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Deformity Correction Techniques

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Operative Techniques in
Orthopaedics

Fixator-Assisted Nailing for Correction of Long Bone Deformities

Mehmet Kocaoglu, MD, and F. Erkal Bilen, MD, FEBOT

Many surgical options exist for the correction of long bone deformities. The fixator-assisted nailing (FAN) technique developed by Paley et al combines the accuracy, lack of invasiveness, and adjustability of external fixation with the stability and comfort of internal fixation. A temporary external fixator is applied for acute deformity correction. Once the desired alignment is achieved, an intramedullary nail is placed and locked statically, interference screws are inserted for additional stability, and the fixator is removed during the surgery. This combinatory technique may further be combined with lengthening or arthrodesis procedures.
Oper Tech Orthop 21:163-173

KEYWORDS deformity correction, external fixator, fixator-assisted nailing, intramedullary nail

Long bone deformities cause significant disability as well as psychological consequences to patients, both in childhood and adulthood. It has been shown that deformities around the knee result in arthritic development at the knee joint.[1] Many surgical options exist for the correction of long bone deformities that either acutely or gradually correct the deformity and provide fixation until bone healing is established at the osteotomy site.[2-4] However, the fixator-assisted nailing (FAN) technique described by Paley et al in 1997 has become the gold standard for the correction of long bone deformities.[5,6] This technique combines the accuracy, minimal invasiveness, and safety of external fixation with the patient convenience of internal fixation. The intramedullary nail prevents the recurrence of the deformity, which is especially important in patients with metabolic bone diseases who are prone to recurrence of the deformity as the metabolic problem continues.[7]

Preoperative Planning

Preoperative assessment and preparation are of paramount importance. Patients must be evaluated for malalignment and limb length discrepancy with standing orthoroentgenograms in both the frontal and the sagittal plane.[8] The center of rotation of angulation (CORA) site(s) should be marked on the x-rays. By the use of paper tracings, the procedure can be simulated preoperatively, which will help in planning the surgery (Fig. 1). Preoperative planning also includes an estimation of the diameter and length of the intramedullary nail to be used as well as the location of the interference screws ("poller," "blocking") for each case. Extra custom-made holes for locking screws may be placed in the nails, if necessary.

Surgical Technique

Osteotomies in the long bones can be executed through limited incisions percutaneously either by the Gigli saw technique or by the multiple drill hole technique. The placement of the intramedullary nail also can be performed through a 2-cm transverse incision over the patellar ligament (Fig. 2). The reason behind the choice for a transverse incision is that it leads to less scarring, thus making it cosmetically more acceptable. The paratenon and the patellar ligament, however, are split longitudinally. Before the acute correction of valgus deformities of the knee of >20°, prophylactic peroneal nerve release must be performed.[6] 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.

FAN for Femoral Deformity

Either an antegrade or a retrograde technique can be used for femoral deformities. The authors prefer retrograde nailing for

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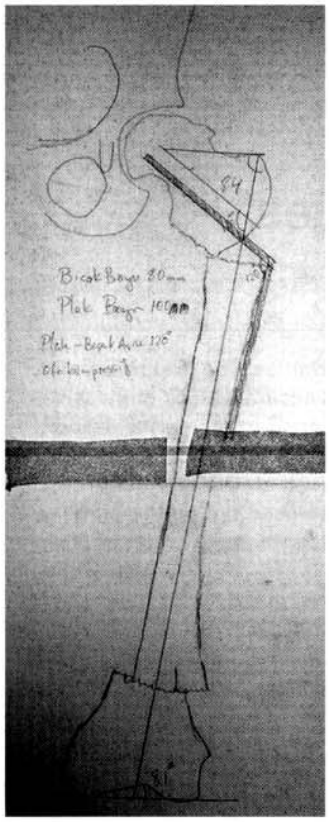

Figure 1 Paper tracing to simulate the surgery.

distal femoral deformity correction and antegrade nailing for proximal femoral deformity correction.

Valgus deformity of the distal femur (14°) with the CORA at the level of the knee joint (Fig. 3A) is performed as follows: Insert 2 pairs of external fixation pins (1 distal and 1 proximal) from the lateral side (Fig. 3B). The pins must be placed away from the path of the intramedullary nail, especially at the site of nail insertion on the sagittal plane (Fig. 3C). When one inserts the distal Schanz screws, both femoral condyles must superimpose on lateral views with the image intensifier (true lateral view). The same applies for the proximal part of the femur. This also enables correction rotational deformities if present.

The osteotomy is performed through a mini incision, preferably by the multiple drill hole technique or with use of the focal dome drill guide as described by Paley (Fig. 4A). The medial and lateral edges of the osteotomy are completed by an osteotome (Fig. 4B, C). The osteotome is inserted into the center of the bone, going through both cortices, and then twisted so the desired translation at the osteotomy site is established (Fig. 5). Alternatively, Schanz pins may be used as a joystick to produce the translation manually (Fig. 6). The translation precedes the angular correction, and its amount is calculated preoperatively using a goniometer (Fig. 7).

The angular correction is then performed either manually or more accurately with use of the external fixator (the authors prefer the EBI monorail system with swivel clamp; Biomet, Warsaw, IN). At this point, the accuracy of the correction must be confirmed with an image intensifier as well as with intraoperative long radiographs (Fig. 8). If the desired correction is achieved, then the surgeon can proceed with the nailing. If not, the correction must be repeated until the desired amount of correction is confirmed.

The authors prefer inserting the interference screws before reaming, to guide the intramedullary drill as well as to prevent loss of the correction (Fig. 9). Retrograde reaming over a guidewire is performed through a mini incision as described previously. The reamings produce an internal grafting effect. The nail is inserted and locked statically (proximally and distally; Fig. 10). The authors prefer using regular tibial nails for retrograde femoral nailing because their curve helps correct any sagittal deformity present. (Figure 11A, B). Additional interference screws may be inserted if needed. The external fixator is removed at the end of the surgery, and the nail maintains the correction (Fig. 12).

FAN for Tibial Deformity

Varus deformity of the proximal tibia (10°) with the CORA at the metaphyseal level (Fig. 13) is performed as follows: 2 pairs of Schanz pins are inserted proximally (parallel to the joint line) and distally (perpendicular to the anatomic axis) in the tibia. The pins should be at the posterior aspect of the tibia on the sagittal plane to leave enough space for the nail (Fig. 14). First, the fibula is osteotomized percutaneously. Then, percutaneous osteotomy is performed through a small incision either by the multiple drill hole technique or with the use of a focal dome drill guide as described by Paley et al (Fig. 15). The authors prefer Gigli saw osteotomy because of the simplicity and quickness. The osteotome is inserted into the center and then twisted to complete the osteotomy and produce the desired amount of translation (Fig. 16). Alternatively, the translation may be created by manipulating the Schanz pins as a joystick (Fig. 17). Angular correction is performed after achieving the desired amount of translation either manually or with use of the monolateral fixator (the authors prefer the EBI monorail system with swivel clamp).

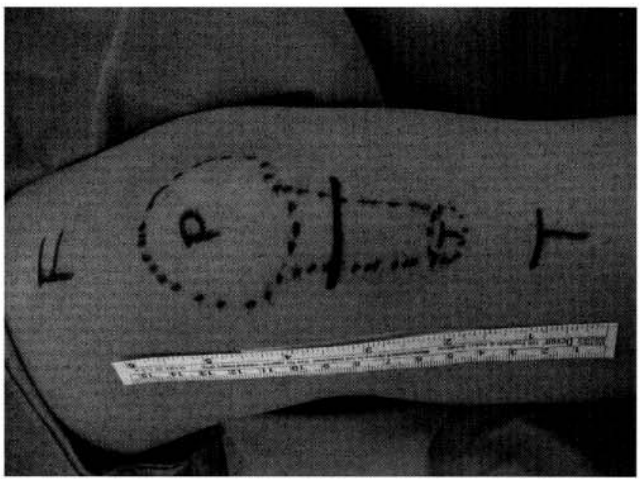

Figure 2 Transverse insicion over patellar ligament. (Color version of figure is available online.)

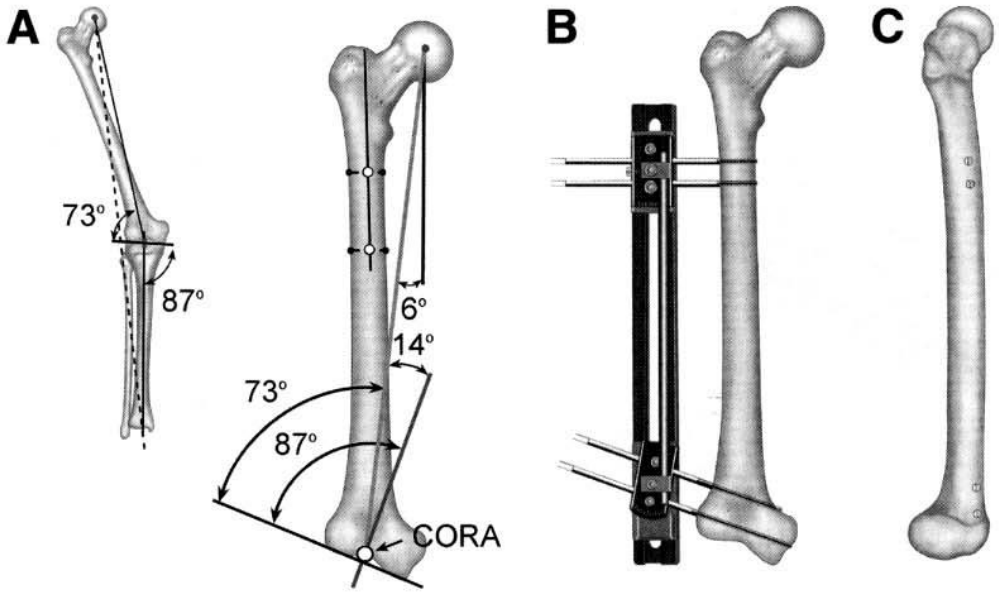

Figure 3 A right femur with a distal valgus deformity of 14°. The CORA is at the center of the joint (A). The Schanz pins and the monolateral fixator are placed (B). Anterior placement of the Schanz screws to leave space for the intramedullary nail (C). (Color version of figure is available online.)

At this point, intraoperative roentgenograms are taken, and a malalignment test is performed. If the desired amount of correction is achieved accurately, then the surgeon proceeds with the nailing. Otherwise, the correction is repeated until it is confirmed by intraoperative roentgenograms. Interference screws are inserted before reaming to guide the intramedullary drill as well as to prevent loss of the correction. Antegrade reaming over a guidewire is performed through a mini incision. The reamings produce an internal grafting effect. The nail is inserted and locked statically (proximally and distally) (Fig. 18). Additional interference screws may be inserted if needed. The external fixator is removed at the end of the surgery, and the nail maintains the correction (Fig. 19).

Case Examples

Case examples are shown in Figure 20A-C, Figure 21A, B, and Figure 22A, B, Figure 23A, B, and Figure 24A-D.

Discussion

Lower-limb deformities, either angular or rotational, can be corrected by many different methods. Two main options exist: external fixation and internal fixation. Each has its own advantages and disadvantages. External fixation techniques provide accuracy, less invasiveness and adjustability.[9-11] By contrast, the patient's comfort decreases significantly, and

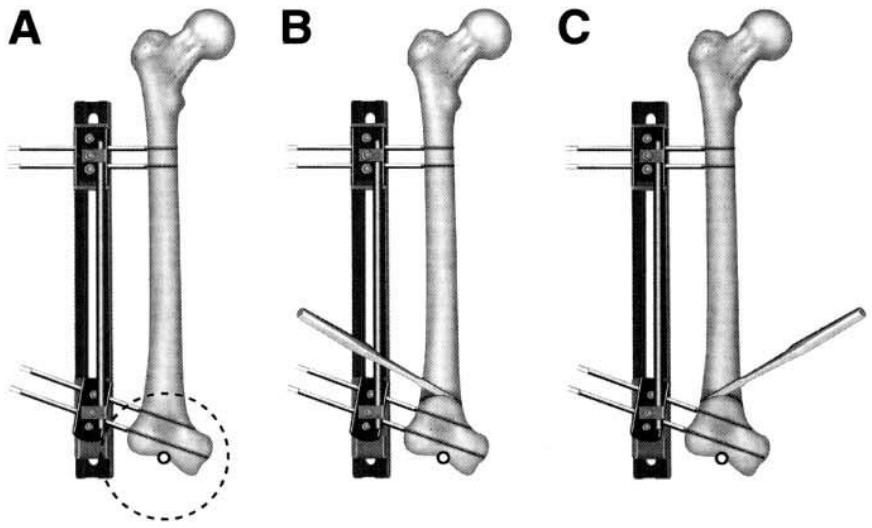

Figure 4 The planning of the focal dome osteotomy around the CORA (A). Cutting of the medial (B) and lateral (C) edges of the osteotomy using an osteotome. (Color version of figure is available online.)

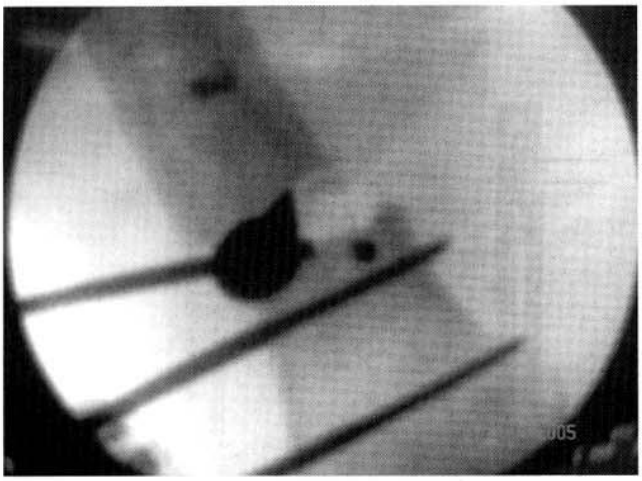

Figure 5 Translation at the osteotomy site obtained by rotation of the osteotome.

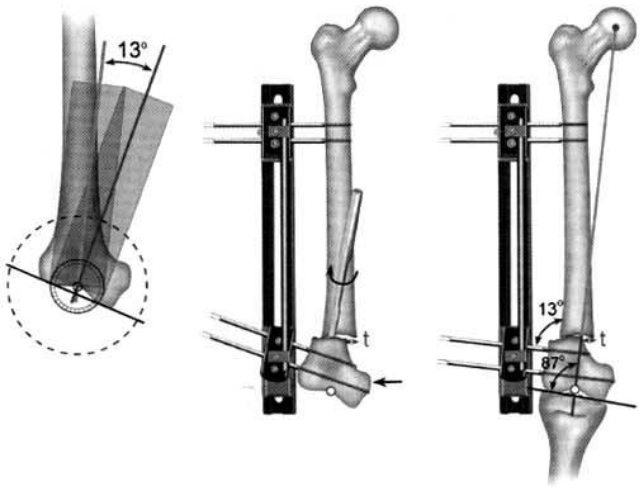

Figure 7 Translation and angulation obtained by the monolateral fixator with swivel clamp (EBI monorail system). (Color version of figure is available online.)

many external fixator-related complications, such as pin track infections and joint contractures as well as others, may occur. Internal fixation methods provide strong stability and convenience but lack accuracy and adjustability.

The FAN technique was developed to combine the advantages of both external fixation and internal fixation techniques while preventing their disadvantages. The temporary external fixator adds the accuracy and adjustability, and the nail adds the stability and convenience.[5,6]

The immediate correction of angular deformities raises concerns regarding neurovascular compromise. There is a particularly high risk of peroneal nerve injury when an acute correction of a valgus knee is performed. To prevent this complication, prophylactic peroneal nerve release can be performed.[6]

FAN can also be applied for ankle deformities associated with ankle arthrosis, ie, fixator-assisted acute deformity correction followed by retrograde nailing for calcaneo-tibial stabilization and fusion. Another combination can be performed for shortening deformities of long bones, as with fixator-assisted acute deformity correction and consecutive lengthening over an intramedullary nail (LON), or the FAN-LON technique.[6,12,13]

During lengthening by the LON technique, particularly in valgus knees, the valgus deformity may increase, which requires correction. This can be performed by the FAN technique at the end of the lengthening period through another osteotomy, if necessary (the LON-FAN technique) (Fig. 25A-D).

Epidural anesthesia can be performed for postoperative analgesia. However, the surgeon must be aware of the risk for compartment syndrome during tibial applications (uncommon but consequential), which might be masked by the epidural analgesia.

FAN, although technically demanding, is an accurate and safe method for the correction of long bone deformities. The accuracy of correction rivals that achieved by circular external fixation. This is achieved by meticulous preoperative planning, preoperative malalignment testing and adjustment of the correction with the monolateral fixator. Percutaneous

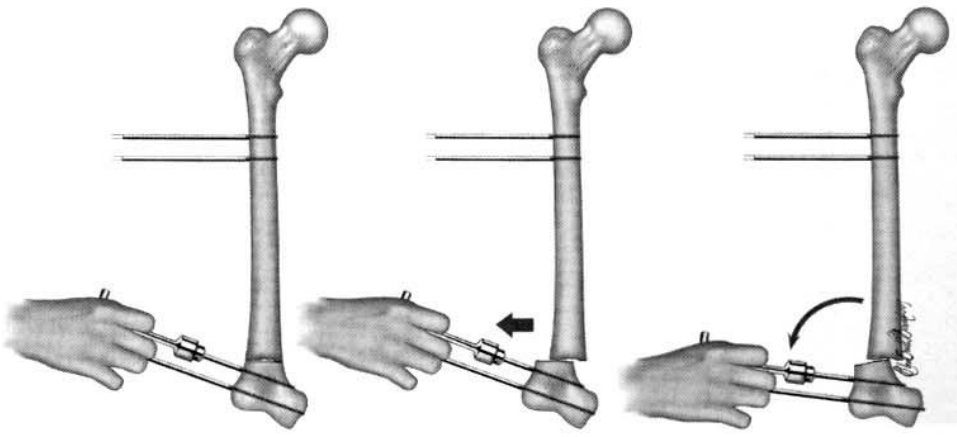

Figure 6 Manual production of the translation and angulation effects at the osteotomy site. (Color version of figure is available online.)

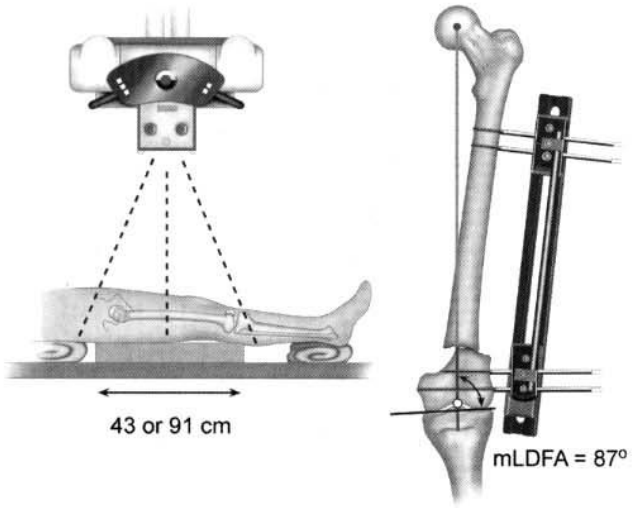

Figure 8 The confirmation of the correction intraoperatively by obtaining long radiographs and malalignment test. (Color version of figure is available online.)

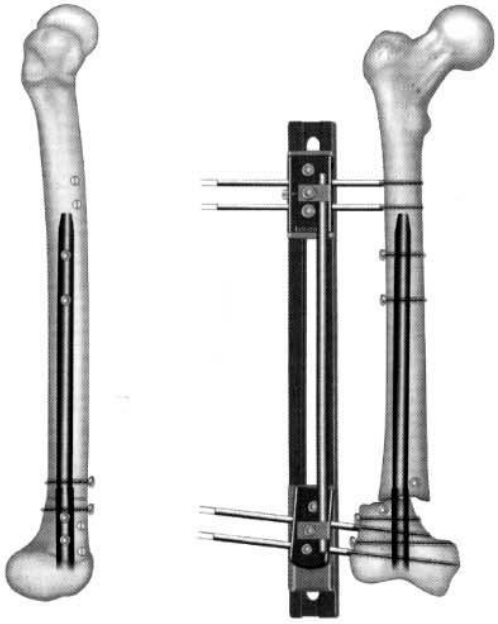

Figure 10 The intramedullary nail is inserted in retrograde direction and locked both proximally and distally. (Color version of figure is available online.)

osteotomy, internal grafting by reaming the medullary canal and the stability provided by the intramedullary nail lead to rapid healing of the osteotomy site.

The FAN technique raises concern about the risk of recurrence of infection in patients with a history of infection. However, it was shown that intramedullary nailing can be performed successfully in patients with infection anamnesis as well.[14,15]

In conclusion, FAN provides accurate deformity correction, reduces patient discomfort (as the external fixator is removed at the end of the procedure), enables more rapid rehabilitation compared with external fixation techniques, and prevents the recurrence of the deformity because of the retained intramedullary nail.

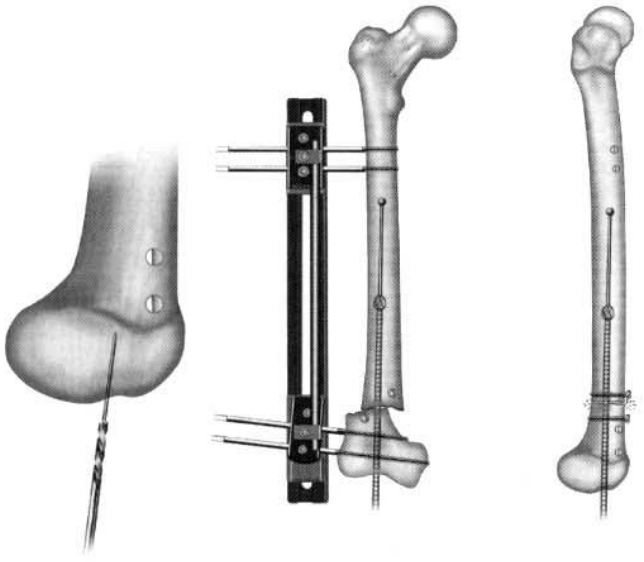

Figure 9 Interference screws are inserted prior reaming so that they guide the drill bit and then the intramedullary nail. (Color version of figure is available online.)

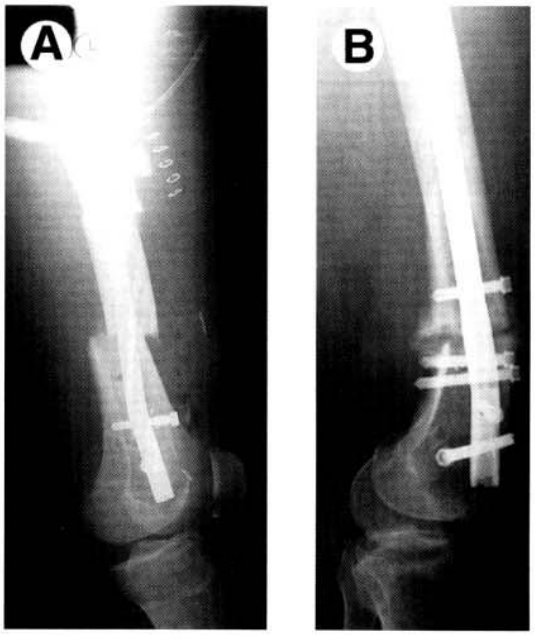

Figure 11 The tibial nail can be inserted to the femur in a retrograde direction to produce extension effect (A) or flexion effect (B).

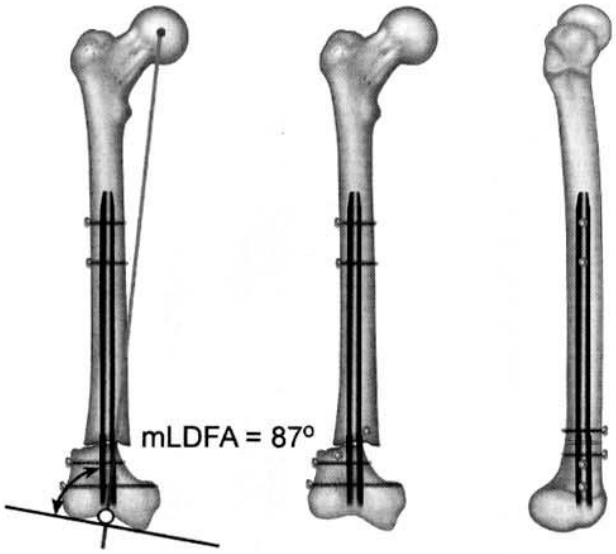

Figure 12 The external fixator is removed once the correction is secured by the intramedullary locking nail and the interference screws. (Color version of figure is available online.)

Figure 14 The Schanz pins are inserted proximally and distally and connected to the monolateral fixator. On the sagittal plane the pins lie anterior in the tibia to leave space for the intramedullary nail. (Color version of figure is available online.)

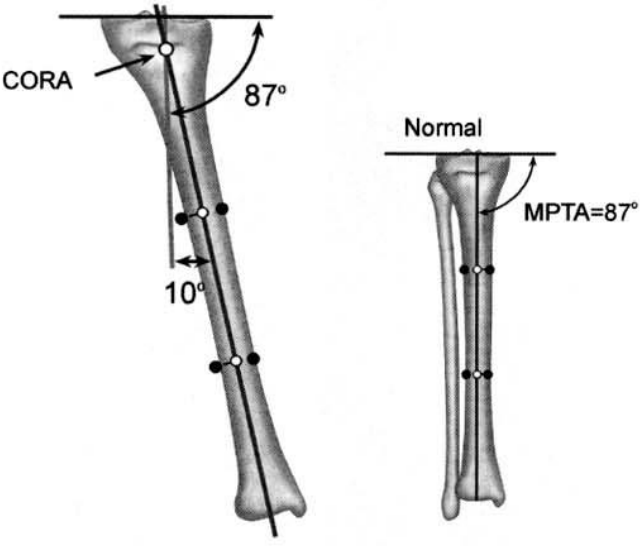

Figure 13 A tibia with a proximal varus deformity of 10°. The CORA is at the metaphyseal level. (Color version of figure is available online.)

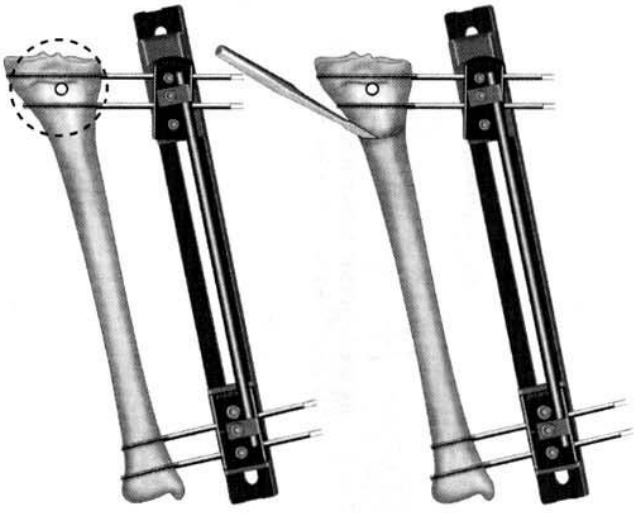

Figure 15 The focal dome osteotomy is planned and performed. (Color version of figure is available online.)

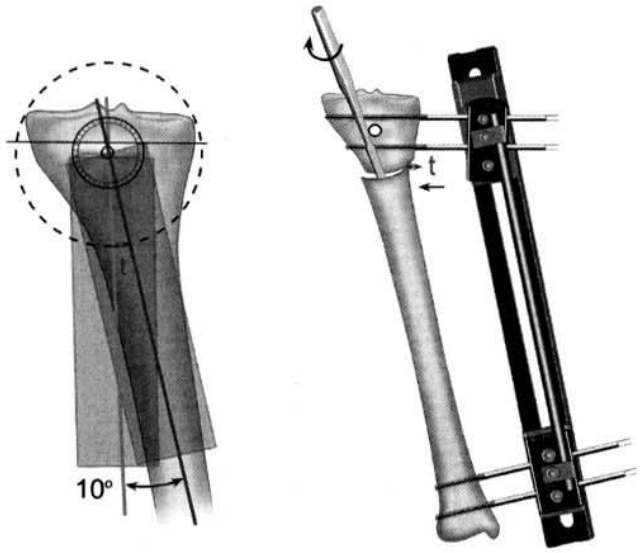

Figure 16 The translation may be produced by the rotational maneuver of the osteotome. (Color version of figure is available online.)

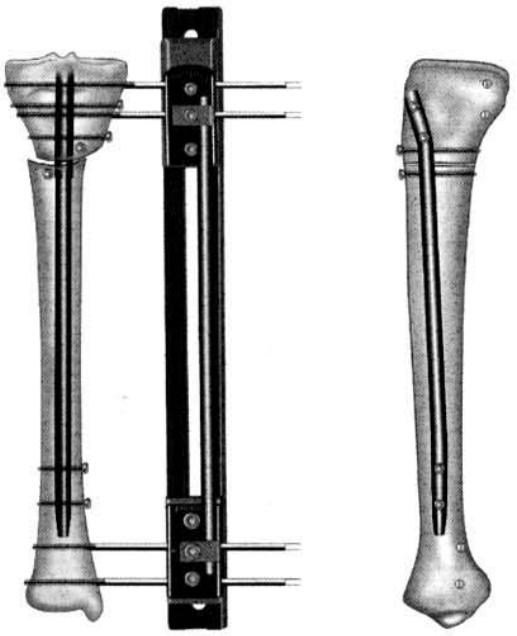

Figure 18 The intramedullary nail is inserted and locked statically (proximally and distally). (Color version of figure is available online.)

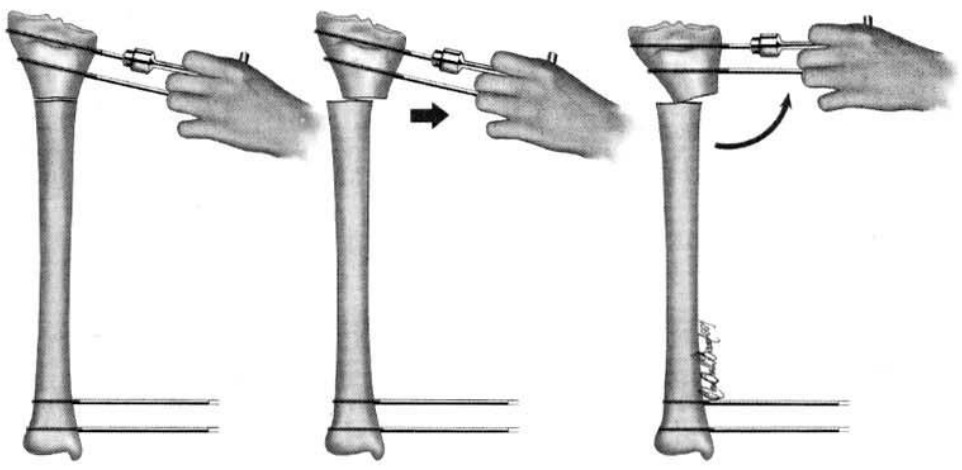

Figure 17 The translation and angulation effects may be performed manually, and then the monolateral fixator may be mounted. (Color version of figure is available online.)

Figure 19 Once the correction is secured by the locking intramedullary nail, then the external fixator is removed during surgery. (Color version of figure is available online.)

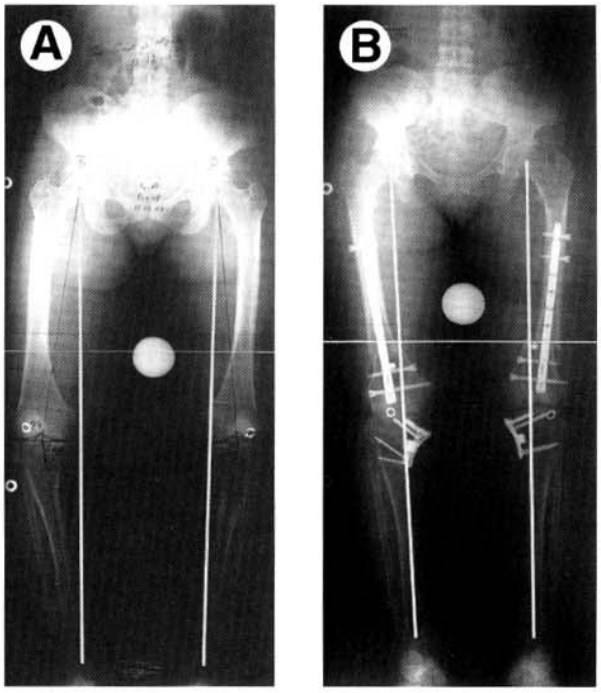

Figure 21 A patient with bilateral genu varum as the result of varus deformities in all of 4 lower-extremity segments (A). Femoral deformities have been corrected via FAN technique (B). (Color version of figure is available online.)

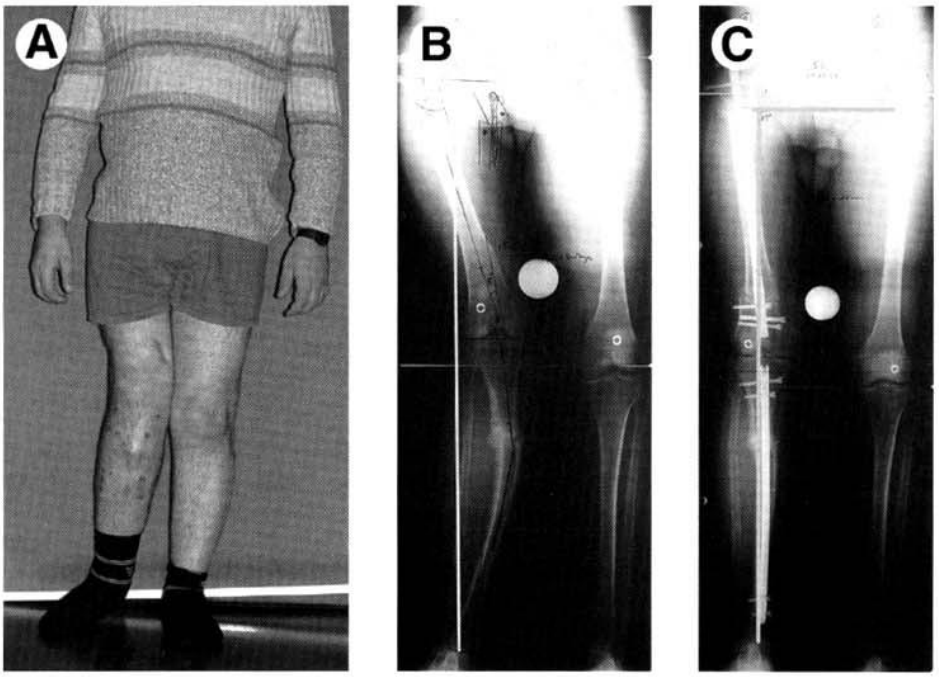

Figure 20 A patient with a right genu valgum (A) as the result of valgus deformities on both femur and tibia (B). The deformities have been corrected by femoral FAN and tibial FAN procedures (C). (Color version of figure is available online.)

Figure 22 A patient with a left femoral deformity. Proximal femoral varus and distal femoral valgus deformities present (A). Distal femoral deformity has been corrected by FAN technique (B).

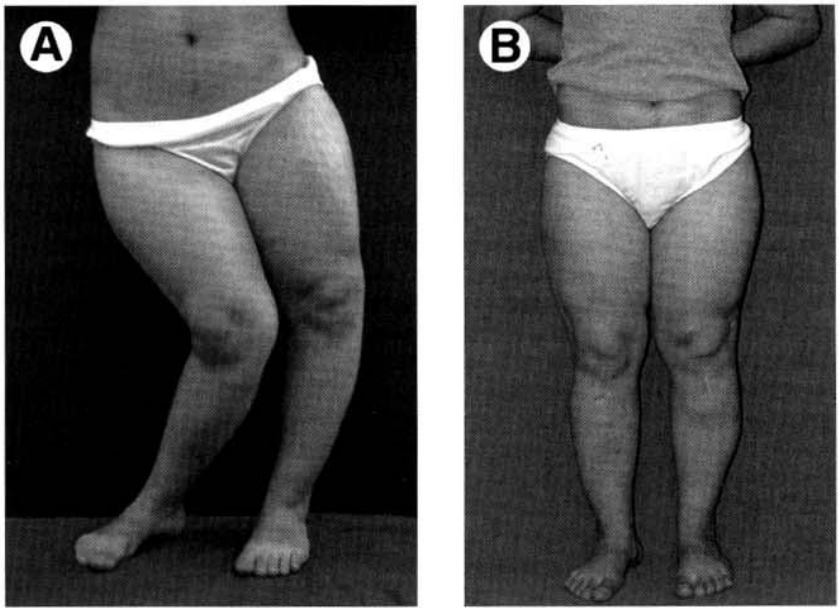

Figure 23 A patient with a "windswept deformity" (A), and the clinical picture at the end of the treatment (B). (Color version of figure is available online.)

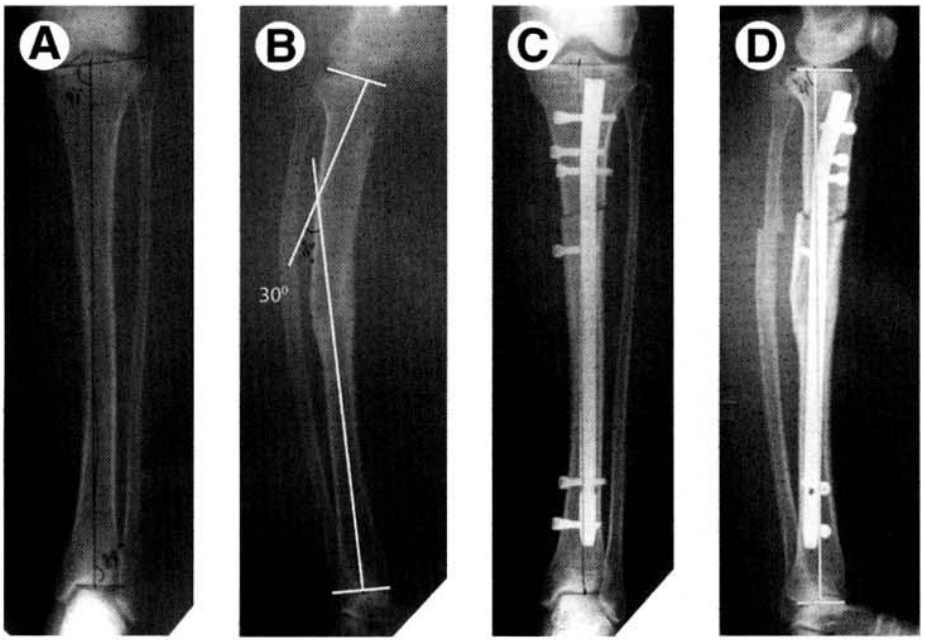

Figure 24 A patient with a left tibial sagittal plane deformity (A, B). The x-rays after FAN procedure (C,D). (Color version of figure is available online.)

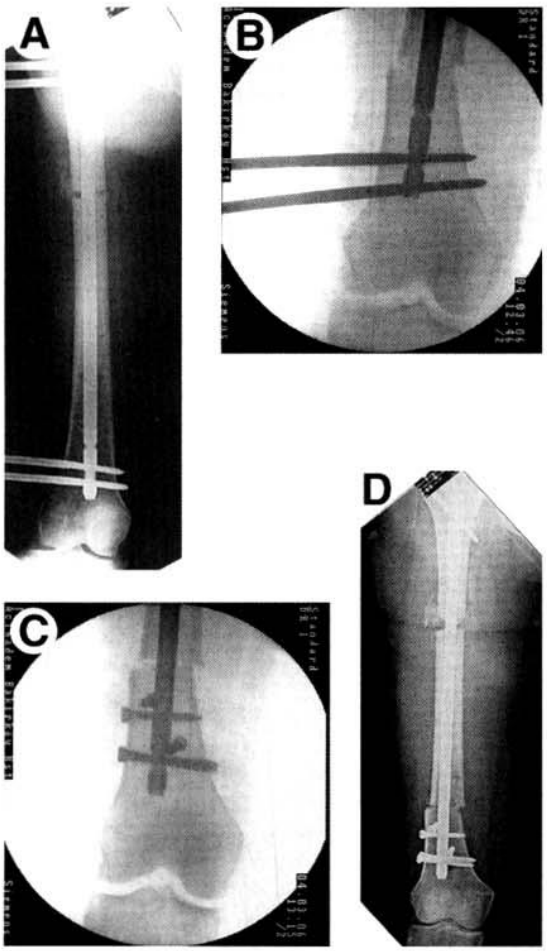

Figure 25 A patient developed valgus deformity during a LON procedure (A). Another distal osteotomy was performed for correction (B), which was secured with interference screws on both sides (C). (D) Postoperative radiograph.

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