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Correction of Tibial Deformity with Use of the Ilizarov-Taylor Spatial Frame

By S. Robert Rozbruch, MD, Austin T. Fragomen, MD, and Svetlana Ilizarov, MD

Introduction

The Ilizarov-Taylor Spatial Frame (TSF; Smith and Nephew, Memphis, Tennessee) is a powerful tool for correcting tibial deformity[1-6]. A specialized feature of the TSF is its virtual hinge, which allows for the simultaneous gradual correction of multiplanar deformities and limb-lengthening through one osteotomy site. The power of the spatial frame lies in its precise control over the final limb length and alignment and in its ability to correct a residual deformity. The stability of this multiplanar circular fixator permits early weight-bearing and provides an ideal environment for both new-bone formation and soft-tissue healing. The classic principles of the Ilizarov method are followed to ensure proper frame application. The TSF web-based software is user-friendly and has greatly simplified the planning of the correction of an oblique plane deformity by utilizing standard anterior-posterior and lateral radiographic measurements. Computer-generated schedules and easy-to-read struts have greatly simplified patient involvement, which is crucial to the success of this technique.

Surgical Technique

Preoperative Planning

Patients are evaluated clinically by a history and physical examination including observation of gait. Special attention is directed toward the assessment of leg length, mechanical axis deviation, and rotational alignment (Fig. 1). An erect bipedal 51-in (130-cm) radiograph in the frontal plane is made. If there is a leg-length discrepancy, then blocks are placed under the affected foot to level the pelvis, and the block height is recorded. Accurate limb lengths are measured in this way. Sagittal deformity about the knee is evaluated with a 36-in (91-cm) lateral radiograph made with the knee in full extension. Routine anteroposterior and lateral radiographs of the tibia are made as well. Ankle deformity should be evaluated with the x-ray beam centered on the ankle. Mechanical axis deviation is determined with use of the malalignment test[7,8] (Fig. 2). The lateral distal femoral angle, medial proximal tibial angle, and posterior proximal tibial angle are measured to analyze deformities of the proximal part of the tibia. The lateral distal tibial angle and anterior distal tibial angle are measured for distal tibial deformities. The center of rotation of angulation[7,8] is identified by locating the intersection of the proximal and distal tibial mechanical axes (Fig. 3). Often this point is chosen to be the origin as well. (In TSF terminology, the origin, in many ways, marks the location of the virtual hinge.) Proper placement of that hinge greatly affects the correction.

An osteotomy site is selected, typically at the apex of the deformity. If the bone is very sclerotic at the apex, then an adjacent alternative site is used to maximize bone-healing potential. When making an osteotomy at a site other than the center of rotation of angulation, one must translate the bone to reestablish alignment. The amount of osseous trans-

Fig. 1

This varus deformity is associated with tibial shortening.

lation in the anterior-posterior and medial-lateral planes is measured at the proposed osteotomy site. These values are entered into the computer as deformity parameters to ensure that the distal fragment will be well aligned at the completion of the adjustment period (Figs. 4-A through 4-F, 5-A, 5-B, and 6).

When a stiff tibial nonunion with a deformity is corrected, often no tibial osteotomy is needed[1,2,5]. Osteotomy of the fibula is required in most patients undergoing tibial osteotomy as correction of most tibial deformities relies on a mobile fibula. For patients with an infected tibial nonunion, antibiotics are stopped two to six weeks before surgery to improve the accuracy of intraoperative cultures.

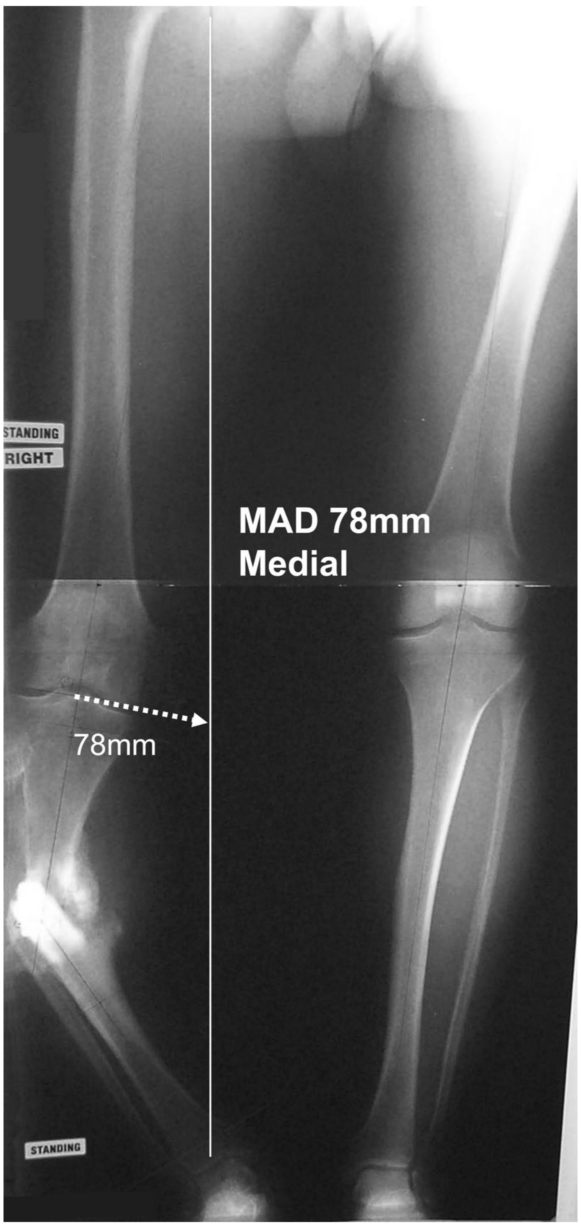

Fig. 2

This image shows the majority of a 51-in (130-cm) standing bipedal radiograph of the patient in Figure 1. A 78-mm medial mechanical axis deviation (MAD) is demonstrated.

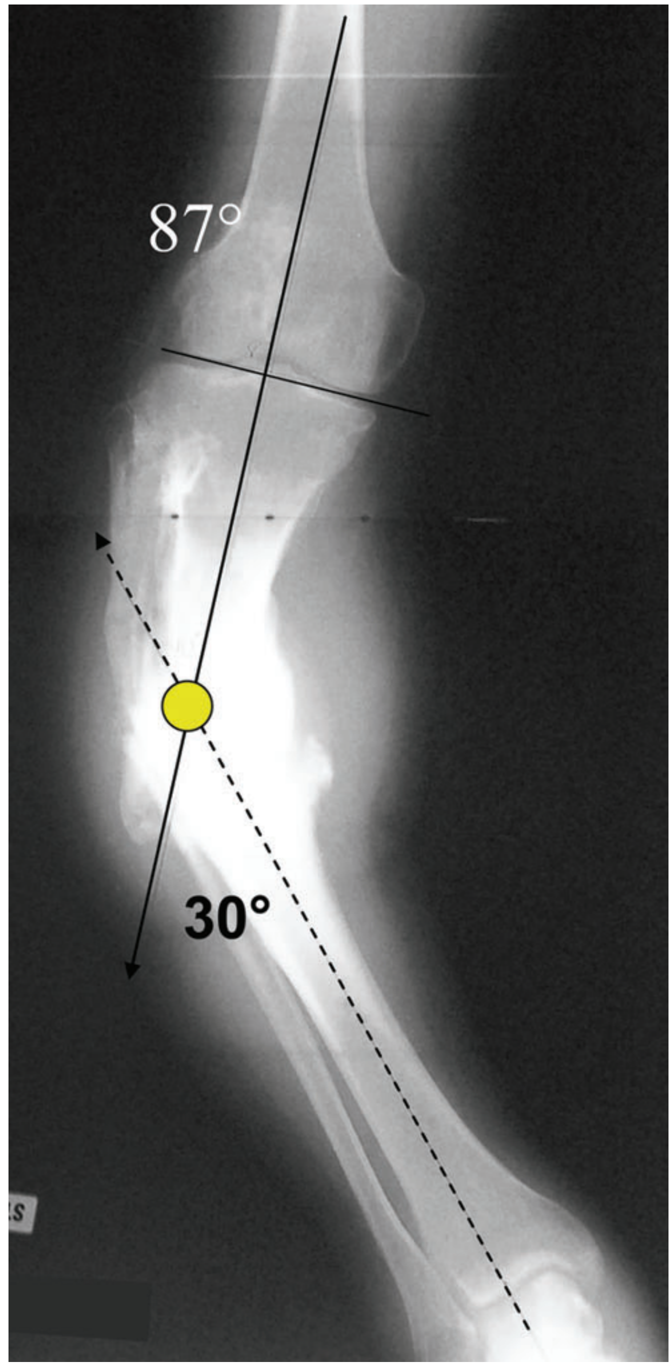

Fig. 3

The mechanical axis of the femur is drawn (solid line), and the lateral distal femoral angle is measured at 87°. Since this is a normal joint orientation, the femoral mechanical axis is extended distally to become the mechanical axis of the proximal part of the tibia. The mechanical axis of the distal part of the tibia is extended proximally (dotted line) until the two lines intersect. This point is the center of rotation of angulation (yellow) of the deformity. There is a 30° varus deformity.

Operating-Room Setup

The patient is taken to the operating room and placed supine on a radiolucent operating table. Sheets are placed under the ipsilateral hip to internally rotate the lower extremity until the patella is pointing directly toward the ceiling (Fig. 7). Regional epidural anesthesia is typically used to provide analgesia for the surgery. Paralyzing medications are not used as they may mask early signs of nerve irritation from a glancing wire. A dose of prophylactic antibiotics with gram-positive coverage is administered in the operating room prior to the skin incision. If infection is suspected, then the preoperative antibiotics are withheld until five deep intraoperative cultures have been obtained. C-arm fluoroscopy is used throughout the procedure to ensure ideal positioning of the fixator and to allow for the implementation of minimally invasive techniques. The c-arm is positioned on the side of the contralateral leg.

Fibular Osteotomy

A fibular osteotomy is carried out under tourniquet control and is performed at the level of the fibular deformity. In general, we try to avoid creating a fibular osteotomy at the same level as the tibial osteotomy for fear of compromising the local blood supply and bone-healing. A direct approach is made to the fibula through the interval between the peroneal muscles and the soleus. Care is taken when performing the subperiosteal dissection as the motor branch to the extensor hallucis longus lies close to the anteromedial border of the fibula. The soft tissue is protected with Hohmann retractors exposing the fibular diaphysis. If a lengthening is needed, then the fibula is predrilled with an Ilizarov wire and the osteotomy is completed with a narrow osteotome (Fig. 8). If an angular correction with minimal lengthening is performed, then an oblique fibular osteotomy is made with an oscillating saw as this cut configuration allows the fibular bone ends to slide and shorten. At times, we resect a small section of the fibula if substantial fibular shortening is anticipated or if early fibular consolidation is anticipated. The fascia is left open, and the skin is closed in layers. The tourniquet is then deflated for the remainder of the operation.

Proximal Ring Application

The frame is then applied to the limb before creating the tibial osteotomy. The technique that we use to apply the TSF is the "rings first" method[4]. We favor this technique because it frees the rings for ideal placement on the leg with regard to the soft tissues. The tourniquet is not recommended for this portion of the surgery as it is thought that adequate blood flow is needed to cool the wires and drills as they pass through the bone and soft tissues. A common location for the tibial osteotomy used for deformity correction is in the proximal metaphysis just distal to the tibial tubercle. The following technique illustrates the method we use for proximal tibial osteotomy. The same principles for frame mounting and osteotomy can be applied at any level of the tibia. With use of the fluoroscopic anteroposterior projection, a smooth 1.8-mm Ilizarov wire is advanced across the proximal tibial metaphysis from lateral to medial, perpendicular to the proximal tibial mechanical axis. The wire should start 14 mm distal to the lateral tibial plateau in order to remain out of the joint capsule[9]. Once this wire has been placed, the proximal ring is centered on the leg and the wire is tensioned (Figs. 9 and 10). We prefer to use a 2/3 ring proximally to accommodate posterior leg swelling and allow knee flexion. The ring is held in a position orthogonal to the mechanical axis of the tibia in the sagittal plane (Fig. 11). A second wire is placed through the fibular head, exiting the anteromedial part of the tibia. The fibular wire is needed when planning a lengthening or a large rotational correction. When placing wires through the fibular head, great care is

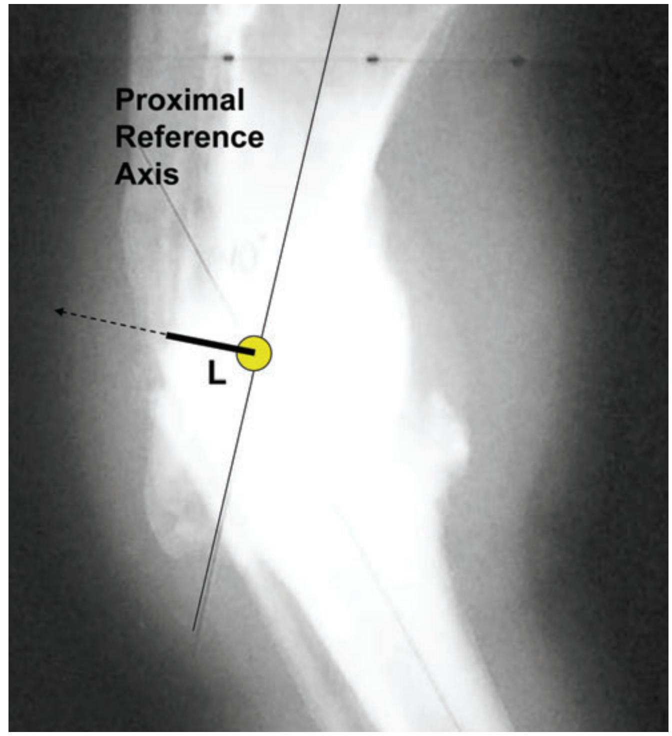

Fig. 4-A

This image is a magnification of the image in Figure 3. The center of rotation of angulation (yellow) is the same as the origin in this example. The proximal bone fragment was selected as the reference fragment. Therefore, the origin lies on the proximal (reference) mechanical axis line. The frame hinges on the origin. In this example, the origin is in the center of the deformity. A central hinge will create a neutral wedge correction (an opening wedge correction in the concavity of the curve and a closing wedge correction along the convexity of the curve). Because no bone is being removed, one must prevent the bone on the convexity from compressing, fracturing, or blocking the deformity correction. This is accomplished by lengthening the osteotomy. How much lengthening is needed is calculated in the following figures with use of the local analysis method. A line is drawn from the origin to the surface of the tibial convex cortex, and its length (L) is recorded. That line represents the width of bone that would otherwise impinge.

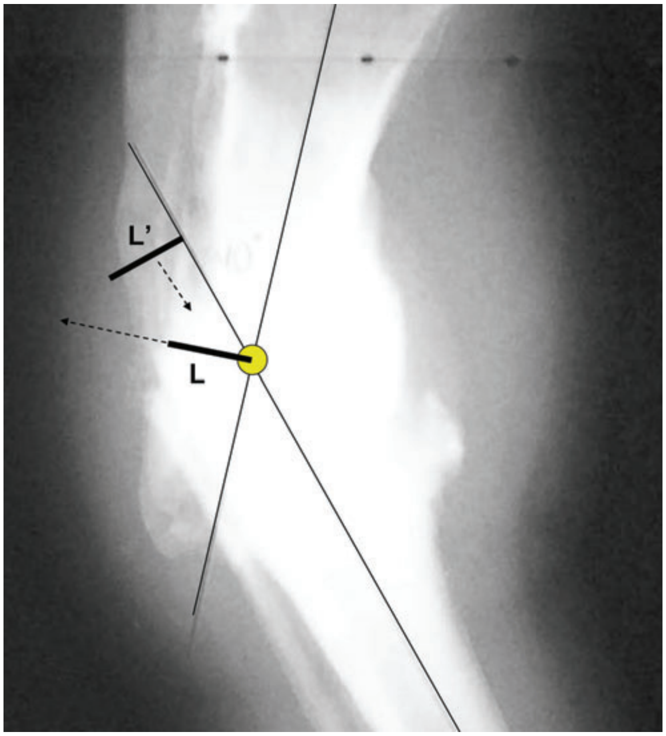

Fig. 4-B
A new line of identical length (L') is drawn perpendicular to the distal tibial axis and is slid down this axis until it intersects with the origin line (L).

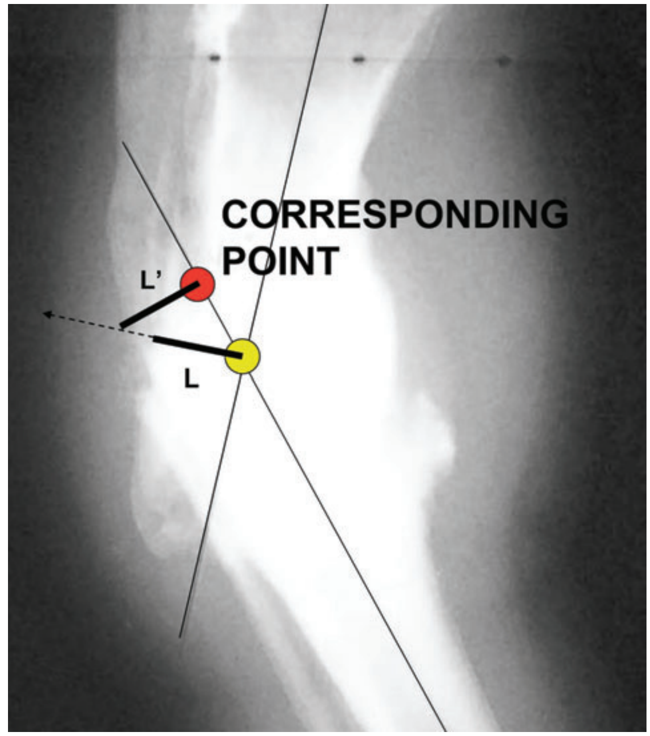

Fig. 4-C
When line L' intersects with line L (or an extension of line L), a point on the distal mechanical axis (the nonreference axis) is defined. This is the corresponding point (red). When the correction is completed, the corresponding point moves to the origin.

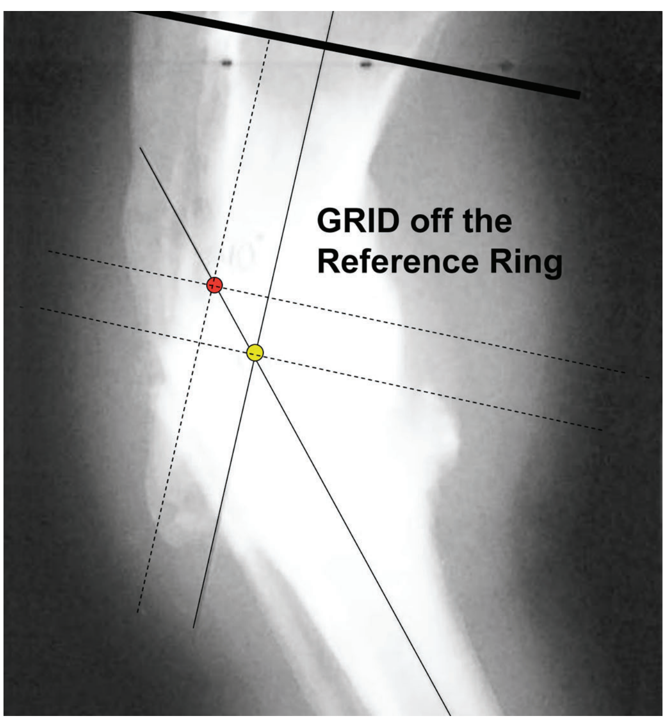

Fig. 4-D
A virtual grid is established in line with the proximal (reference) axis to measure the distance between the origin and the corresponding point.

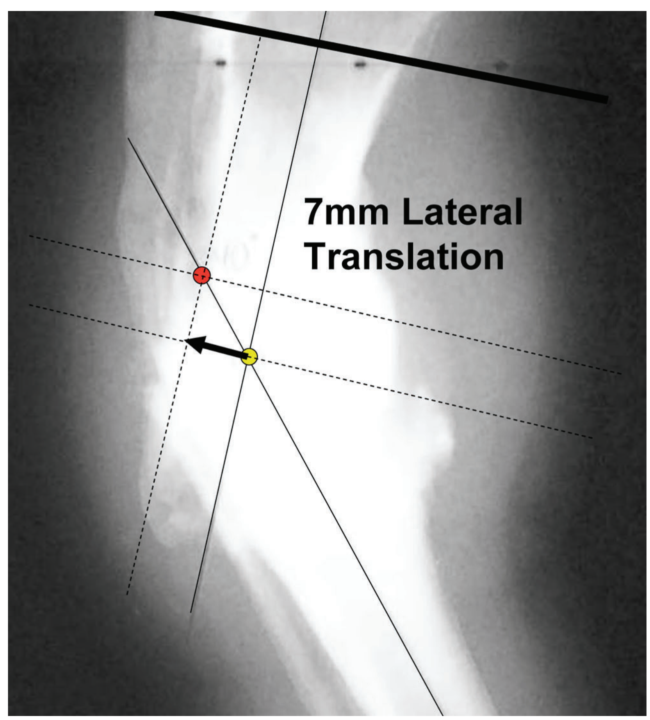

Fig. 4-E
The corresponding point is 7 mm lateral to the origin. This is entered into the program under deformity parameters as "7 lateral."

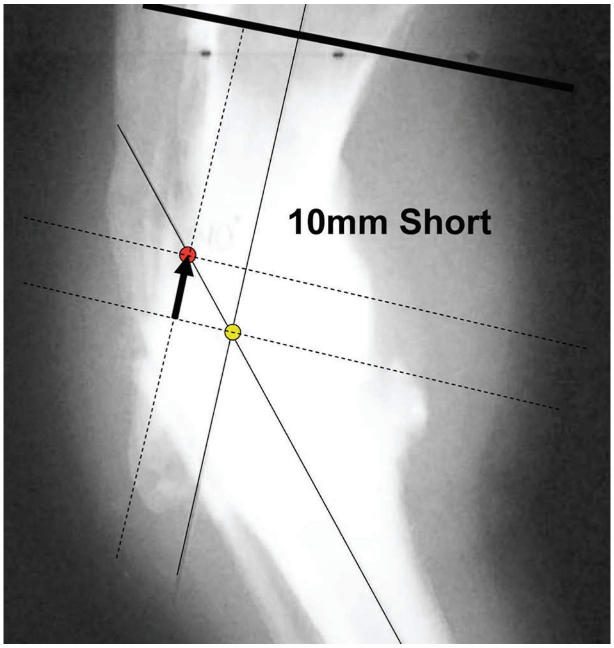

Fig. 4-F

The corresponding point is 10 mm proximal to the origin. This is entered into the program under deformity parameters as “10 short.” The term “short” refers to the need to lengthen the bone to bring the corresponding point distally toward the origin.

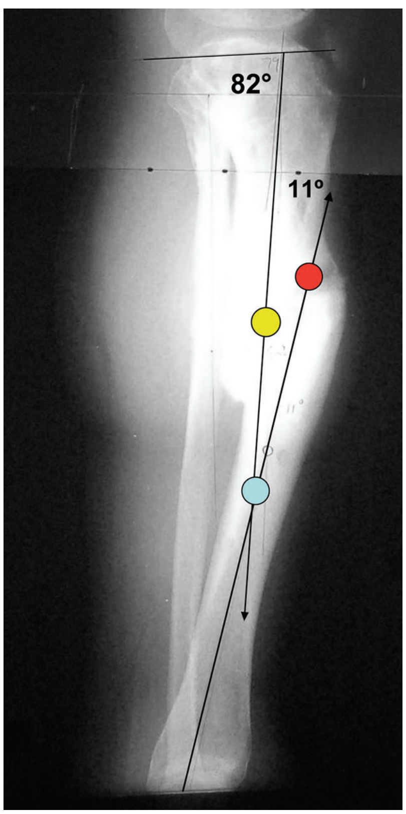

Fig. 5-A

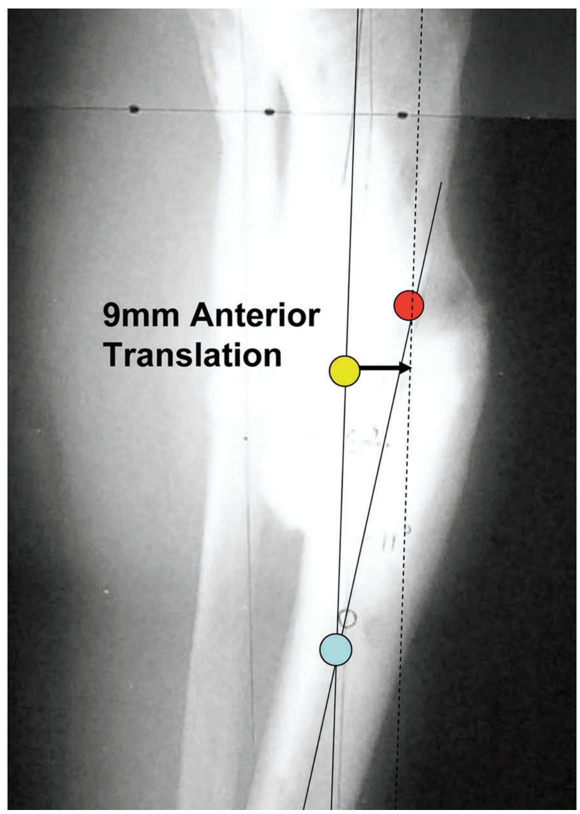

Fig. 5-B

Fig. 5-A The lateral radiograph demonstrates an apex anterior or procurvatum deformity of the tibia of 11°. The angular deformity is entered into the program as “11 apex anterior.” The center of rotation of angulation (blue) is at a more distal location in this plane because translation of the bone fragments has occurred. The origin and corresponding point, established from the anteroposterior radiograph, are marked with a yellow circle and a red circle, respectively. **Fig. 5-B** The distal fragment is anteriorly translated. A grid line (dotted) passing through the corresponding point can be drawn parallel to the proximal (reference) mechanical axis line. The distance between these two lines, 9 mm, is measured and entered into the program as “9 anterior.”

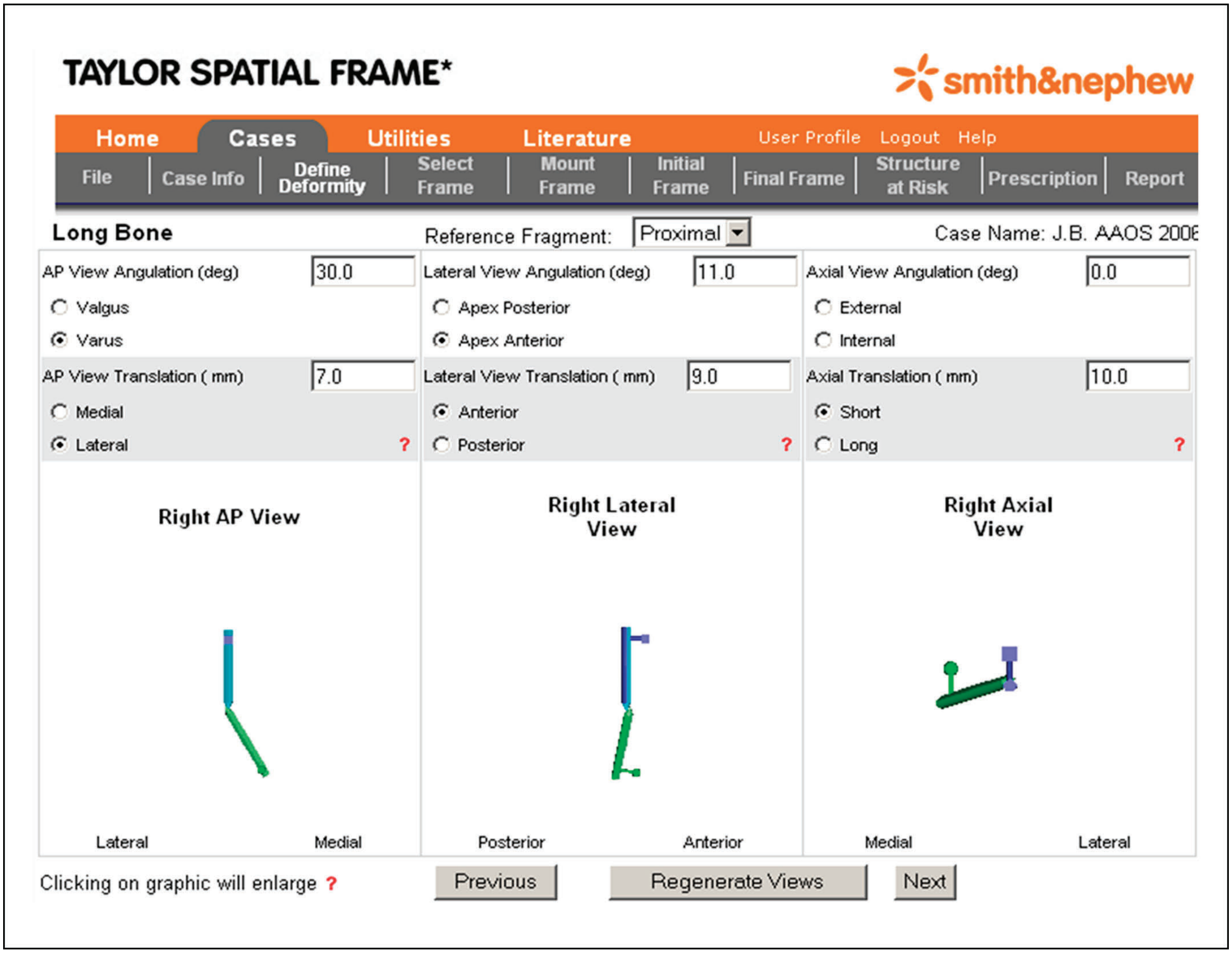

Fig. 6

The deformity parameters are entered into the computer, and anteroposterior, lateral, and axial stick images are generated. These images can be compared with the radiographs to ensure that the correct information has been input.

taken to avoid damaging the common peroneal nerve (Fig. 12). The wire is then advanced in a normal fashion, always watching the foot for motion. Once the wire tip has crossed through the leg and has exited the skin, the drill is removed and the wire is tapped through the remainder of the way. A half-pin is placed anterolateral at Gerdy's tubercle in a posteromedial direction. An additional half-pin is placed from an anteromedial starting point and is inserted in a posterolateral direction (Fig. 13). We advocate the use of hydroxyapatite-coated half-pins for this procedure. These pins have been associated with a decreased rate of loosening and, subsequently, the perception of a lower rate of pin-site infection[10].

Mounting Parameters

Once the proximal ring is secured, the mounting parameters are calculated. The mounting parameters are a set of measurements that inform the computer of the location of the reference ring with respect to the origin. Although any ring can be selected to be the reference ring, the ring closest to the osteotomy site is typically selected to be the reference ring. For a proximal tibial osteotomy, the proximal ring is used as the reference ring. The position of the center of the ring with respect to the origin in the coronal, sagittal, and axial planes is measured in millimeters (Figs. 14-A through 14-G). These values are recorded for later use in the creation of a schedule for strut adjustments.

Distal Ring Application

Attention is then turned to the distal ring. Some thought should be given to determining the optimal distance between the rings. This will help to minimize the number of strut changes, which are an inconvenience to the patient and the surgeon. Typically, medium struts are used, and they are set in

Fig. 7
A soft bump is placed under the ipsilateral buttock and lower back to rotate the patella forward. This helps to assist with proper reference ring orientation.

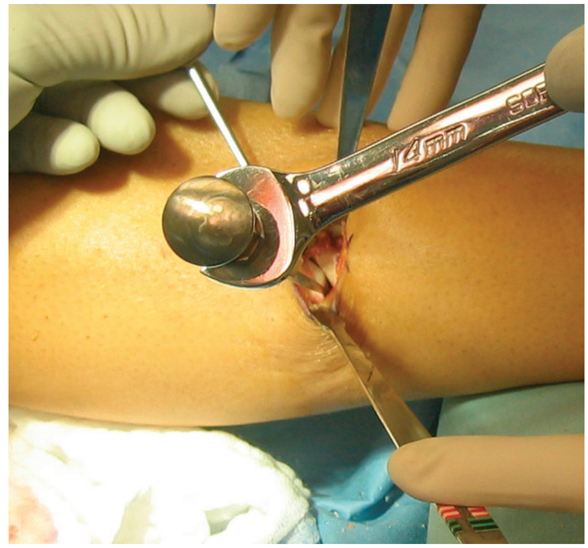

Fig. 8
The fibula is exposed between the lateral and posterior compartments and is cut with an oscillating saw or is predrilled and cut with an osteotome.

the middle length position (145 mm). A medial face wire is advanced from lateral to medial across the tibia orthogonal to its long axis. Care must be taken not to generate heat while advancing the wire through this diaphyseal bone. Frequent pauses are prudent. The distal ring is centered on the leg and fastened to the wire. The wire is tensioned in the usual fashion. Two or three additional half-pins are inserted proximal

Fig. 9
The reference ring is placed carefully to mimic the alignment of the proximal fragment. The central tab needs to line up with the patella, and the ring should be one to two fingerbreadths away from the anterior aspect of the tibia.

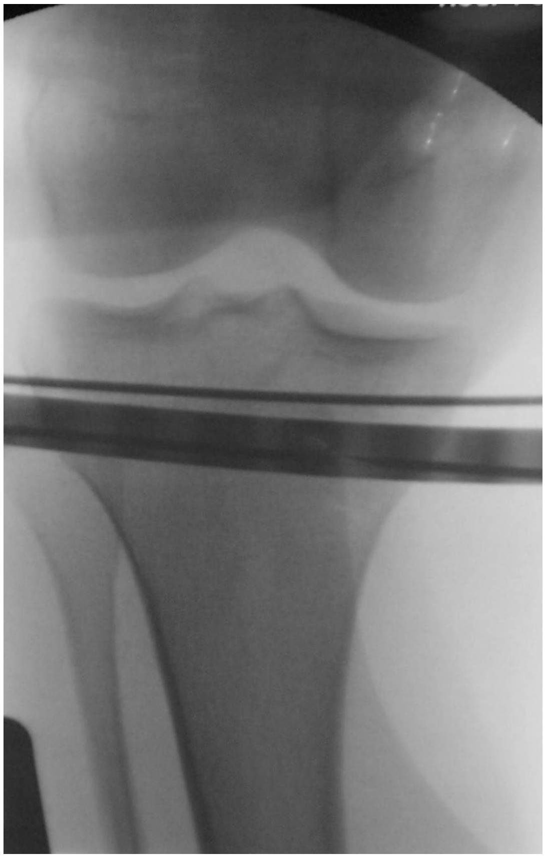

Fig. 10

The ring in this example was placed perpendicular to the desired proximal tibial mechanical axis.

and distal to the distal ring, preferably in different planes, yielding a total of three or four points of fixation distally. Alternatively, a ring block that consists of two rings and a total of four to five points of fixation can be used (Fig. 15).

The six struts are attached to the proximal ring and tightened. The struts are secured to the distal ring without introducing any tension or compression forces to the system. Free rotation of the struts should be possible as the shoulder bolts spin through the ring. The strut lengths are recorded (Fig. 16).

Foot Ring Application

At times, the addition of a foot ring is required. The most common indication to include a foot ring while correcting a tibial deformity is to treat an equinus contracture of the ankle joint. Hinges placed along the oblique axis of the ankle allow for constrained gradual restoration of a plantigrade foot while protecting the articular surface (Figs. 17-A through 17-D). The foot is also included in cases of very distal tibial osteotomies where adequate stability cannot be obtained with use of the distal tibial ring alone. The addition of a foot ring greatly increases the stability of the distal ring block. As healing progresses, the foot ring is removed in the office to dynamize the osteotomy. If an equinus deformity had occurred as the result of a prior unrecognized anterior compartment syndrome, then great caution must be exercised in placing wire fixation through an anterior compartment that contains necrotic muscle tissue as this can lead to severe infection. The open section of the foot ring is closed with a half-ring or a connecting rod. The ring is then attached to the foot with two crossing oblique calcaneal wires and one midfoot wire.

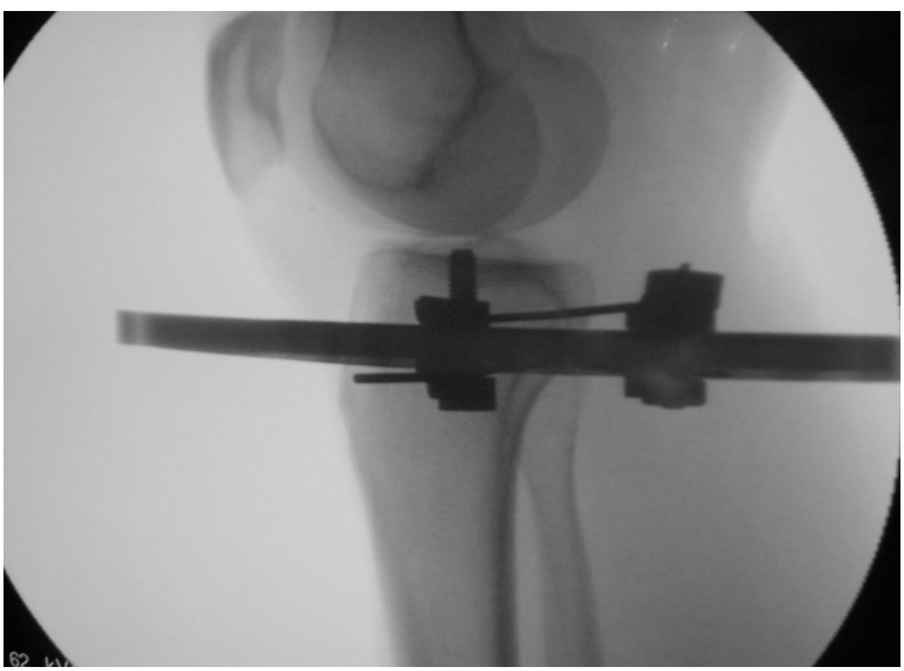

Fig. 11

The lateral radiograph confirms a desirable sagittal ring orientation.

Fig. 12

If one chooses to use a fibular wire, then the wire is placed by hand onto the fibular head while the foot is observed for signs of movement indicative of nerve irritation.

Tibial Osteotomy

To carry out the tibial osteotomy, the struts are detached from the proximal ring. The tibial osteotomy should be made distal to the tibial tubercle to prevent involvement of the extensor mechanism, but it should be proximal enough that it courses through cancellous metaphyseal bone to ensure reliable formation of regenerated bone. The osteotomy we use is a percutaneous drill-hole technique. With the leg well supported on bumps, the c-arm is positioned for a lateral view of the proximal part of the tibia. A 1-cm incision is made over the tibial crest just distal to the tibial tubercle. The incision is carried down through the periosteum and onto the crest. A 5-mm elevator is used to gently raise a portion of the periosteum on either side of the tibia. The cortex is predrilled in multiple directions along the same plane with a 4.8-mm drill. Lateral fluoroscopy helps to prevent passing the drill or osteotome into the posterior compartment as it traverses the posterior tibial cortex. A 5-mm osteotome is advanced through the cortical bone of the medial and lateral cortices of the tibia (Fig. 18). When the osteotome is fully seated through the width of the bone and is engaging the posterior cortex, it is twisted with a 14-mm wrench producing an audible crack as the posterior cortex fails. The distal ring is gently externally rotated with respect to the proximal ring to ensure that the osteotomy is complete (Fig. 19). The bone ends are reduced to their preosteotomy position, relieving stress on the periosteum and decreasing bleeding. The struts are reattached to the rings at their previously measured lengths, stabilizing the osteotomy site in a nondisplaced position. The wound is closed with simple sutures, and the pin sites are dressed with Xeroform gauze (Tyco Healthcare, Mansfield, Massachusetts) and sterile dressings. An elastic bandage is used to pull the forefoot into a neutral position. The epidural block is discon-

Fig. 13

The half-pins are predrilled bicortically. A 6-mm tapered, hydroxyapatite-coated half-pin is inserted by hand to reduce heat production.

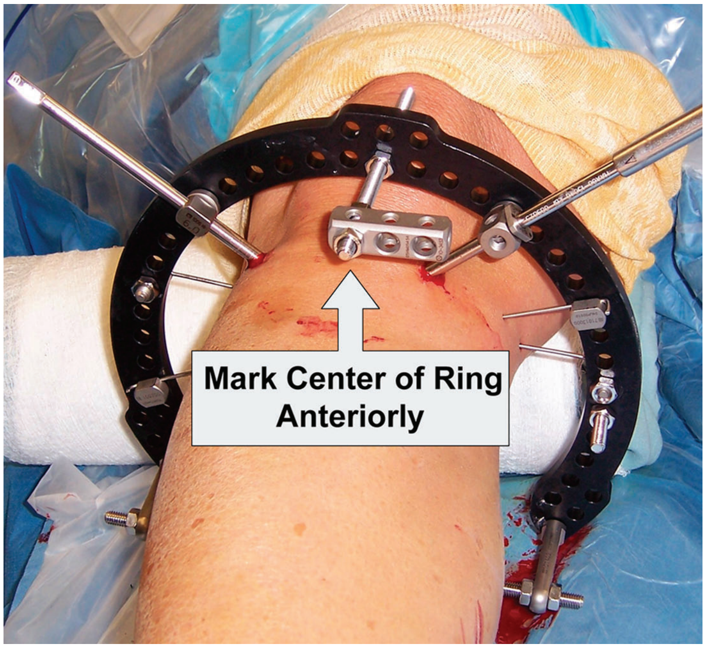

Fig. 14-A

Fig. 14-B

Fig. 14-A Anteroposterior mounting parameters are obtained by first marking the center of the ring. A marker (in this case, a connecting rod and cube) is placed in the middle of the ring anteriorly. The rancho cube is adjusted proximally and distally until it lies at the same level as the origin. **Fig. 14-B** This 2/3 ring needs to be closed temporarily posteriorly with a rod in order to find the center. The nut position is measured to ensure that the nut is positioned centrally on the rod.

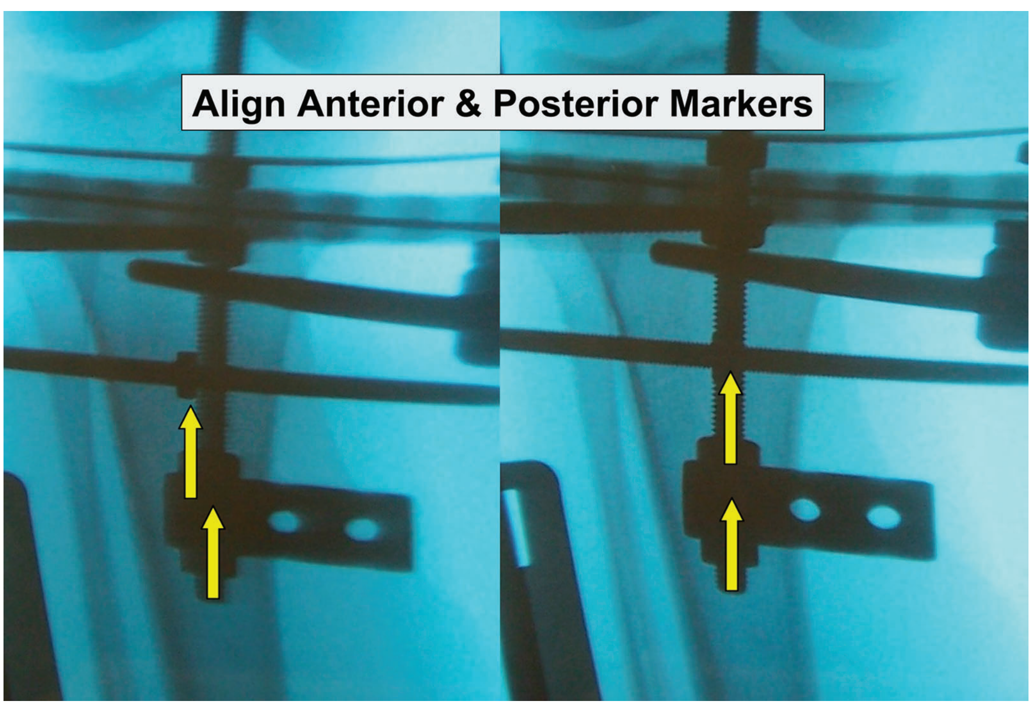

Fig. 14-C

Live fluoroscopy is used briefly to overlap the anterior and posterior markers (connecting rod and nut, respectively). The markers on the left image are not aligned. The leg has been rotated slightly to align the markers (right).

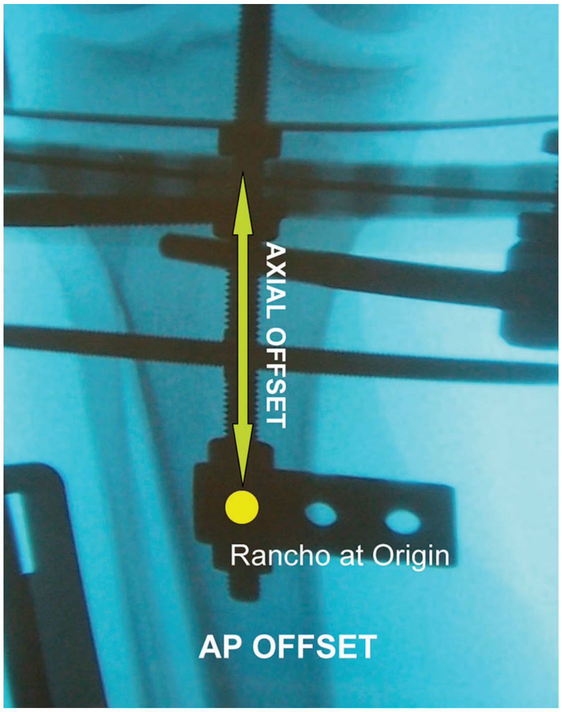

Fig. 14-D

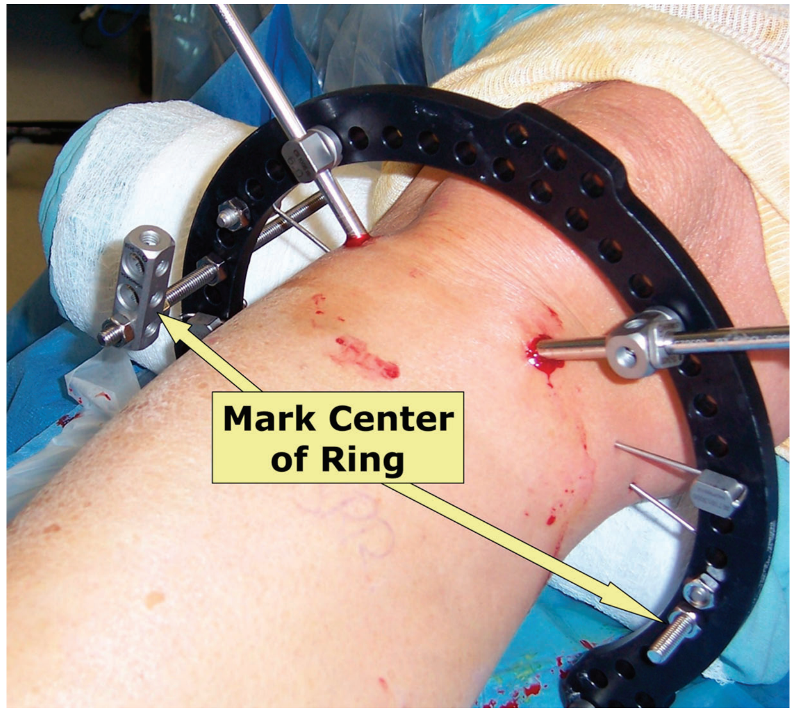

Fig. 14-E

Fig. 14-D The distance from the overlapped markers to the origin is recorded as medial or lateral. In this example, there is no translation, and "0 medial/lateral" would be entered into the program. The distance between the ring and the origin is then measured in millimeters to establish the axial offset. This would be entered as "proximal." **Fig. 14-E** The center of the ring in the lateral plane is then marked, similarly, with a connecting rod and a bolt.

tinued in the immediate postoperative period to avoid masking early signs of compartment syndrome, although we have not yet had any instances of compartment syndrome with use of this technique.

Postoperative Care

Patients are admitted to the hospital for two to three days. The patients receive intravenous antibiotics for twenty-four hours and are then switched to oral antibiotics. The dress-

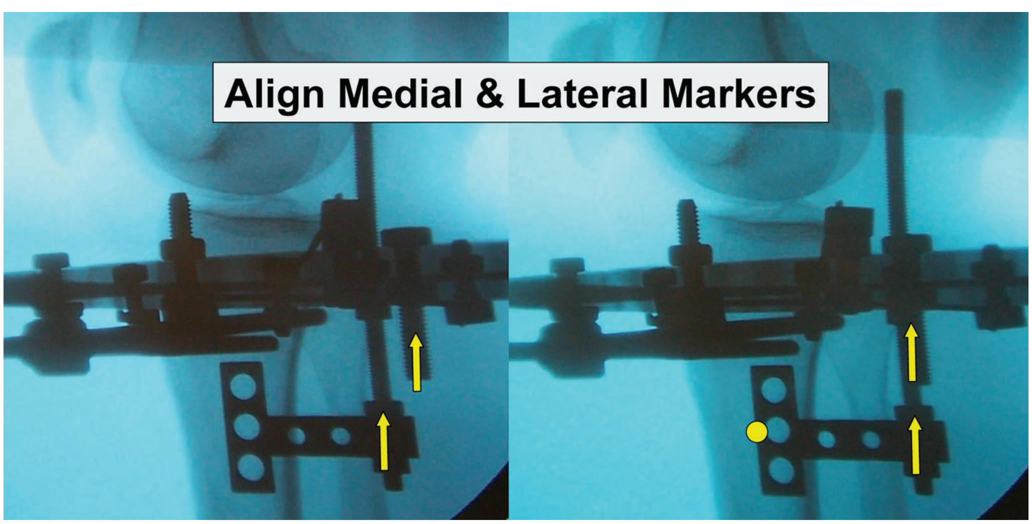

Fig. 14-F

The image on the left shows that the markers are not aligned. Live fluoroscopy is used to overlap the markers and establish the center of the ring radiographically (right). The rancho cube is at the level of the origin (yellow dot).

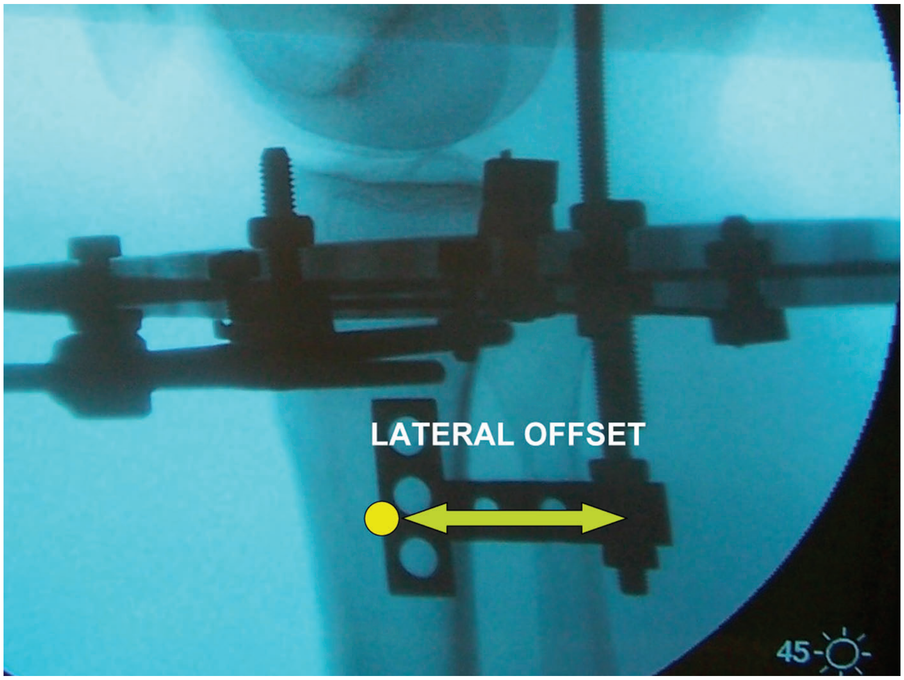

Fig. 14-G
The distance from the overlapped markers to the origin is then recorded in millimeters by measuring the rancho cube. (An additional rancho cube has been stacked on top to reach the level of the origin.)

ings are removed on the second postoperative day. Nurses teach proper daily pin care with a mixture with 50% normal saline solution and 50% hydrogen peroxide applied to the pin sites with sterile cotton swabs. Pins and wires are wrapped with Xeroform dressings at the skin level. Patients are allowed to begin showering on the fourth postoperative day. They are instructed to wash the frame and pin sites with antibacterial soap as an adjuvant form of pin care. Nonsteroidal anti-inflammatory medications are avoided in all osteotomy patients for fear of adverse affects on bone formation. The patients are discharged on oral antibiotics for ten days and oral pain medication. Recognition of early pin-tract infection is taught to the patient. If an infection occurs, oral antibiotics are promptly prescribed. Patients return to the office ten days postoperatively for suture removal, and they are educated in how to perform strut adjustments. Patients are seen every two weeks during this adjustment period and then once monthly during the consolidation period. The success of any gradual correction system is founded in the ability of patients to participate in their own care. Patients are responsible for performing their own strut adjustment three times daily at the outset of treatment. The TSF has simplified this process through color coordination and a precise numbering system. Patients still need to be seen frequently during the adjustment period to avoid errors.

Correction of the deformity begins after a latency period of seven to ten days. The web-based Smith and Nephew program is used to generate a daily schedule for strut adjustments that the patient will perform at home. The computer requires the input of basic information including the limb laterality, the deformity parameters (determined from pre-

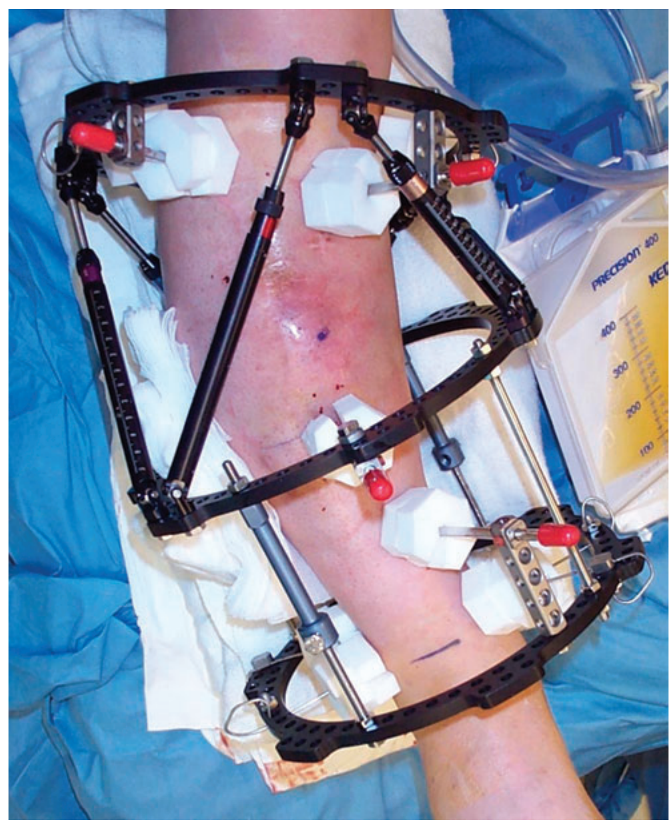

Fig. 15
This patient has one ring (a one-ring ring-block) stabilizing the proximal bone segment and two rings (a two-ring ring-block) stabilizing the distal segment. Proximal and distal ring-blocks are separated with TSF struts.

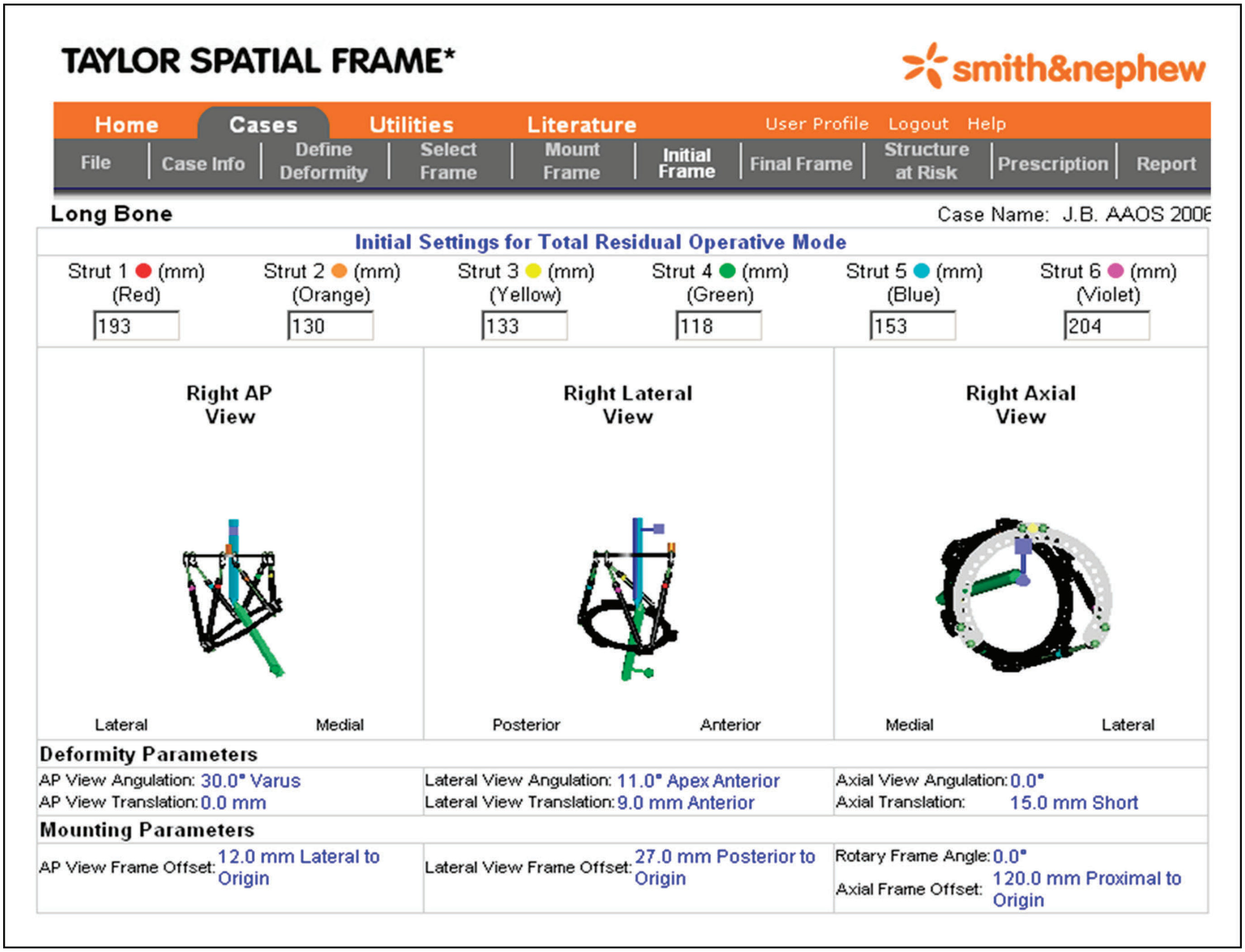

Fig. 16

The strut lengths are entered into the top line, and a stick image with a virtual frame in place is produced. This should look like the frame that has just been placed on the tibia.

operative planning), the size of the rings and length of struts used, the mounting parameters (measured during frame application), and the rate of daily adjustment (Fig. 20-A). Additionally, a structure at risk is selected and entered into the program (in terms of the distance from the origin) to ensure soft-tissue protection during the gradual correction. For a valgus-producing osteotomy, the structure at risk is the medial soft tissues as they are in the concavity of the correction and have the greatest distance to travel. Similarly, if correcting a valgus deformity, then one might choose the peroneal nerve as the structure at risk (Figs. 20-B, 20-C, and 20-D). With use of this information, a clear and simplified prescription is created for the patient to follow every day (Fig. 20-E). We prescribe that struts 1 and 2 be turned in the morning, struts 3 and 4 in the afternoon, and struts 5 and 6 in the evening for a total movement of 1 mm per day (Figs. 20-F and 20-G). The duration of the adjustment phase depends on the amount of correction and lengthening that is needed. In general, adult patients can expect to need the frame for one to two months per centimeter of lengthening. Most angular corrections are completed after two to four weeks of adjustments. The total time in the frame for deformity corrections is usually three to four months.

Ilizarov[11] stressed the importance of early physical conditioning in conjunction with the application of circular fixators. Early motion increases blood flow to the lower extremity, prevents joint stiffness, and shortens recovery time[12]. Physical therapy assists with walking with weight-bearing as tolerated and range-of-motion exercises for the knee and ankle. Occupational therapy provides a custom neutral foot splint to prevent equinus posturing. If the frame includes a ring on the foot, then the same splint functions to prevent forefoot equinus. Patients are encouraged to attend an outpatient physical therapy clinic where they can continue with the rehabilitation program.

Fig. 17-A

This maximal dorsiflexion radiograph demonstrates a patient with a recurvatum deformity of the distal aspect of the tibia and a concomitant equinus contracture of the ankle.

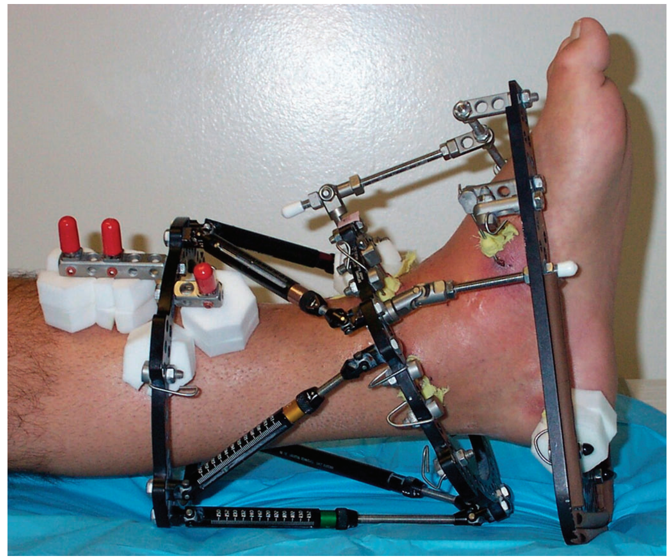

Fig. 17-B

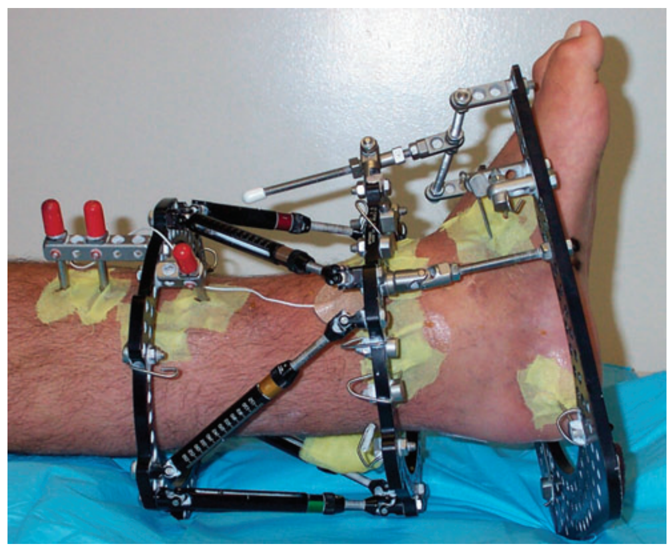

Fig. 17-C

Figs. 17-B and 17-C Simultaneous gradual correction of the osseous deformity through a distal tibial osteotomy and correction of the equinus contracture through gradual distraction of the posterior capsule and heel cord. Photographs made before (Fig. 17-B) and after (Fig. 17-C) correction, with the leg still in the frame. The middle ring has essentially tilted the distal end of the tibia into normal alignment.

Fixator Removal

Fixators are removed when the patients are walking without pain or the use of an assistive device and when callus is seen on three cortices around the osteotomy site. The timing varies tremendously depending on what goals are being accomplished. We prefer to remove the frames in the operating room, particularly since the removal of hydroxyapatite-coated pins can be uncomfortable and bloody. We choose to curet all half-pin sites in an effort to keep all pin tracts clean for possible future use of internal implants. Transfixion wire sites are not débrided unless there is concern over a specific site. At the time of frame removal, osseous union and maturation of the regenerated bone may be evaluated with a stress test under c-arm fluoroscopy. The struts are removed and the rings are manually compressed and distracted to look for motion at the osteotomy site. A lack of consolidation requires replacement of the struts and prolonging the time in the frame. Once the fixator is removed, the patients are managed with a hinged knee brace with full motion or a short leg cast depending on the site of the osteotomy and clinical needs. They are allowed partial weight-bearing for two weeks and then progress to full weight-bearing thereafter.

Fig. 17-D

Final radiographs show correction of both deformities. Despite the presence of ankle arthritis, this realignment procedure produced substantial pain relief. If needed, a simple staged ankle arthrodesis could now be performed.

Critical Concepts

Indications:

- The Ilizarov-TSF is indicated for any tibial deformity correction. Although other fixation techniques have been successful at stabilizing deformities once they have been corrected, the TSF has the distinct advantage of providing a means of correcting the deformity as well as stabilizing the bone after the deformity has been corrected. This allows for gradual correction of deformities, which has important advantages over acute correction, including a lower risk of neurovascular and soft-tissue compromise, preservation of bone stock (by not having to remove a wedge of bone), and precise control over the final alignment. Patients with large deformities are especially well served with this treatment approach.
- Proximal tibial osteotomy for the unloading of unicompartmental knee arthritis can be performed gradually with precision control over the final location of the mechanical axis to achieve ideal overcorrection[4].
- When deep infection is suspected, the temporary and percutaneous nature of the Ilizarov method without internal hardware is useful for the treatment of infection and deformity correction.
- For the patients with tibial shortening, the option of a simultaneous lengthening is made possible with use of the Ilizarov-TSF.

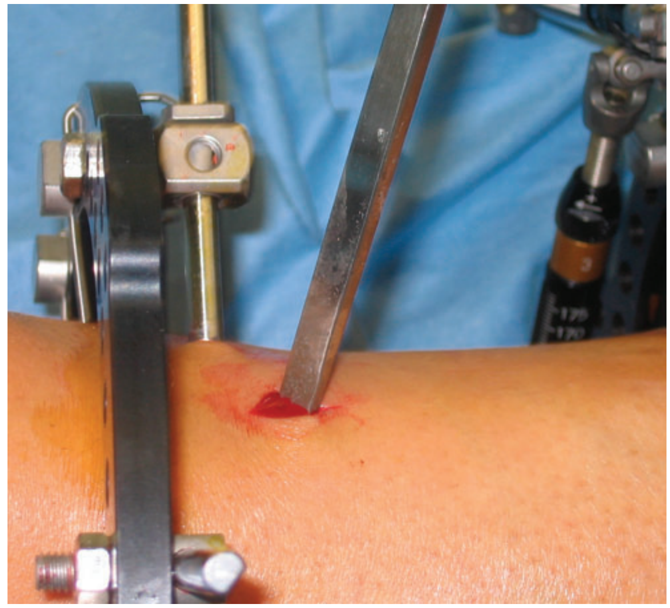

Fig. 18

A narrow osteotome is used to create a percutaneous osteotomy.

Fig. 19

Rotational osteoclasis is used to ensure a complete osteotomy. The distal end of the leg is externally rotated to avoid stretching of the common peroneal nerve.

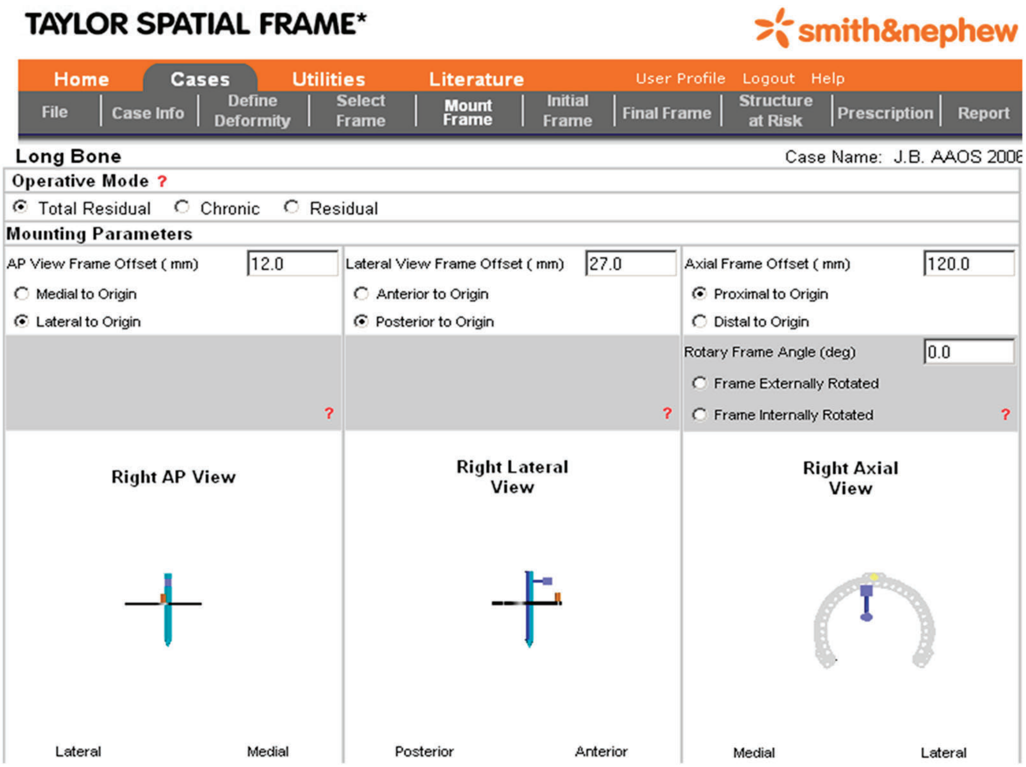

Fig. 20-A

Figs. 20-A through 20-E Images pertaining to the case of the patient presented in Figures 1 through 6. **Fig. 20-A** Mounting parameters were obtained intraoperatively. The stick images mimic the position of the reference ring with respect to the origin.

Fig. 20-B The structure at risk (blue box) is the bone and soft-tissue surface at the maximum concavity of the deformity. The structure at risk is 22 mm medial to the origin (yellow circle) in this example. It is entered into the program as "22 medial." **Fig. 20-C** Similarly, in the sagittal plane, the structure at risk (blue box) is the posterior soft-tissues, which are in the concavity of the flexion deformity. The position of the structure at risk is 20 mm posterior to the origin. This is entered as "20 posterior."

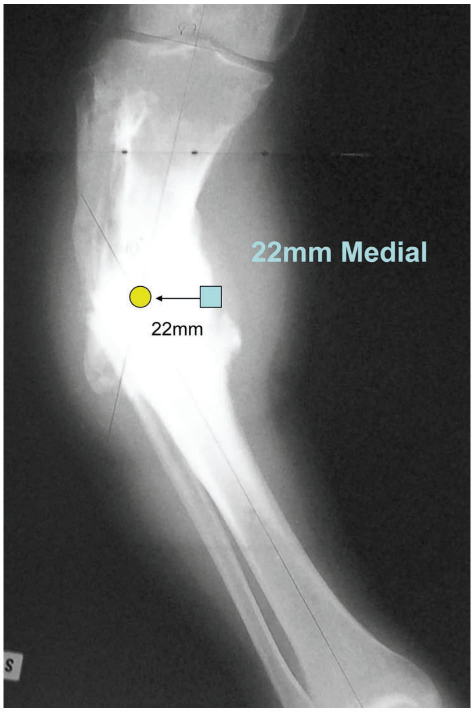

Fig. 20-B

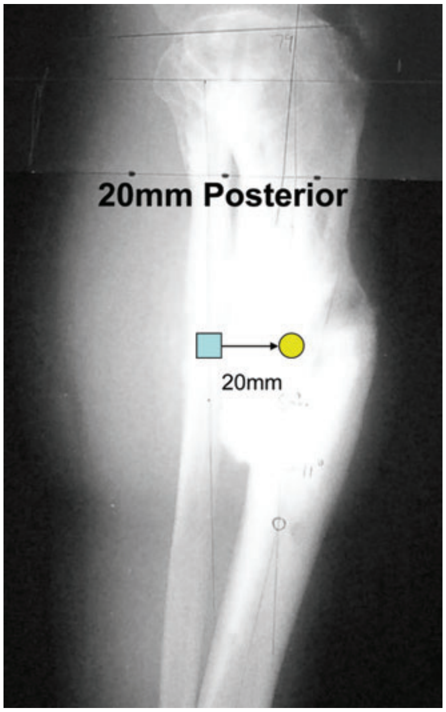

Fig. 20-C

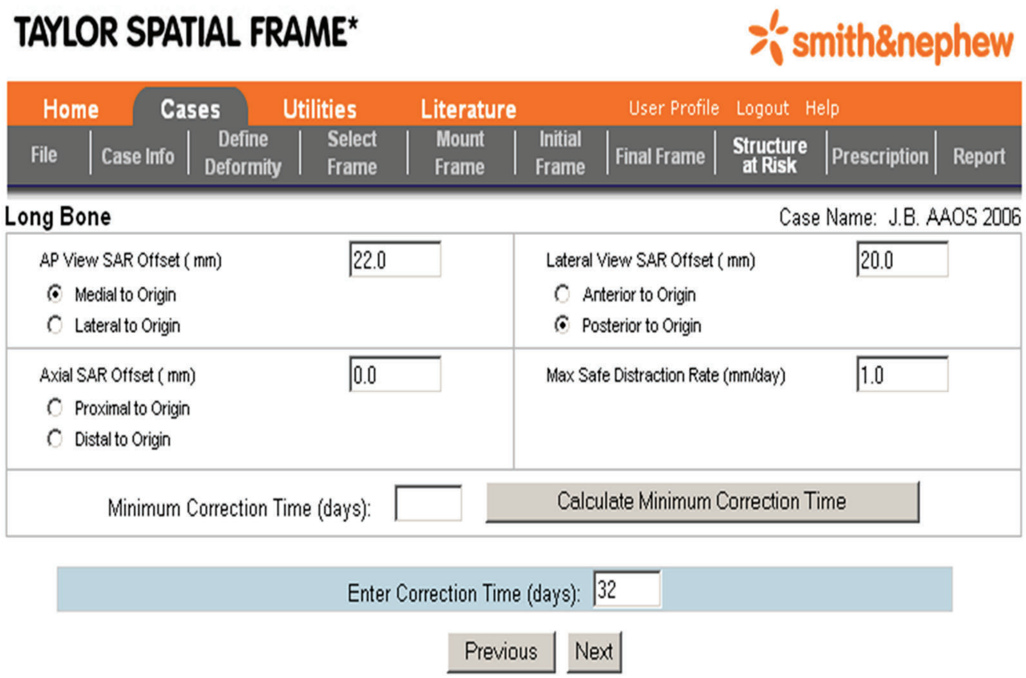

Fig. 20-D

The structure-at-risk information is entered into the program. The safe distraction rate is the speed at which the structure at risk will move. This ensures that important soft-tissue structures are not stretched too quickly. The computer calculates the number of days that are needed to correct the deformity, which is thirty-two days in the case of this patient.

Prescription

Date	Day	Strut 1 (Red)	Strut 2 (Orange)	Strut 3 (Yellow)	Strut 4 (Green)	Strut 5 (Blue)	Strut 6 (Violet)	View
2/28/06	0	193	130	133	118	153	204	View
3/1/06	1	192	131	134	120	153	203	View
3/2/06	2	192	132	135	121	154	202	View
3/3/06	3	191	133	136	123	154	201	View
3/4/06	4	191	134	138	124	155	201	View
3/5/06	5	190	135	139	126	155	200	View
3/6/06	6	189	136	140	127	156	199	View
3/7/06	7	189	137	141	129	156	198	View
3/8/06	8	188	138	142	130	157	197	View
3/9/06	9	187	139	143	132	157	196	View
3/10/06	10	187	140	145	133	157	195	View
3/11/06	11	186	141	146	135	158	194	View
3/12/06	12	186	142	147	136	158	194	View
3/13/06	13	185	143	148	138	159	193	View
3/14/06	14	184	144	149	139	159	192	View
3/15/06	15	184	145	150	141	160	191	View
3/16/06	16	183	146	152	143	160	190	View
3/17/06	17	182	147	153	144	160	189	View
3/18/06	18	182	148	154	146	161	188	View
3/19/06	19	181	149	155	147	161	187	View
3/20/06	20	181	150	156	149	162	187	View
3/21/06	21	180	151	157	150	162	186	View

Fig. 20-E

A daily schedule that is easy for the patient to follow is produced.

Fig. 20-F

Fig. 20-G

Final images after pulling through this hypertrophic, stiff nonunion. No osteotomy was needed to correct this deformity or to obtain healing.

- When a poor soft-tissue envelope is of concern, as is often the case after severe trauma with deformity from osseous malunion, large dissections can often be avoided by implementing a percutaneous osteotomy and external fixation.
- When the true axis of a deformity lies in an oblique plane, correction of that deformity can be very challenging with conventional fixation methods. The TSF computer program has greatly simplified the planning and execution of the correction of these complex deformities with excellent results.
- When early mobilization is of primary concern, as is often the case with large patients who need to be able to bear weight immediately for balance purposes, the TSF provides enough stability to support early weight-bearing and range-of-motion exercises of the adjacent joints.
- Multiple-level corrections can be accomplished with this approach. The Ilizarov-TSF can be used in a modular fashion to simultaneously address multiple levels of deformity including contractures of adjacent joints.

Contraindications:

- Older patients who have no support network and no ability to care for themselves are not ideal candidates, although nursing-home staff can be instructed to perform frame adjustments and pin care successfully.
- Patients who have severe or uncontrolled psychiatric disease are historically not good candidates for external fixation.
- In the case of limb salvage, patients need to be strongly committed and well educated as to the emotional and time commitment needed for Ilizarov limb reconstruction. Amputation reconstruction may be a better option for some patients even if limb salvage is possible.

Pitfalls:

- An incomplete osteotomy often leads to a premature consolidation. A circumferential division of the tibial cortex may be tested by rotating the proximal and distal rings in opposite directions and witnessing translational motion through the osteotomy site. Other methods, including acute distraction and angulation at the osteotomy site, have been described, but these techniques are more disruptive to the periosteum and are not recommended.
- Proper technique for pin and wire insertion, including strict adherence to anatomic safe zones, is paramount to the success of this method. Great care must be taken to avoid thermal necrosis, which leads to loosening of fixation, pin infection, and patient discomfort. Predrilling all half-pins, hand insertion of pins, frequent pausing during wire insertion, and lowering of the tourniquet are all methods for reducing the chances of burning the bone.
- Choosing the osteotomy site requires careful consideration of two independent goals: (1) maximizing the healing potential of the osteotomy and (2) reestablishing proper alignment, not necessarily an anatomic reduction of the deformity. Often correcting a malunion deformity at its center of rotation of angulation would require an osteotomy through an area of sclerotic bone with poor osteogenic potential. A good solution involves cutting the bone distal to the center of rotation of angulation, through metaphyseal bone, which requires osseous translation but offers predictable healing. ■

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