Management of Pediatric Femoral Shaft Fractures

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Abstract

Femoral shaft fractures are the most common major pediatric injuries managed by the orthopaedic surgeon. Management is influenced by associated injuries or multiple trauma, fracture personality, age, family issues, and cost. In addition, child abuse should be considered in a young child with a femoral fracture. Nonsurgical management, usually with early spica cast application, is preferred in younger children. Surgery is common for the school-age child and for patients with high-energy trauma. In the older child, traction followed by casting, external fixation, flexible intramedullary nails, and plate fixation have specific indications. The skeletally mature teenager is treated with rigid intramedullary fixation. Potential complications of treatment include shortening, angular and rotational deformity, delayed union, nonunion, compartment syndrome, overgrowth, infection, skin problems, and scarring. Risks of surgical management include refracture after external fixator or plate removal, osteonecrosis after rigid antegrade intramedullary nail fixation, and soft-tissue irritation caused by the ends of flexible nails.

Femoral shaft fractures, typically caused by blunt trauma, are the most common major pediatric injuries treated by the orthopaedic surgeon. Seventy percent of femoral fractures involve the shaft. In the past, surgery was discouraged, in part because no technique yielded consistently better results than casting. Nonsurgical treatment remains the preferred and most cost-effective form of management for the preschool-age child with an isolated femoral fracture. The accepted methods are a Pavlik harness and/or splints for newborns or young infants and an immediate or early spica cast for older infants, toddlers, and young children.1 For the school-age child with an isolated fracture, the impact of prolonged immobility must be considered. These and other factors have prompted the use of surgical techniques that permit rapid mobilization. Results of a recent survey of members of the Pediatric Orthopaedic Society of North America indicate that surgery is the preferred treatment for older children, particularly those with high-energy injuries.2

Evaluation

Age and mechanism of injury are key elements of the history. Although many pediatric femoral fractures are isolated injuries, children with high-energy trauma frequently have associated head, chest, or visceral injuries. A trauma team should coordinate the care of a child with more than one system injured or who requires intensive care. Initial attention should focus on vital signs, the primary assessment, resuscitation, and stabilization of the cervical spine and pelvis. A secondary survey should more thoroughly assess the cervical spine and pelvis, then focus on the extremities. The thigh and knee are evaluated for swelling or bruising suggestive of a dislocation or an associated fracture. Circumcision, skin integrity, nerve function, signs of compartment syndrome, fracture alignment, knee joint effusion, and knee ligamentous stability should be evaluated. The presence of a bloody knee effusion may signal significant intra-articular pathology.

An anteroposterior (AP) pelvic radiograph, and AP and lateral radiographs of the femur that include the hip and knee, show the fracture pattern and reveal possible associated hip and pelvic injuries. Although the child is often in skin traction by the time a radiograph is obtained, a lateral image with no traction applied gives the best initial indication of shortening. Fracture location, pattern, displacement, angulation, shortening, and associated findings (eg, soft-tissue air) should be noted.
Abuse should be considered and investigated in a young child with a femoral fracture when the child’s age, history of injury, physical examination, or radiographic findings suggest a nonaccidental injury. A skeletal survey should be obtained and further investigation by Child Protective Services should be considered for infants and children of walking age when findings on history or physical examination cause concern. The incidence of all pediatric femoral fractures has a bimodal distribution, with peaks at ages 2 and 12 years, and fractures in toddlers are common. Despite this incidence data, it is not unusual for health care providers to suspect abuse when any active young child sustains a femoral fracture after a simple fall. In a report of 207 patients younger than age 6 years with a femoral fracture, 76 cases were investigated, but only 13 (17%) were determined to be nonaccidental. Recent studies indicate that infants, not toddlers, are most at risk for nonaccidental injury—by about tenfold. Schwend et al reported that abuse was a probable mechanism of injury in 42% of infants (10/24) but in only 3% of children of walking age (3/115). Although children with spiral fractures are more likely to be investigated, a spiral pattern does not specifically indicate abuse. Rex and Kay recommended caution in suggesting that a radiograph indicates nonaccidental injury unless a more specific fracture type (e.g., corner, bucket-handle) is noted.

**Decision Making**

Each option for management of a pediatric femoral fracture has distinct advantages and disadvantages. To choose the best option for a particular child, several factors should be considered, including associated injuries or multiple trauma, fracture personality, ability to obtain an age-appropriate reduction, family issues, and cost (Fig. 1).

Early surgical treatment of the child with high-energy trauma, head injury, or associated multiple trauma may reduce complications and decrease hospital stay (Fig. 2). In a child with a floating knee, care is optimized when the femur is stabilized with fixation. Spasticity after head injury makes traction management difficult. A femoral shaft fracture associated with arterial injury may be best managed with plating at the time of vascular repair.

Fracture pattern, stability, and location are important factors in determining the best treatment option. High-energy fractures with more periosteal stripping are slower to heal and more likely to shorten. Spiral, comminuted, or very proximal or distal fractures may be less suitable for flexible nailing (Fig. 3). Transverse

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**Figure 1** Treatment options for pediatric femoral fractures based on type of injury and patient age.

**Figure 2** Anteroposterior radiograph of a 6-year-old girl with a grade I open femoral fracture, tracheal transection, bilateral pneumothoraces, and a C2 fracture. The femoral fracture was treated after the C2 fracture was stabilized with a halo. Although her age and size made this fracture pattern amenable to casting, flexible nailing was used to allow rapid mobilization and pulmonary care.
fractures have less surface area for callus and are at greater risk of refracture after external fixation.

Casting is ideal for infants and toddlers, in whom considerable angulation and shortening will usually remodel. Internal fixation is best for adolescents, in whom there is little remodeling potential.11 Nonsurgical management of adolescent femoral fractures has a complication rate of 30%. Remodeling potential is greatest in children younger than age 10 years, in fractures near the physis, and for deformities in the plane of joint motion. Angular deformity is tolerated better near the hip than near the knee. Generally, for children aged 2 to 10 years, acceptable fracture alignment at union is ≤15° of varus or valgus angulation, ≤20° of anterior or posterior angulation, and ≤30° of malrotation.12,13 Overgrowth may vary with the age of the child, the fracture pattern and location, the amount of shortening, and possibly the treatment method. In children aged 2 to 10 years, overgrowth averages 0.9 cm (range, 0.4 to 2.5 cm).12 Shortening at union should be no more than 1.5 cm to 2.0 cm. No more than 1.0 cm of shortening is recommended for older children.

Femoral fracture management can have a great impact on the child and family. Many children leave the hospital and return to a home with a single parent or two working parents. A school-age child immobilized in a spica cast disrupts the home with significant nursing needs as well as the challenges of schooling and transportation.14 Some families are not capable of cooperating with simple cast care or external fixator pin care. Consideration of such issues can minimize the burden on the family and limit the risk of preventable complications.

Several studies indicate that the lowest charges are generated by immediate spica cast management and that hospital traction followed by casting generates charges equivalent to those of surgical fixation.15,16 One study indicates that hospital profit is greater with traction and casting than with external fixation.17 Smith et al18 reported that children treated at a pediatric hospital are more likely to have expeditious, definitive management with a shorter length of stay at less cost than those treated at a general hospital.

Management

Children Age 6 Years and Younger

A femoral fracture in a newborn may result from a difficult delivery, osteogenesis imperfecta, or arthrogryposis. Pseudoparalysis is usually the presenting sign; septic arthritis always should be excluded. For infants up to 6 months of age, care may be easier in a Pavlik harness than in a spica cast. The Pavlik harness, sometimes supplemented with a simple splint, provides adequate alignment and comfort for proximal and middle-third shaft fractures and avoids the potential skin problems associated with using a spica cast.19 For the older infant, immediate spica casting is usually better for maintaining comfort and fracture alignment. If the history or physical examination raises any concern, the infant should be further evaluated for abuse.

Early spica casting is preferred for the child between 1 year and 6 years
of age with a low-energy, isolated femoral fracture. High-energy trauma is not an absolute contraindication for early spica casting, but it is a predictor of loss of reduction. The family should be prepared for repeat reduction. Cast application should be delayed until the child’s medical status has stabilized. Prolonged skin or skeletal traction in the younger child is rarely needed. Indications for prolonged traction include a difficult high-energy injury, such as a comminuted shaft fracture or an unstable subtrochanteric fracture. A very large or obese child without a parent strong enough to lift her or him may be better served by surgical fracture fixation. Young children with severe head, chest, or abdominal injuries may be better treated with surgical fixation in specific cases.

The final limb-length difference is usually within 1 cm of preinjury status for children younger than age 6 years with low-energy fractures treated in an early spica cast with the hip and knee in 90° of flexion. Knee flexion <50° in the cast has resulted in a 20% incidence of loss of reduction, which is nine times greater than that of children casted with the knee in 90° of flexion. Early spica casting is indicated in fractures with up to 20 mm of initial shortening. However, the risk of losing an initial reduction doubles with each centimeter of initial shortening (1 cm, 12%; 3 cm, 50%).

A few days of traction or splinting is used for the child with a low-energy displaced femoral fracture if the spica cast is not applied immediately. Although simple, low-energy fractures can be casted under conscious sedation, reduction and casting in the operating room under general anesthesia provides several advantages. Examination under anesthesia is useful to determine fracture stability and the amount of distraction needed for proper alignment. Fluoroscopic evaluation of the fracture after reduction can allow adjustments before the cast has hardened.

The hip and knee should each be flexed to 90° in the cast. Although some surgeons prefer to cast with the hip and knee extended, children casted in the 90°/90° position have less loss of reduction and are much easier to carry and transport. Automobile restraint laws in many states make it difficult or impossible to legally transport a child casted in full extension. Although expensive, a polytetrafluoroethylene liner (Gortex; WL. Gore, Flagstaff, AZ) may decrease skin problems. A folded sheet is temporarily placed over the entire abdomen, and the cast is applied in sections. First, a long leg cast is applied to the injured side. With the child securely on the spica table, gentle traction is maintained through the leg cast, a valgus mold is applied at the fracture, and the rest of the cast is applied up to the nipple line. Great care should be taken to use only gentle traction to get the fracture out to length and to avoid pressure in the popliteal fossa or over the peroneal nerve. Peroneal nerve injury and compartment syndrome have been reported with spica cast use for femoral fractures, especially after high-energy trauma or when the cast was wedged. A recent report recommends applying an above-knee cast first with no posterior calf pressure and leaving the foot out of the cast for observation, then splitting and spreading the thigh and leg portion of the cast if appreciable swelling is anticipated. Reinforcing the cast with splints in either the anterior or posterior groin crease may obviate the need for a bar and allow carrying the child close to the parent.

Follow-up radiographs should be obtained within the first 10 days. Ferguson and Nicol reported that the position noted 7 to 10 days after reduction predicted the final position. A reclining wheelchair with elevated leg rests facilitates mobility in the cast, and a beanbag on the floor provides secure and comfortable sitting. The cast can be removed when mature callus is present, typically at 6 to 8 weeks. For most children, no special therapy is needed after cast removal. The family should be forewarned that a limp may be apparent for several months.

Children Older Than Age 6 Years

Several options are available for children older than age 6 years but not yet skeletally mature. These include traction and casting, external fixation, flexible nailing, and intramedullary rodding, as well as plating. In choosing the best option, consideration is given to the decision-making factors as well as to the surgeon’s skill and experience with each method. The risks and benefits of treatment should be reviewed with the family.

Traction Before Casting

Traction is recommended when there is a high risk of unacceptable shortening with immediate casting. Generally, the risk increases in children older than age 6 years or in children with a high-energy fracture. Buehler et al described the telescope test, in which 3 cm of shortening with gentle force while the child is anesthetized predicted a twentyfold greater chance of unacceptable shortening in an immediate spica cast. Relative contraindications for traction and casting include obesity, multiple trauma, significant head injury, floating knee injury, and very distal fractures that compromise traction pin placement.

The pin is placed in the distal femur to avoid damage to the proximal tibial physis. The pin can be placed under conscious sedation or general anesthesia. A 3/16-in threaded Steinmann pin is drilled medial to lateral, and its position is confirmed radiographically. Areas of tented skin are released, and the child is placed in 90°/90° traction. Radiographs in traction are obtained periodically to ensure that the fracture is out to length and in satisfactory alignment. When radiographs show callus and there is no tenderness at the fracture site (typ-
ically 17 to 21 days), the pin is removed and a spica cast is applied.

**External Fixation**

External fixation is excellent for achieving satisfactory alignment without long incisions, exposure of the fracture site, significant blood loss, or the risk of physeal injury or osteonecrosis.\(^{25}\) External fixation can be considered a form of portable traction for a pediatric femoral fracture. With its relatively quick application using easily available and familiar equipment, external fixation offers a valuable solution for several difficult problems: open fractures or fractures associated with severe soft-tissue injury; multiple trauma or head or vascular injuries; and fracture patterns less amenable to flexible intramedullary nailing. External fixation is also valuable for hard-to-control subtrochanteric fractures as well as fractures at the distal diaphyseal-metaphyseal junction, where callus formation is good but proximity to the insertion site makes flexible nailing difficult.

Use of external fixation as the primary treatment method for children aged 6 to 16 years has waned in recent years with reports of complications\(^ {26}\) and with increasing evidence to support the use of flexible intramedullary fixation.\(^ {27}\) Surgeons who use fixators for other disorders are familiar with several common problems, such as family acceptance of the fixator, pin site irritation or infection, knee stiffness, and unsightly thigh scars. However, reports of delayed union and refracture\(^ {26}\) after device removal have raised concerns that the external fixator may stress-shield the fracture site and prevent the development of satisfactory fracture callus, especially if the fixator is not effectively dynamized (Fig. 4).

**Flexible Intramedullary Nail Fixation**

Flexible intramedullary nailing has become popular again because it allows rapid mobilization of children with little risk of osteonecrosis, physeal injury, or refracture. It functions as an internal splint that holds length and alignment but permits enough motion at the fracture site to generate sufficient callus.\(^ {28}\) Results have been excellent with Ender nails\(^ {29}\) and titanium elastic nails.\(^ {28}\) Pediatric orthopaedic surgeons prefer flexible intramedullary nailing for skeletally immature children older than age 6 years with transverse fractures in the middle 60% of the femoral diaphysis.\(^ {2}\) More proximal and distal fractures, as well as those with comminution or spiral patterns, are more

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**Figure 4**  
A, Anteroposterior radiograph taken after application of external fixation for a transverse femoral fracture in an 11-year-old boy.  
B, Anteroposterior radiograph taken 3 months later showing healing with minimal callus.  
C, Anteroposterior radiograph showing a refracture through the original fracture site 1 week after fixator removal. The injury was salvaged with titanium elastic nails. (Courtesy of Richard Davidson, MD, Philadelphia, PA.)
challenging to manage with flexible nailing; in such instances, intramedullary fixation may be supplemented with a cast or brace. In the only published randomized trial to date, Bar-On et al\textsuperscript{27} reported better clinical results with flexible intramedullary nailing than with external fixation. In a recent prospective trial, titanium elastic nailing was compared with traction and casting for children aged 6 to 15 years. Children treated with titanium elastic nailing reached recovery milestones sooner with a lower complication rate.\textsuperscript{16}

Although both Ender nails and titanium elastic nails offer flexible intramedullary fixation, the fixation techniques have important differences. Stainless steel Ender nails are stiffer than titanium elastic nails. With Ender nails, stability is based on both the bend placed in the nail and on stacking the nails to increase canal fill. Titanium nail fixation technique involves balancing the forces of two opposing implants\textsuperscript{30} (Fig. 5). The entry site, nail size, and nail length should be symmetric; stacking is not done with titanium nail fixation. The most frequently reported complication is soft-tissue irritation by the extraosseous portion of the nail tip at the insertion site.\textsuperscript{16,30} Malunion, shortening, and refracture rarely occur when standard flexible nailing indications and principles are followed.\textsuperscript{7,16,28-31} Refracture has been reported after premature nail removal.\textsuperscript{16,28} Malunion is more likely to occur in unstable fracture patterns and in heavy adolescents.\textsuperscript{32}

Preoperative planning for using titanium elastic nails includes measuring the narrowest diameter of the femoral canal and multiplying by 0.4 to determine the nail size; for example, if the minimum canal diameter is 10 mm, two 4.0-mm nails are used. Surgery can be performed on a radiolucent table or on the fracture table, with the well leg abducted out of the

![Figure 5](image-url)  
Figure 5  Anteroposterior (A) and lateral (B) radiographs of a short oblique closed femoral fracture in a 10-year-old boy treated with titanium flexible nailing. Anteroposterior (C) and lateral (D) radiographs taken 3 months after injury demonstrate abundant callus at the fracture site. The apex of the nail bend is at the fracture site to confer optimum stability. Note the symmetric entry site, nail bend, and length. Only 1 to 1.5 cm of the nail is outside the bone distally, and there is no excessive distal bend.
way. In the standard retrograde technique, the nails should enter the bone approximately 2.5 cm proximal to the distal femoral physis. An incision is made from this point extending distally approximately 2 to 3 cm. Great care is taken to avoid deep dissection in the area of the distal femoral physis. An appropriately sized drill (eg, a 4.5-mm drill for 4.0-mm nails) is used to broach the cortex of the femur at the same distance from the physis on the medial and lateral sides. The drill should be angled obliquely within the medullary canal, aiming proximally to create a sharply angled distal-to-proximal track for the nail to follow (Fig. 6).

The nails are then bent with a gentle contour; ideally, the apex of the convexity is at the level of the fracture. Both nails are tapped up to the fracture site. When there is translation or angulation at the fracture site, one of the two nails will be easier to pass. Instead of passing this easier nail first, the fracture is reduced so that the more difficult nail can be passed initially. This is done because it may be challenging to pass the more difficult nail if the other nail is spanning the fracture (Fig. 7). Sometimes the nail tip can be rotated up to 180° to facilitate passage. Once across the fracture, the nails are tapped distal-to-proximal so that the distal tip of the nail that entered laterally is at the level of the greater trochanteric apophysis and the tip of the nail that entered medially is at the same level near the medial femoral neck. When the nail reaches its final position, each nail is backed out slightly, cut at the skin, then tapped back in so that only 1 to 1.5 cm of nail lies in the soft tissues. The nail can be bent slightly away from the femur to facilitate later removal, but it should not be sharply bent because that causes soft-tissue irritation.

Alternative techniques for flexible intramedullary nailing include the use of stainless steel Ender nails and a proximal entry point (ie, antegrade technique). The Ender nail technique includes either proximal or distal starting points; the nails are bent in either a “C” or an “S” shape to gain cortical contact at the fracture site (Fig. 8). A third nail is added if more canal fill is needed for stability. The eyelet at the near end of an Ender nail can be used to secure the nail to the femur with a screw. However, nail back-out is rare because pediatric metaphyseal bone is dense, so the screw fixation is not generally used. Either titanium elastic nails or stainless steel Ender nails can be inserted in an antegrade fashion. The advantages of proximal entry include elimination of knee irritation from the nail tip (the most common complaint in children treated with the retrograde technique) and better stability for certain fracture patterns. A disadvantage of proximal entry is the lack of a safe medial and lateral starting point, resulting in unbalanced, asymmetric implants. Also, nail removal sometimes leaves a stress riser in the proximal femur, which is a more difficult area to protect. The transtrochanteric approach eliminates the concern about a stress riser but introduces the possibility of trochanteric apophyseal damage, which might lead to coxa valga.

When fixation is complete, traction is released and the fracture can be gently impacted through manipulation so that it is not fixed in distraction. Normal rotation should be ensured before the patient leaves the operating room. Postoperative immobilization is based on the fracture pattern. For stable transverse fractures, a knee immobilizer may be used with partial weight bearing. Immobilization is stopped when callus is noted at the fracture site, usually at 4 to 6 weeks.

Nails are removed when the fracture line is no longer visible, usually 4 to 12 months after injury. The nails should be removed if they are irritating the soft tissues and causing pain, knee effusion, or loss of knee motion. The removal of flexible nails in completely asymptomatic patients is a subject of debate, and patient and family preference is important in the decision. Stainless steel and titanium implants are routinely left in a child’s spine for a lifetime. However, some
surgons are concerned that with growth, the nails will eventually be in the diaphysis and create a stress raiser, although there are no reports of this causing later fracture. Generally, all nails can be removed unless the family wants them left in.

Rigid Intramedullary Nail Fixation

Rigid antegrade intramedullary nail fixation, which offers maximum stability and load sharing, is the treatment of choice for displaced femoral shaft fractures in skeletally mature adolescents. Several studies report attempts to extend the indications for rigid antegrade nails to children with open proximal femoral physes.15 Although results have been good, reports of osteonecrosis of the femoral head are increasing. The standard technique for antegrade intramedullary nail fixation is well-known and effective. An entry site through the tip of the greater trochanter is used in adolescents (Fig. 9) to avoid the piriformis fossa and the potential damage to the blood supply to the femoral head. However, a recent survey of pediatric orthopaedic surgeons documented 14 cases of osteonecrosis, including several in which a “proper lateral technique” was used.2 Until results from the newer pediatric nail designs34 indicate that rigid antegrade nails can be placed without risking osteonecrosis, other options are recommended for skeletally immature patients.

Open Reduction and Plate Fixation

Plating is an effective method of treating pediatric femoral fractures.35 Advantages include a familiar technique with widely available equipment and rigid fixation in anatomic alignment that allows rapid mobilization. However, the large incision, higher blood loss, reports of refracture and implant failure,36 and issues regarding implant removal limit the indication when other methods are available. The narrow indications include children younger than age 12 years with multiple trauma, open fractures, head injury, or compartment syndrome. Some surgeons use plating for very proximal or distal fractures for which no other treatment allows rapid mobilization. Specific technical recommendations include the use of 4.5-mm dynamic-compression plates with fixation to at
least six cortices on each side of the fracture. Newer plating techniques include longer plates with fewer screws, percutaneous plate placement with indirect reduction, and less soft-tissue stripping (Fig. 10). Six to 8 weeks of protected weight bearing after surgery is common. There are few published data comparing the risks and benefits of submuscular plating with other established methods of pediatric femoral fracture management.

Difficult Femoral Fractures

Difficult femoral fractures include those in the child with multiple injuries or head injury, open femoral fractures, subtrochanteric and supracondylar femoral fractures, or floating knee. In young children, the head is prominent and frequently is involved in high-energy injuries. Head injury is the most frequent cause of death resulting from trauma. Although early stabilization of a femoral fracture in a child with a head injury leads to a shorter hospital stay and fewer general complications, it does not decrease the number of orthopaedic and neurologic complications.8 The patient should be adequately resuscitated before surgery, which may delay surgical stabilization of the femur. Open plate fixation performed on a regular operating table can be a safe way to rapidly stabilize the femur of a child with a severe head injury. Intramedullary nails

Figure 10  Anteroposterior (A) and lateral (B) radiographs of a grade III open segmental midshaft femoral fracture in an 11-year-old boy. C, Anteroposterior radiograph taken 3 months after internal fixation with a 4.5-mm limited-contact dynamic-compression plate, demonstrating excellent interval healing. Screws were placed percutaneously, and periosteal stripping was kept to a minimum. D, Anteroposterior radiograph taken 14 months after surgery. The fracture is well healed. There were no complications. (Courtesy of Enes Kanlic, MD, PhD, El Paso, TX.)
can be used but may involve more intraoperative motion to achieve reduction and nail insertion. If an open procedure is not acceptable, an external fixator can be applied quickly with minimal blood loss and later may be converted to another construct.37

Open femoral fractures in children comprise only 3% to 4% of all open fractures.38 Seventy-six percent of children with open femoral fractures have associated injuries.38 Management of grade I or II open injuries is similar to that for other high-energy open fractures and includes irrigation and débridement followed by stabilization. Grade III open injuries are the most difficult to manage, with a 50% risk of osteomyelitis and a 20% risk of malunion.38 The best form of surgical stabilization for the grade III injury has not been established. Regardless of the treatment method used, open femoral fractures have a longer time to union, particularly in the older child and in those with more severe soft-tissue injury. Lawn mower injuries, an infrequent cause of open femoral fracture, are severe, high-energy injuries with extensive soil contamination. Treatment involves surgical extension of the initial zone of injury for meticulous débridement and several return visits to the operating room before wound closure is attempted. Amputation is sometimes necessary. Delayed closure is either direct with skin graft or, rarely, with a microvascular tissue transfer. Vacuum-assisted closure can provide early simple wound coverage and may avoid the need for a microvascular procedure.39

Fractures at either end of the femoral shaft can present difficulty with alignment, stability, and function. Subtrochanteric femoral fractures often are caused by high-energy trauma, such as a motor vehicle injury or a fall from a height. In the younger child, traction in 90° of hip and knee flexion until the appearance of fracture callus, followed by spica casting, is effective. Although early spica casting in younger children is possible, in one study, 27% of fractures (6/22) required a remanipulation.40 Adolescents, or younger patients with an unacceptable position, require surgical treatment, such as a solid nail through a trochanteric entry point, flexible titanium or Ender nails if the fracture pattern is reasonably stable, open plate fixation, or percutaneous submuscular bridge plate stabilization. (The latter is in the investigational stage.)

Distal supracondylar femoral fractures occur in approximately 12% of nonphyseal femoral fractures and may occur through abnormal bone in children with osteogenesis imperfecta or neuromuscular disease, or through a benign bone lesion.42 An external fixator can maintain anatomic alignment until there is enough callus for a walking cast. When there is enough room for screws between the fracture and the physis, plate fixation is also a viable option.42

A floating knee injury pattern is usually the result of high-energy trauma. Nonsurgical management has been used for the young child. Yue et al.10 compared a group of patients who received skeletal traction with a group undergoing surgical stabilization of at least one fracture. Despite higher injury severity scores, children in the latter group had a shorter hospital stay, decreased time to independent walking, and fewer problems with limb-length discrepancy and angular deformity. Surgical stabilization of at least the femur is recommended for children with a floating knee. Adolescents are best managed with surgical stabilization of both the femur and the tibia.

**Complications**

The most frequent and costly malpractice risk in pediatric orthopaedics involves closed treatment of a femoral fracture.43 Complications of nonsurgical management include malunion and shortening, pin-tract infection or associated tibial growth arrest from the skeletal traction pin, decubitus ulcer, compartment syndrome, skin problems in the cast, nerve injury, re-fracture, and skin burns from a cast saw. The risk of complications, including peroneal nerve palsy, is greater in children treated for several weeks with traction compared with children placed in a cast within 48 hours. However, high-energy femoral fractures placed in a 90°/90° early spica cast can be at risk for a peroneal nerve palsy when excessive traction or wedging is used or when insufficient padding is placed behind the knee.22 Potential risks of surgical management include those of anesthesia, malunion, infection, implant prominence, unacceptable scarring, refracture after implant removal, and femoral head osteonecrosis.

**Leg-Length Discrepancy**

When shortening in a cast is noted within the first 3 weeks of injury, the surgeon should recast the leg in a 90°/90° position after the fracture has been manipulated to an adequate length. An opening wedge of the cast can correct both angulation and some shortening. When >3 cm of shortening is noted within 2 weeks of injury, beginning or returning to skeletal traction can often reestablish and maintain proper length until sufficient callus develops for casting. Shortening after callus formation is more difficult. Families should be counseled on the risks and benefits of immediate or delayed treatment to cope with the final amount of leg-length inequality. When immediate treatment is selected, osteoclasis with application of an external fixator that can maintain both the length and alignment is effective. Shortening noted after complete fracture union is best managed with an optimally timed epiphysiodesis of the contralateral distal femur, which can provide up to 3 to 5 cm of leg length correction. In the rare circumstance of extreme leg-length inequality, the in-
jured side may be lengthened or the uninjured side shortened.

Angular Deformity

Angular deformity remodeling is modulated by differential physeal growth and, to a lesser extent, bone apposition at the fracture site. Remodeling is much greater in young children than in adolescents. Varus and valgus deformities are more likely to cause problems than are flexion/extension deformities, although the latter can be problematic in fractures near the knee. Varus malalignment is most common in proximal femoral fractures managed with casting. The deforming muscle forces can be counteracted by a valgus mold at the fracture site and abduction of the distal shaft fragment on the proximal fragment. Some varus malalignment can be corrected or improved in the first 3 to 4 weeks after injury with cast wedging or recasting. When a varus deformity is noted after final union, a 2-year delay in treatment is recommended to allow maximum correction through remodeling. When the symptomatic varus malunion exists long after the fracture is healed, osteotomy with external or intramedullary fixation may be used.

Distal varus or valgus malunion is poorly tolerated, especially in adolescents with little growth remaining (Fig. 11). When cast treatment is chosen for a supracondylar femoral fracture, optimal alignment should be ensured. Late correction of distal varus or valgus deformity, especially in an older child, may require complex treatment, such as the Ilizarov technique, to correct all planes of the deformity. Staple epiphysiodesis can be used for distal uniplanar deformities when at least 2 years of growth remain.

Rotational Malunion

Up to 25° to 30° of rotational malunion seems to be well-tolerated44 unless it worsens an underlying femoral antetorsion or retrotorsion. The key to avoiding rotational malunion is understanding the muscle forces on the proximal fragment and aligning the distal shaft fragment with the rotated fragment.

Delayed Union and Nonunion

Delayed union and nonunion are rare in pediatric femoral fractures. Typical causes are either infection or stress shielding, often caused by the fracture management itself. External fixation substantially slows the rate of union, even after dynamization. Plating or intramedullary fixation that holds a fracture distracted also can cause delayed union or nonunion. Management of such problems involves both biologic and mechanical solutions. When an infection is present, antibiotics and surgical treatment with bone grafting are needed. The ideal mechanical solution involves a load-sharing implant that will reduce stress shielding. To achieve satisfac-

Figure 11  A, Anteroposterior radiograph demonstrating a short oblique fracture at the distal diaphyseal-metaphyseal junction in a high school–age boy. Because of the fracture location and fear of physeal injury, the surgeon chose skeletal traction followed by casting. Anteroposterior (B) and lateral (C) radiographs in traction demonstrating satisfactory length and sagittal alignment; however, some lateral translation and angulation is evident on the anteroposterior radiograph. D, Full-length anteroposterior radiograph demonstrating that, after casting, the fracture healed with varus angulation. Little remodeling occurred, and the patient had to quit cross-country running because of knee pain. There was also shortening of 1.5 cm on the injured side. The patient was treated with an osteotomy and external fixation to correct both leg-length inequality and angular malunion.
Compartiment Syndrome

Although compartment syndrome of the thigh is very rare, it has been reported after femoral fracture and treatment. The surgeon should be particularly suspicious of high-energy injuries accompanied by massive thigh swelling as well as complaints of continuing pain despite stabilization, traction, or immobilization. When compartment syndrome is suspected, thigh compartment pressure should be measured. Thigh fasciotomy is indicated when the pressure is >30 mm Hg and the clinical scenario suggests compartment syndrome. When a child in traction experiences severe swelling or elevated compartment pressure, traction should be stopped immediately, and the thigh should be closely monitored. In some instances, compartment pressure may decrease, thereby avoiding the need for fasciotomy. Compartment syndrome after a femoral fracture is not confined to the thigh: it also can occur in the ipsilateral leg (especially when there has been any vascular compromise) or in the contralateral leg that was elevated in the well-leg holder during femoral fracture stabilization surgery.

Summary

In evaluating a child with a femoral fracture, decision making for management is based on the risks and benefits of each treatment method and the functional needs of the patient. In addition, the possibility of abuse must be considered. Fractures in young infants can be managed with splints or a Pavlik harness. The older infant and preschool-age child may be best treated with an early spica cast. For the school-age child, especially one with high-energy trauma or associated injuries, surgery is preferred. When making treatment recommendations, the surgeon should consider the presence of associated injuries or multiple trauma, the fracture personality, acceptable age-appropriate reduction, family issues, and cost. Complications include but are not limited to leg-length discrepancy, angular deformity, rotational malunion, delayed union and nonunion, and compartment syndrome.

References


