Current Concepts in Fracture Bracing Part II: Lower Extremity

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Introduction. The current treatment of choice for most adult femoral shaft fractures is closed intramedullary nailing.[1] The efficacy of this technique has been well documented. With the recent development of several locking intramedullary nail systems, the indications for closed nailing have been expanded to include virtually any fracture within the femoral shaft. There are fractures, however, which are too distal or comminuted to be stabilized by locking nails. Some patients are not surgical candidates due to their medical condition or reluctance to undergo surgery. In these types of clinical situations, fracture brace treatment has been used alone quite successfully. Femoral fracture bracing, in combination with internal fixation, is also commonly used.

The indications for femoral fracture bracing are limited. Fractures should be located in the distal third of the femur and should not be intraarticular. The fracture reduction must be satisfactory, preferably with not greater than 5° varus/valgus angulation and less than 10° anteroposterior angulation. Variable amounts of shortening can be accepted depending on the degree of fracture comminution. The method is effective with both closed and open fractures.

Most of the reported series of ambulatory treatment of femoral shaft fractures have utilized cast braces.[1-4] The disadvantages of cast braces are difficulty in adjustment for volume changes of the thigh, excessive weight, and inability to remove the brace for hygienic purposes or wound treatment. A prefabricated fracture brace manufactured of thermoplastic material can overcome all of these disadvantages.

Design. The fracture brace must control the fragments of bone through compression of the surrounding soft tissues. Proximal fractures provide a very poor lever arm for soft tissues to resist the varus moment produced by abductor muscle pull. Additionally, the most proximal portion of the femur is surrounded by bulky soft tissues. Thus, the femur may angulate significantly before resistance can be provided by the fracture brace. Therefore, varus angulation is very difficult to control with a fracture brace alone. A much longer lever arm is present in distal fractures and the distal muscular mass is much thinner. Excellent soft tissue control may be obtained by the surrounding sleeve of a fracture brace5 in this location.

Double upright knee joints provide added mediolateral stability (Figure 1). These joints are coupled to the leg by a component very similar to the tibial fracture brace. A footpiece is essential for maintaining suspension of the brace. Since mediolateral instability is the most common problem in the femur, closure of the proximal sleeve is mediolateral, with interlocking shells. Thus, by maintaining tightness of the sleeve, the mediolateral dimension reduces to the maximum degree necessary to control varus angulation.

Figure 1. The prefabricated femoral fracture brace consisting of a thigh section with polycentric knee hinges attached to a leg section.

Clinical Protocol. As with other fractures, a strict protocol must be followed if fracture brace treatment is elected. After initial emergency treatment, our patients are placed in skeletal traction with a proximal tibial pin. Four to six weeks of traction are required, depending on the individual fracture. Traction is discontinued when the fracture is nontender to stress and radiographs show some early callus. It must be emphasized that an acceptable reduction should be achieved in traction as the fracture brace can, at best, maintain the reduction present at the time of brace application. The fracture brace selected should have an adjustable thigh portion to accommodate for volume changes, polycentric knee hinges, and an effective, simple means of suspension. The femoral fracture brace is applied on the day traction is discontinued and the patient begins partial weight-bearing ambulation and active motion exercises of the extremity. A weight-bearing radiograph, in the brace, is obtained to confirm that fracture reduction is maintained. Generally, the patient is scheduled for outpatient follow-up within two weeks.

At each outpatient visit it is essential that the brace be checked for proper fit and that a radiograph be obtained in the brace. Progressive weight bearing is encouraged. Patients are followed at monthly intervals until clinical fracture union is achieved. Clinical union is defined as full painless weight bearing and bridging and remodeling callus on radiographs. Rehabilitation should be continued until joint motion and muscle strength is maximized.

Results. Crotwell reported on the treatment of 30 fractures of the femoral shaft using skeletal traction for an average of 27 days and then applying a plastic thigh lacer with pelvic belt suspension. Patients were allowed to walk, but full weight bearing did not occur until two months. All fractures healed and the mean angulation was 5° Eight patients (27%) had 1 to 2 centimeters of shortening.

In 1972, Sarmiento published his results of 70 femoral fractures treated with a custom fabricated Orthoplast brace with metal knee hinges and uprights attached to the shoe.[5,6] Fracture union was achieved in an average of 15 weeks without a nonunion. Fractures of the middle or proximal thirds had the most angulation and shortening. Limitation of knee motion was encountered often and the author concluded that the optimal treatment of femur fractures was probably surgical.

Mooney et al reported on the results of cast bracing for distal femoral fractures in 150 patients. The mean time to clinical union was 14.5 weeks with no nonunions reported. At the time of follow-up, knee motion less than 90° was observed in 30% of the cases.

In our center, femoral fracture braces, prefabricated of low-density polyethylene, have been used mostly for open, comminuted fractures of the distal third of the femoral shaft. Our results in 17 patients show an average time to union of 14 weeks with mean final fracture angulation of six degrees. Knee motion of 90 degrees or greater was observed in 14/17 patients, but only two patients regained normal motion.

Complications are usually secondary to a lack of adherence to the treatment protocol or to improper indications. Loss of fracture reduction is related to insufficient fracture stability at the time of brace application or use of the method for fractures that are too proximal in the femoral shaft. Distal edema in the foot and ankle may be caused by wearing the brace too tight or not properly elevating the extremity when not walking. Decreased joint motion should be avoidable by early institution of function of the extremity.

Conclusion. Femoral fracture bracing is a suitable method for distal third femoral shaft fractures. A high rate of union can be expected with satisfactory anatomic and functional results. Potential disadvantages are several weeks of skeletal traction in the hospital and excessive shortening in some comminuted fractures.

Tibia Fractures

Introduction. Experience with fracture bracing techniques for the management of tibial shaft fractures is more extensive by far than all other fractures combined. Ihe experiences of Dehne,[7]Brown,[3] and Sarmiento[8] regarding early weight bearing for tibial fractures laid the groundwork for fracture bracing in the tibia. The results of those investigators who have used bracing, and in particular prefabricated bracing, have been extremely favorable.[8-10] One of the basic premises of fracture bracing techniques for tibial shaft maintain the fit of the brace. The proximal and distal extensions of the brace over the bony prominences have been eliminated and the shoe insert is of minimal size. Laboratory and clinical studies have indicated that the principal role of the shoe insert is to maintain the proximal position of the sleeve of the brace, which does all of the mechanical work.

A tight-fitting functional cast and functional tibia fracture brace with condylar extensions and PTB molding were developed by Sarmiento and used for many years at the University of Miami.[8] The patellar tendon compression and condylar extensions had been questioned for their mechanical effectiveness as early as the mid-seventies.[11] Many patients were observed to remove the condylar extensions of the brace proximally and the malleolar extensions of the brace proximally and the malleolar extensions of the brace distally, with no apparent side effects. This led to the design of mechanical studies in the laboratory on fresh, above-knee amputation specimens with closed fractures created in the tibia and fibula, to measure the stabilizing effect of various design features of the fracture brace.[12] Early results in 1972 indicated that the major load-bearing portion of the brace was the proximal half of the cylindrical portion of the sleeve encompassing the bulky, soft tissues of the gastrocsoleus complex.[11] Tightness of the fit of the brace and the molding of the posterior soft tissues was identified as the major factor in accomplishing load bearing and rotational and angular control of the limb in 1975.[5] The actual direct load transfer accomplished by the brace was measured to be less than 20% of the total load borne on the limb. Other investigators observed similar behavior for tibial fractures in casts and braces.[13]

Recent studies of the same design identified similar results in prefabricated braces, but also specifically looked at the role of the proximal condular extension.[14] In short leg functional casts of the PTB design, custom-applied Orthoplast short leg functional braces and prefabricated fracture braces, no significant change was demonstrated in stabilizing effect after removal of the condular extensions under compression, bending, and torsional loading conditions with the knee in extension or flexion. A short leg functional cast which molded the soft tissues in the same manner as described by Sarmiento for the PTB cast, but without molding around the patellar tendon and condylar extensions, and a similarly designed custom-fit Orthoplast fracture brace demonstrated no significant differences in the clinical results in a small series of patients.

Based on these laboratory and clinical results, the investigators began the development of a prefabricated fracture brace system, designed to mold the proximal soft tissues and maintain snugness of fit the appliance in the critical area of load transfer, that is, the proximal soft tissue mass. Laboratory studies verified the stability of these prefabricated designs to provide at least as good stability as provided by custom fit or plaster appliances of the conventional design.[14] This is the basis of the shape of the current prefabricated tibial fracture brace used by the investigators, which flattens the posterior soft tissues with a posterior shell and closes on to a padded anterior shell. A relief is created over the anterior tibial crest so that the anterior/posterior closure of the interlocking shell maintains the triangular cross-section of the device during soft tissue compression, regardless of the degree of circumferential adjustment required to maintain the fit of the brace. The proximal and distal extensions of the brace over the boby prominences have been eliminated and the shoe insert is of minimal size. Laboratory and clinical studies have indicated that the principal role of the shoe insert is to maintain the proximal position of the sleeve of the brace, which does all of the mechanical work.

Management Protocol. The use of a fracture brace for tibial fractures is a secondary procedure, i.e. initially, patients must have a reduction of the fracture and should be placed in a long leg cast. We prefer to admit patients to the hospital for observation and elevation of the extremity for at least 48 to 72 hours postinjury. Patients are begun on crutch ambulation with weight bearing as tolerated on the third postinjury day and should be seen in follow-up at about two weeks after the injury. Appropriate radiographs are obtained. Patients may be changed to a short leg functional cast (made with initial layers of elastic plaster) for an additional two to four weeks, depending upon the stability and nature of the fracture. Full weight bearing with crutches is encouraged during this period of time. A prefabricated fracture brace may then be applied at the fourth to sixth week postinjury. Progressive weight bearing is encouraged. Radiographs must be obtained after any change of immobilization. A follow-up one week after fracture brace application is recommended to check fracture alignment and fit of the brace. Routine monthly follow-ups are arranged until union.

Anatomic Results. The experience of Sarmiento at the University of California[9] and ours at the University of Miami[4] have demonstrated that over 90% of the patients have satisfactory anatomic results. In our recent series[4] of 385 tibial shaft fractures followed, theaverage shortening for nonsegmental fractures was 8 mm. Ninety percent (90%) of the patients had 50 or less anteroposterior angulation and 92% had 50 or less varus or valgus. No significant rotational deformities were present. The majority of patients had minor varus deformities which were cosmetically and functionally acceptable. Recurvatum deformities were more cosmetically acceptable than anterior bowing. Deformities up to 50 were not clinically significant; however, as angulatory deformities approached 100, problems with progressive angulation did occur.

It is important, therefore, to stress that anatomic alignment should be achieved whenever possible. Rotational deformities are generally not a problem with tibia fracture bracing techniques, provided that most patients are maintained in a plaster cast during the first few weeks of treatment. Rotational stability is achieved first as it is determined by soft tissue healing. At the time of brace application the soft tissues are usually sufficiently healed to provide for rotational stability. Angulatory stability, however, is the last to be achieved. Therefore, careful follow-up of all patients is an important requirement of this method of management. Our average time to union for closed fractures was 15.5 weeks and for open fractures 23 weeks.

Functional Results. Most patients who were treated with fracture bracing techniques had full or nearly full range of motion of the foot, ankle, and knee. Four percent of our patients had a mild limp due to shortening which was correctable by a shoe lift.

Complications. Complications related to fracture bracing include angulatory deformities, unacceptable shortening, nonunion, and skin maceration. The overall incidence of unacceptable angulation (greater than 120) in our experience is 4%, and the incidence of unacceptable shortening is 1.5%. These complications are generally preventable if patients are followed closely throughout the course of their treatment. The rate of nonunion was 2%. Skin maceration occurred in 1% of the cases.

Summary. The extensive experience with prefabricated fracture bracing for the tibia has documented successful results in the vast majority of tibial shaft fractures. The method requires strict adherence to suggested protocols and close monitoring of the patients. However, the low morbidity and complication rate and the predictability of satisfactory results make this method preferable to many other techniques in tibial fracture care.

Special Indications

Introduction. The usual indications for fracture bracing are the treatment of selected diaphyseal fractures of long bones as previously outlined. In their classic book,[5] Sarmiento and Latta mentioned that there were instances in which fracture bracing might be useful for other than the nonsurgical treatment of fractures. These applications were to supplement internal fixation and for the treatment of nonunion. They believed, theoretically, that fracture bracing could be an effective adjunct in these situations, as long as the basic conceptual conflict between soft tissue stabilization and rigid internal fixation was kept in mind.

Observing patients in our Special Fracture Clinic, it was discovered that they were often very reluctant to discontinue use of a fracture brace, even though the fracture was completely united. These patients related a sense of security, and some felt that wearing the fracture brace actually improved their extremity function. It was thought, in some way, the soft tissue compression produced by the brace was responsible for these effects. We began to use fracture braces for expanded indications after these experiences.

Special indications for fracture bracing encompass three general areas: (1) stress relief, (2) as an adjunct to internal fixation, and (3) secondary to external fixation. The rationale for using fracture braces in these areas was developed from theory, laboratory experimentation, and extensive clinical experience.

Stress Relief. Stress risers are produced in bone after removal of plate fixation or after bone biopsy. Fractures may occur through these stress risers and are often difficult to treat. In cases of rigid fixation with poor buttress due to comminution or bone loss supplemented with cancellous graft, a relief of the load is needed to prevent device or fixation failure before the fracture can heal. If the bone can be protected until the stress riser is eliminated or the buttress reestablished by normal bone healing and/or remodeling, then this complication could be avoided.

Fracture braces appear to be effective at relieving stress on the bone during full functional activity. Stress relief comes from two mechanisms: active and passive. Soft tissue compression provides support to the bone through the passive properties of the soft tissues. In the laboratory, there was a significant increase in the load required to fracture a bone with a stress concentrator in bending, torsion, and compression when soft tissue compression was applied via a fracture brace. In another study, estimates of active muscle forces on the bone were made from EMG measurements in subjects as they ambulated. When soft tissue compression was applied through a fracture brace, there was a significant decrease in the estimated forces of the muscles on the bone for each subject during normal ambulation. These studies gave some confidence that soft tissue compression with fracture braces may have a significant effect in relieving stress on the bone, while maintaining full functional activity in patients where stress relief is required.

Braces of either the ulnar or Colles' type are used for eight weeks after removal of forearm plates and tibial or femoral braces for 12 weeks after removal of tibial or femoral plates. Using these guidelines, we have not seen a fracture in a series of 20 cases after plate removal. Similarly, fracture braces have been used to protect bone weakened from surgical biopsy, in cases of incomplete fracture and in cases of rigid internal fixation with poor buttressing. Although these results are very preliminary, they have been encouraging.

Adjunct to Internal Fixation. Laboratory studies have demonstrated that semirigid or flexible internal fixation (e.g., Ender nails) supplemented by a fracture brace provides more fracture rigidity than either the flexible internal fixation or brace alone.[1] The brace primarily provides angulatory and rotational stability which are not adequately provided by the Ender nail alone. The Ender nail provides the length stability which the fracture brace alone cannot provide.

This concept has been employed in the management of a difficult clinical problem: segmental tibial fractures. Segmental tibial fractures treated by early weight bearing alone have poor anatomic results, with excessive shortening, angulation, and rotational deformities. This problem has been alleviated with the combination of flexible fixation and fracture bracing. Within a few days after injury, closed antegrade flexible intramedullary nailing is performed. After the acute pain and swelling have subsided, a standard tibial fracture brace is applied and the usual tibial fracture protocol followed. The clinical results with this combined fracture treatment have been highly satisfactory. This method has proven helpful in the management of other types of fractures where rigid medullary fixation is not possible.

Secondary to External Fixation. Fracture braces have been utilized with external fixation, both early and late in the treatment plan.

Early. Fracture braces are applied when the soft tissues are healed sufficiently to provide the intrinsic strength to maintain length and rotation of the limb. In such a case, the external fixator is removed at four to six weeks. The fracture brace is applied to provide angular stability and the standard fracture brace protocol is then followed until complete fracture union.

Late. If external fixation has been used to achieve primary fracture union, some potential complications exist after fixator removal. Usually, the fracture is incompletely remodeled due to lack of normal stresses in the bone. Therefore, the fracture site is vulnerable to refracture at this time. Another concern is that stress risers are created by the removal of the fixator pins which increases the potential for refracture through these holes. A fracture brace allows normal function while relieving stresses in the bone, as in the previously described protocol for stress relief with soft tissue compression. The fracture brace is used until it has been determined that no external support is necessary; this time period will vary, depending on bone quality, Fracture type, etc.

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