indicates the presence of an angular deformity in the lower extremity. It is the horizontal distance in millimeters from the center of the knee joint to the mechanical axis.

tremities (Cases 13 and 14) underwent operative correction of both extremities with approximately seventeen months between procedures.

Nine patients (ten femora) had preoperative pain that limited activities of daily living, and nine patients (ten femora) had difficulty walking because of the deformity. Twelve of the thirteen patients were so-called community walkers prior to the surgery; one patient (Cases 13 and 14) with bilateral Blount disease was a household walker prior to the surgery[19].

Prior to the reconstruction, six femora had a distal valgus deformity and eight had a distal varus deformity. Two of the femoral valgus deformities were associated with a tibial deformity due to a previous proximal tibial fracture. Four of the femoral varus deformities were associated with a concomitant proximal tibial varus deformity due to adolescent Blount disease[2]. These six extremities (five patients) underwent tibial realignment with use of the Ilizarov method at the same time as the femoral reconstructive procedure. Other procedures performed at the same time as the distal femoral dome osteotomy included resection of osteochondromas (one femur) and proximal segmental femoral osteotomies for a multiapical deformity (one femur; Case 7) due to complications from previous lengthenings of a congenital hypoplastic femur.

Clinical Evaluation

Clinical evaluation was performed preoperatively and at the time of the most recent follow-up (mean, 32.7 months; range, six to forty-seven months). Except for three patients (Cases 8, 9, and 13) who could not be located, all patients were followed for at least twenty-four months. Excluding two of the three patients who could not be located would have falsely improved the overall results because, at the time of follow-up, one (Case 8) had an abnormal mechanical lateral distal femoral angle and the other (Case 13) had abnormal deviation of

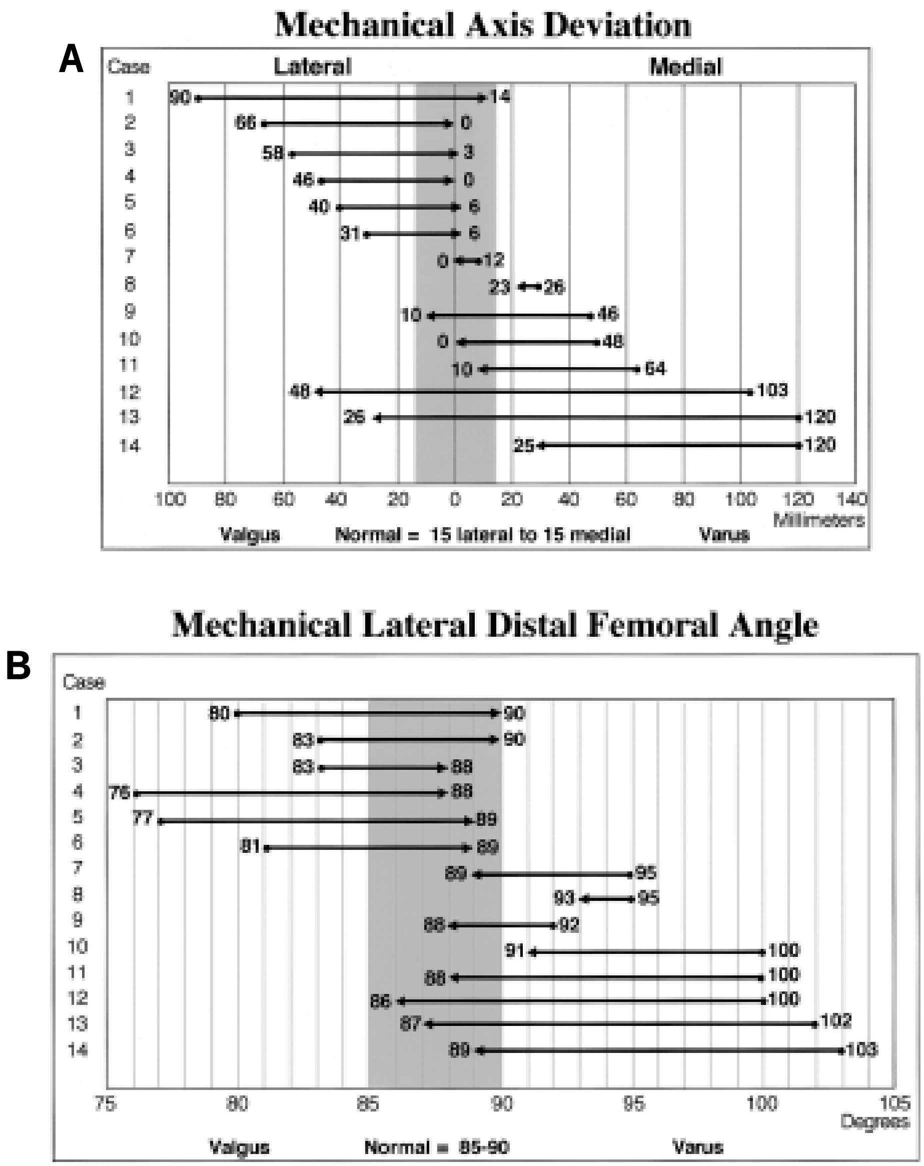

Fig. 3
The preoperative deformities are represented by the circles, and the postoperative values are represented by the arrowheads. *A:* Mechanical axis deviation. *B:* Mechanical lateral distal femoral angle.

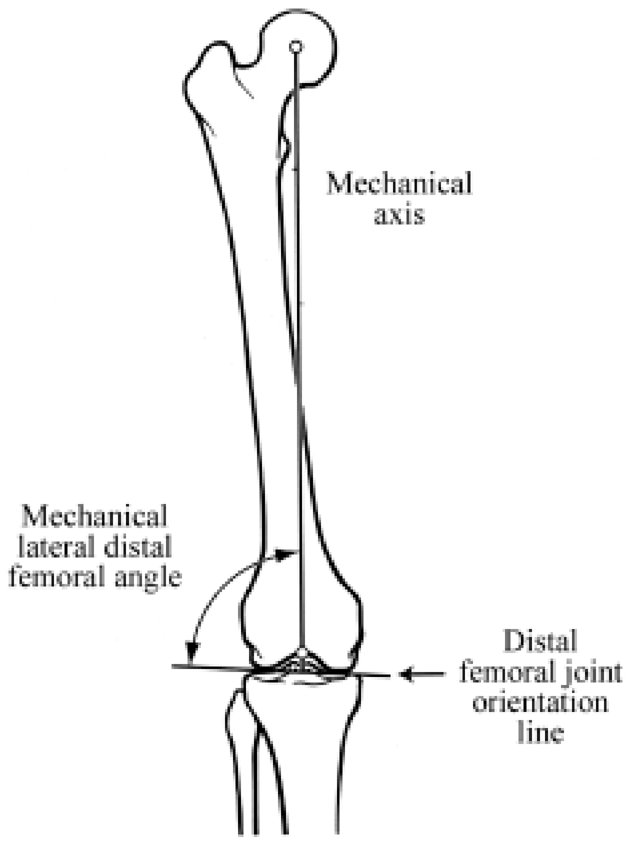

Fig. 4
The mechanical lateral distal femoral angle identifies an angular deformity in the femur; it is formed by the intersection of the mechanical axis and the distal femoral joint orientation line.

The mechanical axis of the lower extremity is a straight line extending from the center of the femoral head to the center of the ankle. The horizontal distance in millimeters from the center of the knee joint to the mechanical axis is the deviation of the mechanical axis (Fig. 2). We defined a normal mechanical axis of the lower extremity as passing within 15 mm of the center of the tibial spines[21-25]. Deviation of the mechanical axis indicates the presence of a deformity but does not specify whether the deformity is in the femur or tibia, or whether it is due to excessive ligamentous laxity of the knee joint. A valgus deformity is characterized by a lateral deviation of the mechanical axis, and a varus deformity is characterized by a medial deviation of the mechanical axis. Preoperatively, thirteen of the fourteen lower extremities had an abnormal mechanical axis. The one limb (Case 7) with a mechanical axis within the normal range had a multiapical varus deformity of the femur. The nearly semicircular femur, as seen in the coronal plane, paradoxically resulted in a nearly normal mechanical axis. Preoperatively, the lateral deviation of the mechanical axis averaged 55 mm (range, 31 to 90 mm) for the limbs with a valgus deformity, and the medial deviation of the mechanical axis averaged 67 mm (range, 12 to 120 mm) for the limbs the mechanical axis. The sites of all fourteen femoral osteotomies had united at the time of the final review.

At the most recent follow-up evaluation, the patients were asked to rate their walking ability, as compared with their preoperative ability, on the basis of pain, the ability to walk distances, and the need for assistive devices. Both preoperatively and at the most recent follow-up evaluation, the patients were asked to rate their average knee pain during the course of a typical week on a scale ranging from 0 (no pain) to 10 (most severe pain).

Radiographic Evaluation

Preoperative and postoperative anteroposterior and lateral weight-bearing radiographs were made on a 130-cm (51-in) film, with the x-ray tube 305 cm (10 ft) from the film, and with the patient standing with the patellae forward. The deformities of the distal part of the femur and proximal part of the tibia were located and were quantified with use of the method of Paley et al.[17,20]. Malalignment was quantified on the basis of the deviation of the mechanical axis, and malorientation was quantified on the basis of the mechanical lateral distal femoral angle.

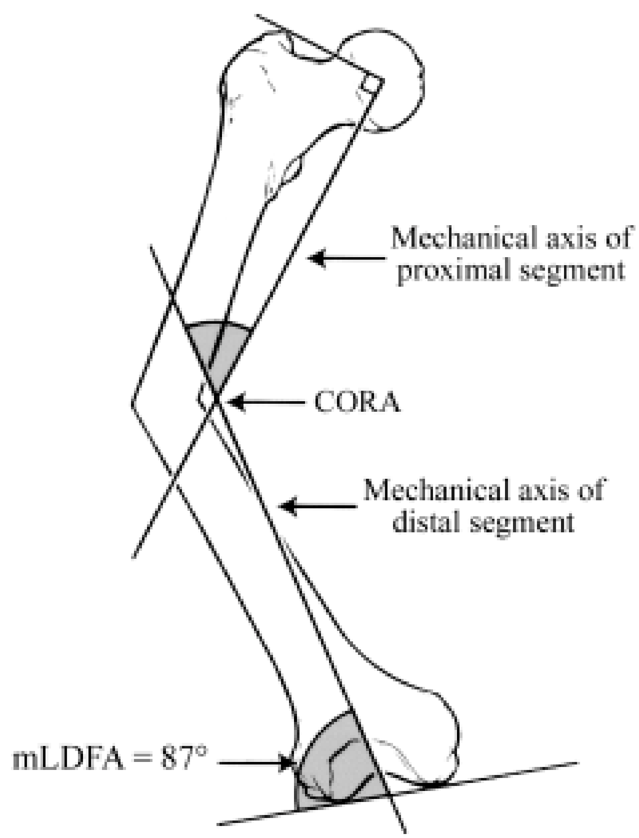

Fig. 5
The center of rotation of angulation (CORA) locates and quantifies the femoral angular deformity. mLDFA = mechanical lateral distal femoral angle.

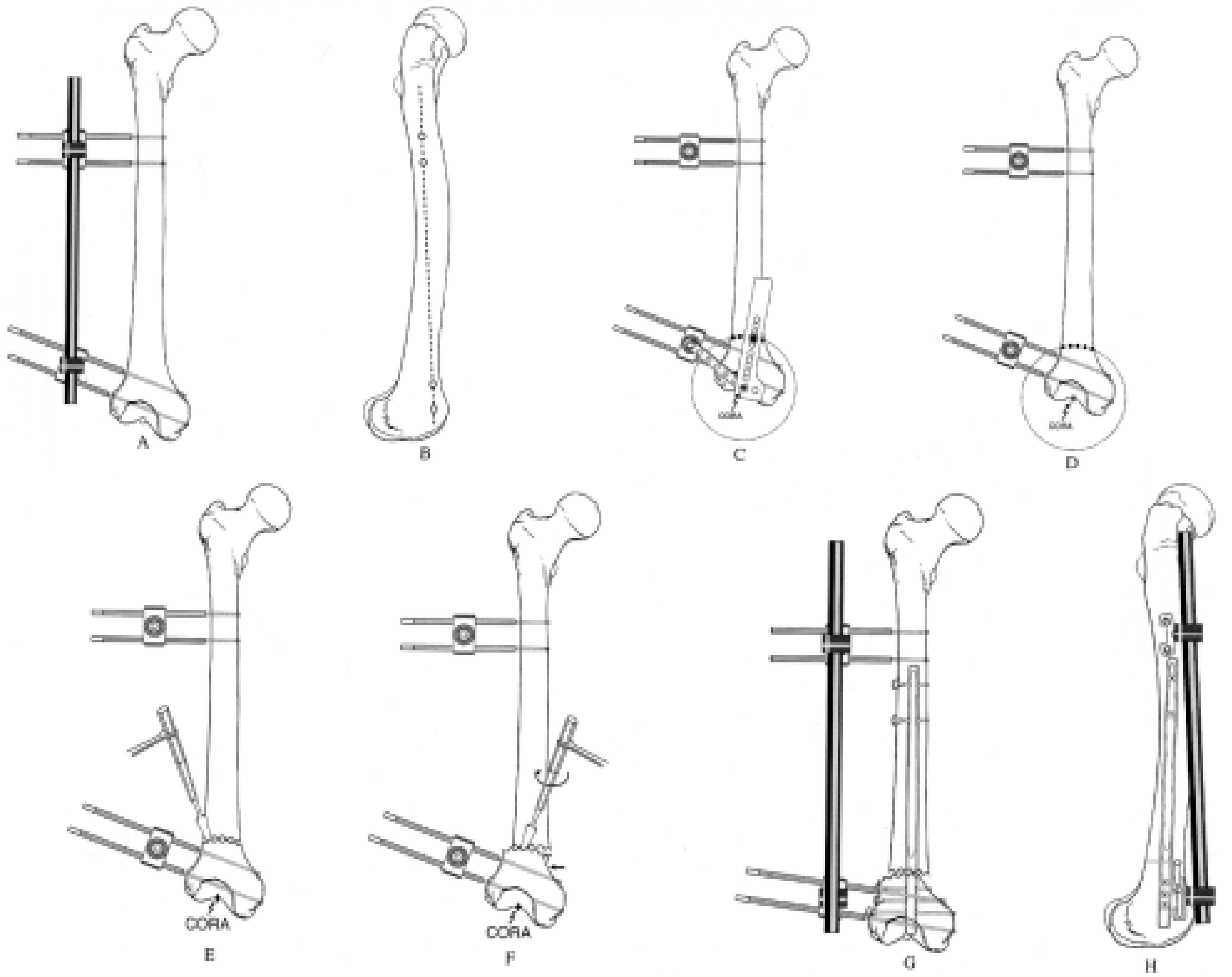

Fig. 6

The surgical technique. *A* and *B:* Pins for the external fixator are placed in the anterior cortex distally to facilitate passage of the intramedullary nail. The proximal pins are placed in the medullary canal. *C* and *D:* The acrylic block attached to the fixator outlines an arc of drill-holes with the center of rotation of angulation (CORA) of the level determined by preoperative planning. *E* and *F:* A straight osteotome completes the osteotomy, with twisting of the handle to translate the distal fragment in the desired direction. Since the CORA is at the intercondylar notch and the osteotomy is performed at a site other than the CORA, a combination of angulation and translation is necessary to attain correction. *G* and *H:* The intramedullary nail is inserted, and locking screws are inserted before removal of the fixator.

with a varus deformity (Fig. 3 and Appendix).

Malorientation of the distal part of the femur was quantified by the mechanical lateral distal femoral angle (Fig. 4). A straight line drawn tangential to the medial and lateral femoral condyles was the distal femoral joint orientation line. The intersection of the femoral mechanical axis (a straight line extending from the center of the femoral head to the center of the knee joint) and the distal femoral joint orientation line forms the mechanical lateral distal femoral angle; the normal range for this angle is 85° to 90°[16,18,26]. A value below the normal range indicates a distal femoral valgus deformity, and a value above the normal range indicates a distal femoral varus deformity. Preoperatively, the mechanical lateral distal femoral angles averaged 80° (range, 76° to 83°) for the valgus femora and 98° (range, 92° to 103°) for the varus femora (Fig. 3 and Appendix).

The magnitude and level of femoral deformity were determined at the junction of the mechanical axis of the proximal femoral segment and the mechanical axis of the distal femoral segment with the method of Paley et al.[17,20]. The intersection of the proximal and distal axes identifies the deformity resolution point, called the center of rotation of angulation (Fig. 5). At the center of rotation of angulation, the deformity has no translation component, only angulation. Correction of the angular deformity at the level of the center of rotation of angulation

Fig. 7-A

Fig. 7-B

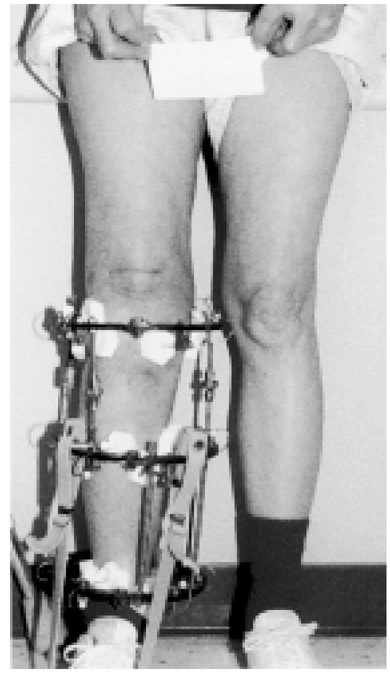

Fig. 7-C

Figs. 7-A through 7-E Case 1, a fifty-four-year-old woman with an idiopathic valgus deformity of the right femur and a tibial valgus deformity secondary to a malunion of a tibial plateau fracture. **Fig. 7-A** Preoperative radiograph. **Fig. 7-B** Preoperative photograph. **Fig. 7-C** Photograph showing the Ilizarov tibial frame after acute femoral realignment and gradual tibial realignment.

and by the magnitude of the angle formed should restore the normal axis and the normal joint orientation. If an osteotomy is performed at a level that is not at the center of rotation of angulation, a combination of angulation and translation must be achieved for correction[17]. The center of rotation of angulation of the femoral deformity in all fourteen knees was at the level of the knee joint or at the femoral condyles. Neither level was practical for an osteotomy. Because a metaphyseal osteotomy would have been proximal to the juxta-articular center of rotation of angulation, both angulation and translation were performed at this osteotomy site.

Proximal tibial deformities were identified with a method that was similar to that used for identification of the distal femoral deformities—i.e., with measurement of the medial proximal tibial angle formed by the intersection of the proximal tibial joint orientation line and the tibial mechanical axis. The normal range for the medial proximal tibial angle is 85° to 90°[18].

Osseous union at the osteotomy site was determined by the presence of bridging bone on all four cortices as seen on the anteroposterior and lateral radiographs made at three to four-week intervals following the procedure.

Surgical Technique (Fig. 6 and Appendix)

The surgical technique consisted of application of an external fixator to the femur, performance of a percutaneous distal femoral curved (dome) osteotomy with the center of the dome at the level of the center of rotation of angulation, angulation and translation at the osteotomy site, locking of the external fixator, placement of a statically locked intramedullary nail after confirmation of correction, and removal of the fixator[27]. Poller (so-called bumper) screws were inserted percutaneously from anterior to posterior if they were necessary to augment stability at the distal metaphyseal flare[28].

A monolateral Hex-Fix external fixator (Smith and Nephew, Memphis, Tennessee) was used in twelve cases. Two parallel 6-mm half-pins were inserted in the anterior cortex of the distal part of the femur, avoiding the medullary canal in order to facilitate insertion of the intramedullary nail. Two more 6-mm half-pins were inserted in the femur, proximal to the anticipated location of the proximal intramedullary nail tip. The Hex-Fix frame was loosely assembled with the bar anterior to the plane of the half-pins. Inserting the bar posterior to the half-pins would have obstructed later insertion of the intramedullary locking screws of the intramedullary nail from the more desirable lateral aspect.

An Ilizarov external fixator (Smith and Nephew) was used in two cases. With use of this fixator, the distal 1.8-mm wires were placed in the anterolateral and anteromedial cortices in a crossing configuration to avoid the medullary canal. The proximal implants were 6-mm half-pins affixed to a proximal ring with use of the standard technique.

The level of the osteotomy was planned to create a distal fragment of sufficient size to insert at least two interlocking screws into the intramedullary nail. The dome osteotomy consisted of a semicircular arc (concave distally), with the center of the arc at the level of the center of rotation of angulation.

The osteotomy site was exposed through a 3-cm trans-

Fig. 7-D

Fig. 7-E

Figs. 7-D and 7-E Final clinical appearance and anteroposterior radiograph at forty-five months after the procedure.

verse skin incision. The osteotomy was outlined by creating a series of holes with a drill guided by an acrylic block (Smith and Nephew) mounted on the distal section of the external fixator (see Appendix). The holes were connected with a 6.3-mm straight osteotome to complete the osteotomy. Translation was performed by twisting the handle of a 12.7-mm osteotome inserted into the osteotomy site; angulation was then performed by moving the leg medially or laterally. The fixator was locked, an anteroposterior radiograph was made to measure the lateral distal femoral angle, and a lateral radiograph was made to confirm that there was no displacement in the sagittal plane. The incision was then closed in layers.

A statically locked retrograde intramedullary nail (Smith and Nephew) was then inserted after reaming. The fixator was removed, and the stability of the construct was checked under fluoroscopy. Bicortical Poller screws were inserted if any movement was seen[28]. No external immobilization was used.

Postoperative pain was controlled with either intravenous patient-controlled analgesia or epidural patient-controlled analgesia. Patients began walking with crutches with 22.5 kg (50 lb) of weight-bearing on the day following surgery. When radiographs showed osseous healing, patients returned to full weight-bearing.

Results

At the most recent follow-up evaluation, nine of the thirteen patients (ten of the fourteen femora) reported an improvement in their walking ability (see Appendix). No patient required a walking aid for community walking. Nine patients (ten knees) had had pain preoperatively, whereas two patients (two knees) had pain localized to the patella at the most recent follow-up evaluation. The average score for knee pain improved from 5.0 points (range, 0 to 10 points) preoperatively to 0.2 points (range, 0 to 2 points) at the most recent follow-up evaluation. One patient (Case 7) with a congenital hypoplastic femur and hip arthritis who had undergone realignment to facilitate placement of a total hip prosthesis still had hip pain. Another patient (Case 6), with a preoperative valgus deformity, reported persistence of the preoperative retropatellar pain and a sensation of the knee giving way after the procedure.

The sites of all osteotomies healed at an average of thirteen weeks (range, six to thirty-nine weeks). In one patient (Case 7) with a congenital hypoplastic femur and a multiapical deformity who had had a three-level osteotomy, a nonunion developed at the most proximal osteotomy site; this site was treated with a plate and bone graft at twenty-four weeks. Osseous union occurred at thirty-nine weeks from the time of the initial osteotomy. There was no loss of fixation, infection, or loss of knee motion in any patient.

At the time of follow-up, the mechanical lateral distal femoral angle was within the normal range in twelve of the fourteen knees. The final mechanical lateral distal femoral angle averaged 89° (range, 88° to 90°) in the extremities that had had a distal femoral valgus deformity and 89° (range, 86° to 93°) in those that had had a distal femoral varus deformity (Fig. 3 and Appendix). Of the two limbs with an abnormal mechanical lateral distal femoral angle at the most recent follow-up evaluation, one (Case 8) had had a preoperative distal femoral varus deformity that was undercorrected by 3° and the other (Case 10) had had a preoperative distal femoral varus deformity that was undercorrected by 1°.

At the most recent follow-up evaluation, the mechanical axis was within the normal range in ten of the fourteen lower extremities (Fig. 3 and Appendix). The deviation of the mechanical axis at the time of follow-up averaged 5 mm of medial deviation (range, 14 mm of medial deviation to 0 mm of deviation) in the extremities that had had a distal femoral valgus deformity preoperatively and 3 mm of lateral deviation (range, 25 mm of medial deviation to 48 mm of lateral deviation) in the extremities that had had a preoperative distal femoral varus deformity.

Discussion

The goal of this realignment procedure was to correct malalignment of the lower extremity and perhaps to prevent or delay the onset of osteoarthritis by normalizing the mechanical axis and the distal femoral joint orientation line as measured by the mechanical lateral distal femoral angle. If there was a coexisting proximal tibial deformity, as demonstrated by an abnormal medial proximal tibial angle, a corrective proximal tibial Ilizarov procedure was also performed (Figs. 7-A through 7-E). Since both varus and valgus deformities may lead to osteoarthritis, we strove for correction to normal radiographic parameters, not overcorrection or undercorrection.

We believe that femoral alignment with use of temporary external fixation offers several advantages over traditional osteotomies. The bone is not shortened as it is with a closing wedge osteotomy. The dome-shaped cut affords a large contact surface at the osteotomy site, allows correction in the coronal plane, and minimizes the chance of unwanted displacement in the sagittal plane. The bone fragments produced by reaming for the nail insertion at the time of the osteotomy serve as autograft. The method involves a limited soft-tissue dissection, achieves correction with an external fixator, allows correction of both valgus and varus deformities with the same surgical technique, and provides the stability and convenience (for the patient) of intramedullary nail fixation.

The magnitude and location of the deformity are determined preoperatively. The center of the arc-shaped metaphyseal osteotomy is at the level of the juxta-articular center of rotation of angulation. The amount of translation at the osteotomy site that is necessary for correction of the deformity is determined preoperatively and can be attained reliably during the procedure. Our results with the use of this technique confirm the concepts of Paley et al.[17] and Schulak et al.[29] that pivoting of the distal fragment at the center of rotation, not the osteotomy site, results in correction of angulation with excellent osseous contact.

The procedure has some limitations. Preexisting shortening of the bone cannot be corrected. The magnitude of angular deformity that can be corrected is limited by the amount that the osteotomy site can be translated and still accommodate the intramedullary nail. This procedure is used only when the center of rotation of angulation of the deformity is at the level of the knee joint or the femoral condyles because it is impractical to perform any femoral osteotomy this far distally. Therefore, a combination of angulation and translation was necessary and was attained with the temporary use of the external fixator. The procedure is not appropriate before skeletal maturity because of the danger of injury to the distal femoral physis during retrograde nail insertion. Axial rotation cannot be corrected with this technique because of the hemicylindrical shape of the osteotomy surfaces.

A Hex-Fix monolateral fixator was used in twelve cases, and an Ilizarov circular fixator was used in two. The monolateral fixator appeared to be more rigid when we inserted the nail, and we now favor its use.

Four lower extremities in three patients had an abnormal mechanical axis at the time of follow-up. One undercorrection of an idiopathic varus deformity of the femur (Case 8) occurred early in our experience with this technique. Three knees (Cases 12, 13, and 14) in two very obese patients with Blount disease underwent simultaneous application of an Ilizarov external fixator for gradual correction of a tibial deformity and acute bone realignment with use of temporary external fixation of the femur for correction of a distal femoral deformity. The femoral deformities in these knees were fully corrected, as evidenced by the normal mechanical lateral distal femoral angles. The tibial deformity was overcorrected in two extremities (Cases 12 and 13) and undercorrected in one (Case 14), causing deviation of the mechanical axis.

Except for a nonunion of the proximal osteotomy site of a three-level osteotomy (Case 7) and one case of undercorrection of the mechanical lateral distal femoral angle (Case 8), there were no complications related to the procedure in this series. Because we used the deviation of the mechanical axis and the joint orientation angles to measure the deformities postoperatively, our criteria for accurate correction are stricter than those in previous series, in which only varus or valgus angulation at the knee was quantified[3,14,15,30-32].

Three patients (Cases 8, 9, and 13) were lost to follow-up. Although the duration of follow-up was less than two years for those patients, their most recent radiographs showed osseous union. We included those cases because one of them had a femoral undercorrection (Case 8) and the other had a tibial overcorrection (Case 13) and omitting them would have falsely improved our results.

In conclusion, we believe that bone realignment with use of temporary external fixation for distal femoral deformities offers accurate correction, a low complication rate, stable fixation, the ability to correct both valgus and varus deformities with the same technique, and early mobilization of the patient without the inconvenience of wearing an external fixator.

Appendix

eA Tables showing the patient data and radiographic measurements as well as a detailed description of the surgical technique with illustrative cases are available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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