U·P O·J

Volume 11 Spring 1998
Pages 27-35

Current Treatment Options for Pediatric Femur Fractures

John M. Flynn, M.D.

From the Division of Orthopaedic Surgery, The Children's Hospital of Philadelphia, 34th and Civic Center Boulevard, Philadelphia, PA.

Address correspondence to: John M. Flynn, M.D., Division of Orthopaedic Surgery, The Children's Hospital of Philadelphia, 34th and Civic Center Boulevard, Philadelphia, PA 19104.

Abstract: Historically, the vast majority of femur fractures in children have been treated with casting alone, or with traction followed by casting when there is a risk of excessive shortening. These methods have been very successful, although malunion and limb length inequality continue to occur in a small percentage of children. Surgeons who treat large numbers of pediatric femur fractures have increasing enthusiasm for methods of internal and external fixation that obviate the need for lengthy traction. External fixation, flexible, or rigid IM nails, and plating are used to maximize early mobility and minimize the length of hospital stay. Each method has particular indications, contraindications, and complications that must be considered in choosing the optimal treatment for a particular child and his or her fracture.

Introduction

Femur fractures are the most common major injury treated by pediatric orthopaedists. These fractures typically occur either in early childhood, when weak woven bone is changing to the stronger lamellar bone, or during adolescence, when children are subjected to high-energy trauma from sports and motor vehicle accidents [16]. Child abuse must be considered, especially in infants and toddlers. One study reported that 80% of children under walking age who sustained a femur fracture were victims of child abuse [11].

The vast majority of femur fractures in children heal without any long-term sequelae regardless of treatment method [6]. Spica casting, or traction followed by spica casting, has been used with great success, largely because children have a tremendous ability to remodel the deformities that remain after closed treatment [27,30]. In the past, operative treatment has been reserved primarily for children with significant associated injuries, such as thoracic or head injuries [9], or an ipsilateral tibia fracture [4]. Previous studies have also recommended fixing femur fractures in adolescents [14,26] and in children with metabolic bone disease (e.g., osteogenesis imperfecta) [33].

Recently, increasing attention has been focused on the difficulty of caring for an older child or adolescent in a body cast for 2--3 months [15]. Such prolonged immobilization stresses the child and the family with missed school, lost work, and deleterious psychosocial effects. Social changes over the last three decades have made standard cast treatment particularly challenging. More families have two working parents and rely on day-care or schools for the supervision of their children.

Aggressive efforts to manage health care costs have inspired all to consider the most efficient use of resources. The costs of different treatment methods for femur fractures have been considered in several studies [22]. The long hospital stays required for traction are extremely expensive [13], in most cases equaling or exceeding the cost of surgical treatment. Few studies have considered the additional costs of outpatient care, specialized transportation, and lost income from missed work. All of these considerations have led to a search for better ways to treat femur fractures in school-age children.

Orthopaedists who treat many pediatric femur fractures recognize the success of standard casting and traction, but increasingly are looking for methods to address the many negative physical, emotional, and financial effects of prolonged immobilization. The goal of this review is to summarize concisely the indications, contraindications, and techniques of casting, external fixation, rigid intramedullary nailing, plating, and flexible intra-medually nailing and to discuss the potential complications and their avoidance.

Spica Casting

Spica casting has a long record of success in the treatment of pediatric femur fractures. No specialized tools or implants are needed, the treatment is considered non-invasive (except for the placement of a traction pin), and the complication rate is low. Most of the disadvantages are the result of prolonged immobilization. Older children, in particular, suffer from lost academic and social opportunities at a time when their self-image is most fragile. Often a homebound caretaker is necessary in families with two working parents.

Indications

The vast major of children less than 6 years of age can be treated with casting within 48 hours of injury. Older children and children with more than 2 cm of initial shortening require between 1 and 3 weeks of traction. A recent study [5] reported the "telescope test": if the femur shortens more than 25 mm with gentle compression, traction (usually until callus is visible on radiographs) is advisable to avoid shortening in the cast. In infants, the Pavlik harness is a safe, simple, effective treatment for stable fractures [28].

Contra-indications

Traction followed by casting is difficult to use in patients who have other major injuries, such as serious head trauma, chest, or vascular injuries; a floating knee injury [4], or severe soft tissue injury that cannot be well-managed in a spica cast. Children with osteogenesis imperfecta or other metabolic bone diseases may benefit from internal fixation to prevent refracture after the cast is removed.

Technique

If child abuse is a possibility, a skeletal survey is recommended before the cast is placed so as not to obscure occult fractures. If skeletal traction is required, the pin should be placed in the distal femoral metaphysis at least 1 cm from the physis and parallel to the knee joint. An oblique pin may cause angulation and malunion [1]. Satisfactory alignment in traction can be very difficult to achieve when the fracture is at the distal metaphyseal/diaphyseal junction (Figure 1). Tibial pins are to be avoided, as they risk injury to the proximal tibial physis [7]. For most children, reduction and cast application are performed in the operating room.

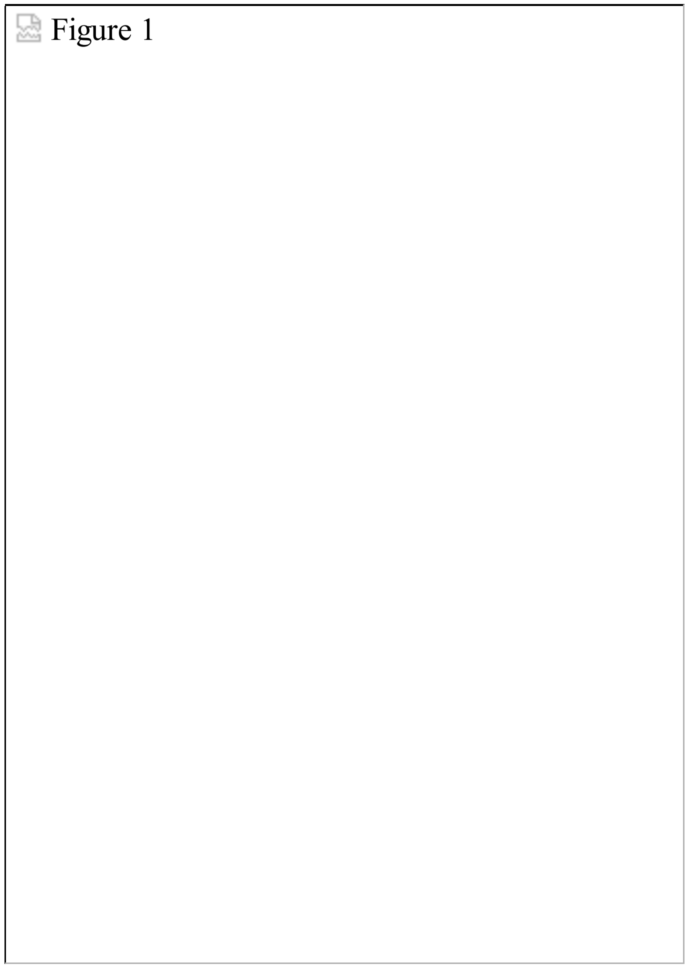

Fig. 1. This radiograph was taken 4 days after a 10-year-old boy was placed in traction. This angular mal-alignment is typical for distal fractures.

First, a long leg cast is applied to the injured leg, with care taken to pad the heel and the popliteal area. Gentle traction on the injured leg helps reduce shortening during casting. An appropriate three-point mold will lessen the tendency of these fractures to heal in varus malalignment (Figure 2).

Figure 2

Fig. 2. Despite wedging, this 9-year-old has 25 degrees of varus angulation 5 weeks after injury.

After a long leg cast is applied to the injured leg, the child is placed on the spica table to finish the 1 1/2 spica cast. The top of the cast should go to the nipple line, a pad should be placed to maintain adequate room for an expanding abdomen and a bar is usually used to connect the legs. For toileting, the bar is placed under the legs in boys and on top of the leg portion of the cast in girls. For easier molding, we prefer to use a plaster long leg cast, then finish with fiberglass to keep the cast as light and durable as possible. Some have recommended a cast in the sitting position (90 degrees of hip and knee flexion) in younger children [20,21], as it permits easy portability, no need for a bar, and easier seating and toileting. Older children may even be able to attend school. In general, we repeat radiographs within 10 days of cast application to monitor the maintenance of reduction.

Complications

Despite its non-invasive nature, many complications have been reported from this method of femur fracture treatment. Cast pressure sores, especially in the lower back area, are not unusual, and can be avoided by turning the child frequently from side to side. When angulation is unacceptable the cast can be wedged. The surgeon should be aware of the reports of peroneal nerve palsy when a 90/90 cast is wedged [32]. Shortening is quite common: one study [19] reported that 43% of the fractures evaluated shortened more than 2 cm. Scanograms can be used to accurately monitor leg length inequality. Rotational deformities should also be avoided. If excessive shortening is present and cannot be improved with a cast change, external fixation may be used to distract and stabilize the fracture during healing. In addition, muscle atrophy and osteopenia put the child at risk for possible refracture after spica cast removal.

External Fixation

External fixation of pediatric femur fractures has been an increasingly popular way to rapidly stabilize the fracture and mobilize the patient while correcting malalignment and shortening [2]. Unfortunately, the external fixator may stress-shield the fracture leading to delayed union, minimal callus response, and risk of fracture after the fixator is removed. In addition, pin track infections are common and pin care can be difficult for many families.

Indications

External fixators are indicated for children with multiple injuries, especially head injuries or severe soft tissue or vascular injuries that are not appropriate for casting. External fixators can be used for femur fractures in children older than 6 as an alternative to traction and spica casting. Perhaps the best indication for external fixation is the treatment of fractures that have shortened or angulated excessively in the cast and the treating surgeon needs the ability to correct these deformities while maintaining the fracture in proper alignment during healing (Figure 3).

Figure 3

Fig. 3. (**A--D**): A 6-year-old girl sustained a spiral midshaft femur fracture. **A:** She presented to an outside institution with marked shortening and a 90-degree rotational malalignment. **B:** A Steinman pin was incorporated into her cast. This radiograph, taken 16 days after injury, shows unacceptable shortening and angulation. **C:** She was transferred to the Children's Hospital of Philadelphia and an external fixator was placed. Malalignment and

shortening have been corrected and early callus is visible here 7 weeks after fixator placement. **D:** Ten months after injury and 5 months after external fixator removal she is healed in good alignment. (Case courtesy of Dr. Richard Davidson.)

Contra-indications

Very proximal or distal fractures may preclude proper pin placement. A relative contra-indication to the use of external fixation is a family or social environment that cannot support compliance with pin care, precautions, and follow-up.

Technique

Unilateral half pin fixators have been the most widely and successfully used. At The Children's Hospital of Philadelphia we use both the AO and EBI systems. The AO external fixator is simple, inexpensive, and has no device constraints restricting pin placement. The EBI fixator has a more advanced conical pin design, instrumentation to facilitate frame application, and fracture reduction and the ability to distract, compress, or later manipulate the fracture without anesthesia. Ilizarov and other fine wire fixators have not been used in the immediate care of pediatric femur fractures as half-pin unilateral fixators are much easier and safer [16].

The fixator can be placed on a radiolucent table or a fracture table with image intensifier control. The surgeon first places a fixation screw approximately at the level of the lesser trochanter and then distally several centimeters proximal to the distal femoral physis. These screws should be placed perpendicular to the anatomic axis of each segment of the fractured femur. The external fixator frame is then applied to these outer pins and the fracture is reduced. Although anatomic reduction is the goal, bayonet apposition has the advantage of creating a larger area for callous development. After the outer two pins are applied and the fracture is reduced, the central two pins are placed and final reduction adjustments are made. Before leaving the operating room the surgeon should check to see that the knee can be flexed to 90 degrees. If flexion is limited, the iliotibial band should be released at the pin site. If the skin is tented on the pins, it should be released as well so that skin motion on the pin does not lead to infection.

For pin care, we use normal saline only. If crusting develops around the pin, half-strength hydrogen peroxide is used. The patient is progressed to weight bearing as tolerated, and the fixator can be dynamized once callous is visible. Because of concerns of stress-shielding, we are dynamizing the fixators even earlier than in the past. The fixator remains in place until there is solid, bridging callus visible on radiographs. This typically takes 10--15 weeks or more depending on the age of the child, the fracture pattern, and the rigidity of the external fixator construct. Fixators may be removed without a general anesthetic. In practice we find that there are few children or parents who allow us to perform fixator removal outside of the operating room. After the fixator is removed, 6 weeks of partial weight bearing is recommended as the screw holes fill in with bone. We use a fracture brace to further protect the fractures if "primary bone healing" is present.

Complications

As mentioned, external fixation of pediatric femur fractures has been associated with several complications. Pin track infection occurs frequently [29]. Superficial infections can be treated with good pin care and oral antibiotics. Deeper infections require irrigation and drainage and intravenous antibiotics. Delayed union, union with minimal fracture callous, and refracture are all major concerns when the external fixator is used (Figure 4). Although one series of 44 patients reported no refractures, other centers (our included) have seen several refractures [24]. Careful patient selection, prolonged use of the fixator beyond the early appearance of callus, and extra protection after the fixator is removed may help reduce the incidence of refracture. Finally, knee stiffness occurs in many children when the fixator is in place. This resolves in the vast majority of cases once the fixator is removed. We often perform a gentle knee manipulation in the operating room at the time of external fixator removal.

Figure 4

Fig. 4. (**A--D**): This 12-year-old sustained a low-energy mid-shaft femur fracture. **A:** The fracture was anatomically reduced and an external fixator was placed. This AP radiograph was taken 2 weeks after injury. **B:** This radiograph, taken 14 weeks after the external fixator was placed, shows "primary bone healing" without callus. **C:** With minimal trauma, he refractured through the original site one week after fixator removal. **D:** The

case was salvaged with retrograde flexible nailing. This radiograph was taken 10 months after injury and 6 months after the flexible nails were placed. (Case courtesy of Dr. Richard Davidson.)

Rigid Intra-Medullary Nailing

The advantage of rigid intra-medullary nailing is rapid fracture stabilization and mobilization of the patient with essentially no risk of non-union, malunion, or refracture. Home care is generally not needed. The major disadvantage is the need for surgery to place and remove the implant and the serious concern about avascular necrosis, the most devastating and least manageable of all the complications from femur fractures.

Indications

Locked, rigid intramedullary nailing is indicated for the vast majority of femur fractures in skeletal mature adults. No particular age serves as a clear dividing point. We tend to reserve intramedullary nailing for mature females, 14 years of age or older, and mature males, 15--16 years of age or older. Some have recommended antegrade intra-medullary nailing for children as young as 10 years old with multiple trauma [3].

Contra-indications

Antegrade rigid intramedullary nailing is contra-indicated in children younger than those outlined above. Intramedullary nailing should obviously not be used in pathologic fractures when contamination of the entire medullary canal with tumor is possible.

Technique

The operative technique and post-operative regimen are well known and widely practiced. To minimize the risk of avascular necrosis, several papers [3,10] have emphasized the importance of a lateral starting point in the greater trochanter. Ideally, an unreamed, statically locked nail is preferred. Even in the "unreamed" nail the canal diameter may be so small that reaming may be necessary in some cases.

Complications

Avascular necrosis is the most feared complication [3,23]. To minimize risk, the piraformis fossa is avoided with an entry site in the greater trochanter. There have been reports of premature closure of the trochanter apophysis when rigid intramedullary nails are placed [25]. Overgrowth after intra-medullary nailing is also a concern.

Plate Fixation

With so many other options available, only very unusual situations justify plate fixation as the treatment of choice for pediatric femur fractures. One such clinical scenario is femoral shaft fixation after repair of a vascular injury in the thigh.

The disadvantages of plate fixation include the open operation necessary to apply and remove the implant as well as stress-shielding from the plate. Kregor et al. [17] reported a series of 12 patients in which plates were used for children with polytrauma. They saw overgrowth averaging 1 cm in 7 of the 12 patients. Ward et al. [31] used plating for 25 femoral shaft fractures, mostly in children with associated head injury or polytrauma. Leg length inequality was not a problem.

Flexible intramedullary nails

Flexible intramedullary nails have been used for pediatric femur fractures for many years. They were first reported for use in children by Mann in 1986 [18]. A prospective study by Heinrich [12] reported 78 fractures with no major complications. Leg length inequality occurred in 30% of the cases, ranging from 6 to 26 mm. These authors concluded "no other form of operative management for diaphyseal femur fractures in children is as universal or produces better results than the use of flexible intramedullary fixation." In their large prospective series Heinrich et al. felt this method gave comparable results to traction and casting in children 6--9 years old and better results than casting and traction in children older than 10.

Intra-medullary fixation combines the advantages of external fixation---rapid fracture stabilization, immediate patient mobilization, and anatomic fracture union---without the major disadvantages---stress shielding and pin tract infection [8]. Similar advantages have made interlocked intra-medullary nails the standard of care for adult femur fractures. Retrograde flexible nailing avoids the risk of avascular necrosis that has been caused by antegrade nailing in children. The disadvantage of flexible intramedullary nailing is the lack of rotational control, the necessity of a general anesthetic to implant and remove the nails, and soft tissue irritation that can develop distally at the insertion site.

Indications

Flexible intramedullary nailing may be indicated in children who cannot be treated with immediate spica casting and have not yet reached skeletal maturity. They are ideal for transverse fractures with excessive shortening or instability in children who would benefit from rapid mobilization (Figure 5). They can be used as a salvage after refracture when an external fixator or cast was used for the primary fracture treatment (as seen in Figure 4). They can also be used in children with metabolic bone disease such as osteogenesis imperfecta.

Figure 5

Fig. 5. (**A--D**): This 6-year-old boy was a pedestrian struck by a car at a high rate of speed. He sustained a closed head injury and a femur fracture that shortened more than 4 cm. **A:** The head injury made it difficult to maintain him in traction so retrograde flexible nailing was performed. **B:** Here, 13 days after placement of the nails, the fractured has impacted. He is up walking in a brace. **C:** AP radiograph showing abundant callous at 3

1/2 months. **D:** Lateral radiograph at 3 1/2 months

Contra-indications

Contra-indications include very distal or very proximal fractures that precludes nail insertion. Relative contra-indications include long spiral or comminuted fractures that might shorten with this method or pathologic fractures in which entire canal may be contaminated if this device is used.

Technique

Flexible intra-medullary nails can be inserted either on the radiolucent table or the fracture table. With the leg in traction on the fracture table, the surgeon's hands are freed to pass the nails or align the fracture with external manipulation. Before the operation, the minimum diameter of the femoral canal is measured. The nail selected should be 40% of this minimum diameter. Before preparation and draping a test reduction is performed. Preparation and draping should extend from the pelvis to below the knee. Using image control, a point approximately 2 cm proximal to the distal femoral physis is located. A 3-cm incision from this point distal is made and then the soft tissue is cleared down to bone. Great care is taken not to disturb the periosteum in the area of the distal femoral physis. A drill of appropriate diameter with soft tissue guide is used to broach the medial and lateral femoral cortex at the flair of the metaphysis, at least 2 cm proximal to the physis. The drill is then directed toward the center of the medullary canal proximal to the entry site (that is in the direction that the nails will pass). The medial and lateral nails are then passed up to the fracture site. Generally one of the two nails will tend to further reduce the fracture when it is passed across and contacts the opposite cortex of the proximal fragment. This nail should be passed first and with alignment improved, a second nail is then passed across into the proximal fragment. If the first nail knocks the fragment too far out of position, then both nails should be passed across the fracture nearly simultaneously with alternate advancement of each nail. The nails should be passed until the tips contact the cortical bone proximal to the lesser trochanter. The nails should then be withdrawn 2--3 cm, cut, and hammered back so that the cut end is just outside the cortex of the distal femur and the tips are again abutting the cortical bone in the proximal femur.

Post-operative activity and immobilization should be tailored to the fracture stability, as well as the environment and reliability of the child and his family. For stable fractures and reliable children, we use either an above-knee fracture brace or a knee immobilizer with partial weight bearing for 4--6 weeks. Once callous is visible, the children can be brace free and weight bearing as tolerated. Even in stable fractures some rest for the knee seems to diminish irritation of the medial and lateral soft tissues by the extra-osseous nail end. Unstable fractures in unreliable children are treated with long leg casts with a pelvic band allowing weight bearing as tolerated until callous is visible. We have routinely removed the nails once the fracture is healed.

Complications

Potential complications include infection, neurovascular injury, and overgrowth. We have seen some soft tissue irritation around the knee from the portion of the nail that is extra-osseous. Rotational malunion is possible but has not yet been observed. One of the major concerns is the potential injury to the distal femoral physis either at the time of nail insertion or at the time of removal. To date this has not occurred and we will continue to take great care to avoid this potentially serious problem.

Current Recommendations

In infants, the Pavlik harness may be the best option for stable fractures [28]. A spica cast is used for unstable fractures in this age group. Child abuse must be considered. For children younger than 6, early spica casting is the treatment of choice as long as there is not excessive shortening with stress.

For children from age 6 to adolescence, spica casting is appropriate for any minimally displaced fracture not require traction. Traction and spica casting can be used for any fracture in this age group, although children with neuromuscular problems such as cerebral palsy, head injuries, and vascular repair may be difficult (if not impossible) to manage using these standard methods. External fixation is ideal for the long spiral fracture with shortening and for the very distal femoral shaft fracture that is difficult to align in traction or fix with flexible intra-medullary nails. External fixators are also an ideal way to salvage a failure of traction and spica casting. As attractive as ante-grade rigid intra-medullary nailing appears, avascular necrosis is a major risk and limits its use to older adolescents.

Flexible nailing may prove to be the best way to rapidly mobilize a school-age child while ensuring rapid healing with good callous and alignment. Continued experience will determine if the tremendous benefits to the injured child and their family gained from flexible intramedullary nailing are balanced by acceptable risks and costs.

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