56 Knee Fractures

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Overview

Distal femur fractures are a traumatic injury that extends from the distal metaphyseal-diaphyseal junction to the femoral condyle articular surface. An understanding of the distal femur anatomy is necessary both to achieve anatomical reduction and restore function.

56.1 Distal Femur Fractures

56.1.1 Introduction

Distal femur fractures are a traumatic injury that extends from the distal metaphyseal-diaphyseal junction to the femoral condyle articular surface. An understanding of the distal femur anatomy is necessary both to achieve anatomical reduction and restore function. Anatomical landmarks can be divided into the three anatomical planes. In the sagittal plane, the anterior femoral cortex aligns with the front half of the femoral condyles. In the coronal plane, anatomical axis of the distal femur forms a valgus angle of 7–10° with the knee joint. In the axial plane, the lateral femur cortex slopes 10°, compared to the medial cortex which slopes 25°.

The majority of the key deforming forces on the distal femur involve the quadriceps muscle and the hamstrings (causing limb shortening and flexion or extension deformity), adductor magnus (causing varus deformity), and gastrocnemius (which may cause rotational deformity of the condyles).

56.1.1.1 Epidemiology and History

Distal femur fractures account for 3% of all femur fractures and 0.4% of all fractures combined. The demographic of patients reveals a bimodal distribution. Young healthy males suffer a high-energy mechanism of injury with significant displacement, whereas elderly females encounter a low-energy mechanism of injury with less fracture displacement.

Classification System

Several classification systems have been described, including a descriptive and AO/OTA (Orthopaedic Trauma Association) classification system (Fig. 56.1). The descriptive classification system identifies either supracondylar fractures or intercondylar fractures. The AO/OTA further describes extra-articular fractures as avulsions

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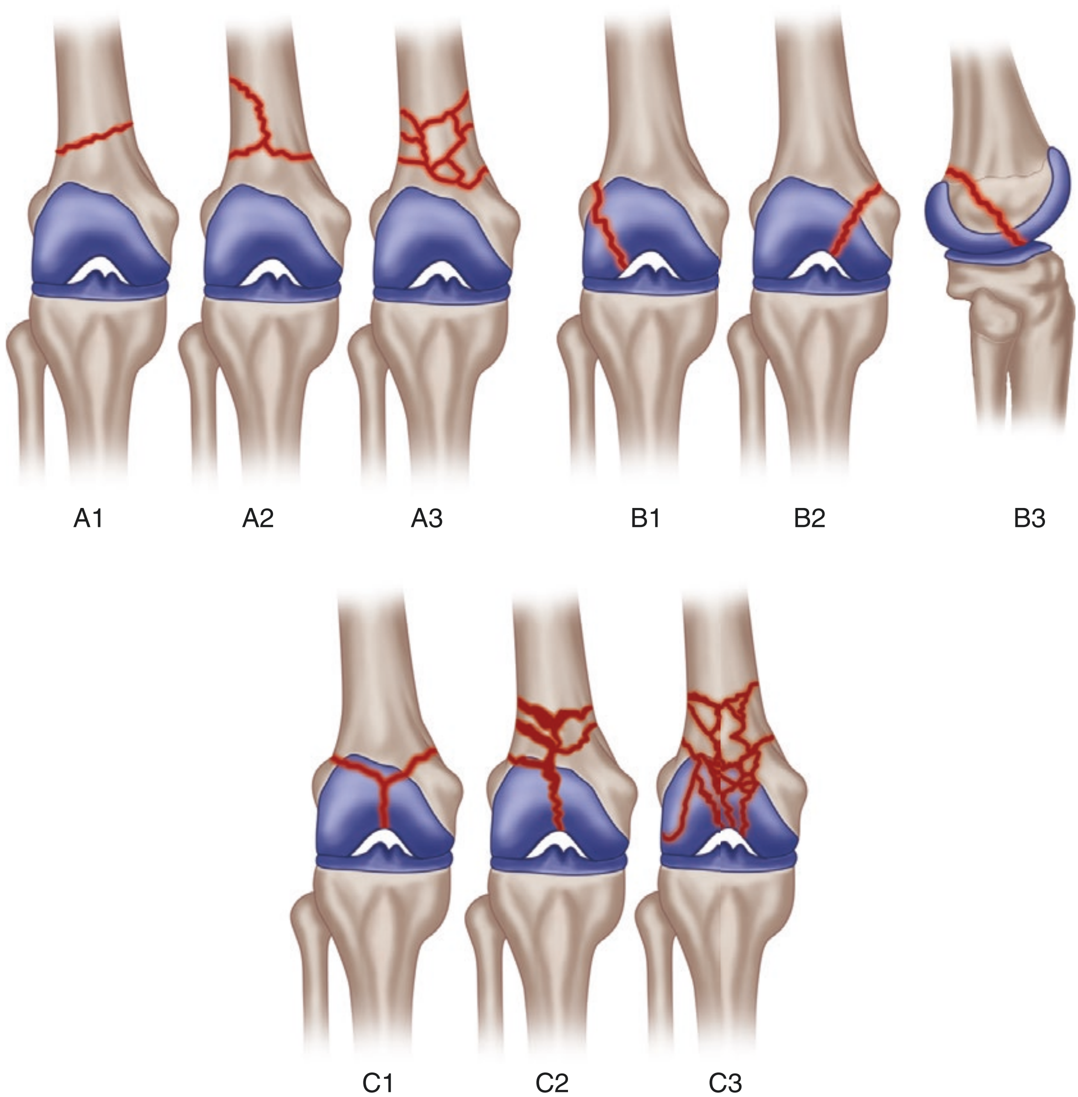

Fig. 56.1 AO/OTA (Orthopaedic Trauma Association) classification system

(A1), simple fractures (A2), or multifragmentary fractures (A3). Partial articular fractures can be divided into the lateral condyle (B1), medial condyle (B2), or involving the coronal plane (B3, also known as a Hoffa fragment). Type C fractures are more complex, involving both condyles and complete articular surface, as a T-shape or extensive comminution. Fractures of any type may be associated with skin, soft tissue, vascular, or nerve injuries.

Assessment

Assessment of distal femur fractures should involve a standardized approach in accordance with ATLS (Advanced Trauma Life Support®) principles, considering the mechanism of injury, patient risk factors, and search for possible other associated injuries. A thorough examination of the affected limb must be performed, including neurological and vascular assessment. This can involve measurement of an ankle brachial index

(ABI), Doppler ultrasound, and/or CT angiogram. There should be a high index of suspicion for vascular injury, given that early detection and treatment directly affect the outcome.

Plain-film radiographs may be taken either in the emergency department with mobile X-ray or in the radiology department if the patient is clinically stable. Adjacent joint X-rays are important to rule out associated injuries. Furthermore, contralateral femur X-rays may be useful in preoperative planning, templating, and identifying leg-length discrepancies.

Whilst X-ray alone can characterize the fracture, computed tomography (CT) is often necessary to fully understand the articular fracture pattern. A Hoffa fragment (type B3) can be missed in plain-film radiographs and can be as prevalent as 38% of distal femur fractures.

Management

Principles of management for distal femur fractures should include minimizing iatrogenic soft-tissue trauma, restoration of limb length, alignment, and rotation, and preservation of the normal knee joint function, by achieving articular congruity of the knee with absolute stability. These principles can be achieved using multiple surgical modalities, each one with advantages and disadvantages that should be used appropriately according to the fracture pattern and severity of the injury.

Briefly, a nonoperative approach is rarely indicated and a hinged knee brace may be used in this setting. This should be strictly limited to non-displaced fractures, nonambulatory patients, and trauma patients that present an unacceptably high surgical or anesthetic risk.

Immediate Stabilization

As part of ATLS principles, having first stabilized the cardiorespiratory status of the patient according to the ABCD method, the fracture should also be stabilized. In the emergency room setting, this can be achieved, with the patient adequately sedated, by closed reduction of the affected limb to relatively normal alignment and an above-knee plaster of Paris backslab applied or skin traction. This will maximize pain management and reduce disruption of the fracture site when being transferred for essential imaging and to the operating room.

External Fixation

External fixation is a key aspect of damage control orthopedics, when the patient's clinical condition does not allow for definitive internal fixation. This achieves the main treatment goals of relative stability, minimizing operative time, minimizing blood loss and surgical exposure, reducing the risk of surgical site infection, and reducing pain.

Various types of external fixation can be used to treat distal femur fractures. The Taylor Spatial Frame (TSF) has been used as a type of external fixation for the treatment of both supra- and intra-condylar femur fractures, showing effective definitive fixation and fracture healing, of 19 out of 19 fractures, with no reported cases of infection.

However, whilst the Ilizarov fixator, a type of external fixation, can be an attractive option for complex C2 and C3 fractures, poor outcomes with higher infection rates have been reported with a limited open approach and external tensioned wire fixation. It is likely that these infection rates are linked to the severity of the initial injury with associated soft-tissue trauma, rather than a criticism of the technique itself. These methods have the advantage of minimizing soft-tissue disruption and are well-known treatment modalities when combined with debridement and irrigation for open fractures.

Other studies strongly support the provisional use of external fixation for extensively compounded distal femur fractures, with early conversion to internal fixation (one study within a mean of 5 days, compared to others which quoted within a mean of 4.7 weeks). Of note, the group with intended definitive external fixation achieved active flexion of 62.3° at 1-year follow-up, compared to 101° for the group with early conversion to internal fixation.

Minimally Invasive Plate Osteosynthesis (MIPO)

The MIPO technique is an attractive option for minimally displaced distal femur fractures in elderly patients suffering a low-energy injury. The hallmarks of this technique include traditional exposure of the fracture site and internal fixation of intra-articular fracture components, and closed reduction of metaphyseal/diaphyseal fracture components and fixation by submuscular plating. Relative fracture-site alignment is achieved with closed reduction of metaphyseal/diaphyseal fractures under image intensifier (II) guidance and can be performed on a traction table. The technique lends itself to minimal periosteal stripping, maintenance of tissue viability, and quicker operative time. Various locking plates have been developed, including the Synthes LISS (Less Invasive Stabilization System) plate or the Zimmer Periarticular plate.

MIPO allows early mobilization and stimulates the healing process from loading at the fracture site generating compression. The risk of hardware failure due to loading in some cases may be reduced using longer plates, which spreads the load over a larger surface area, creating a longer working length. Despite early mobilization, DVT rates were still reported to be as much as 25% in one study, although routine chemoprophylaxis was not utilized in this patient cohort.

Multiple complications can arise from the MIPO technique. Due to the minimally invasive nature of this method, the surgeon's percutaneous approach for metaphyseal/diaphyseal fixation may result in unforeseen neurovascular injury. Multiple studies outline a safe zone to prevent neurovascular injury, on both the medial side and the lateral side. The median distance from screw tip to superficial femoral artery was 21 mm, in particular for the distal sixth to tenth holes. Hardware malpositioning can also be the source of surgical related complications. Follow-up radiographs of distal femur fractures treated with LISS plate identified common errors including valgus-varus mal-reduction, malrotation, sagittal malalignment of the plate, screw penetration into the knee joint, and drilling holes for unicortical screws. The authors also identify that the use of Kirschner wires should be avoided.

Open Reduction Internal Fixation

Open reduction and internal fixation aims to anatomically restore the articular surface of the distal femur. To restore congruency of the knee articulation, the intra-articular fracture site can be exposed, reduced under direct vision, and held with Kirschner wires. This requires adequate exposure within an operative window whilst minimizing soft-tissue trauma, as outlined by Hoppenfeld et al. A direct lateral approach to the distal femur is traditionally utilized with the knee in flexion. The swashbuckler approach has been described as a modified anterior approach, by making an incision on the lateral edge of the tibial tubercle to the superolateral corner of the patella with the ability to perform a lateral parapatellar arthrotomy. Studies show the swashbuckler approach to be comparable to the standard lateral approach for patients managed with locking compression plate (LCP) for distal femur fractures.

It should be noted that achieving a congruent knee joint may not be possible with severe C3-type distal femur fractures due to bone loss, gross instability, or lack of suitable proximal bone. Studies indicate that a double-plating technique with an extended medial parapatellar anterior approach can achieve good outcomes for severe C3-type fractures. This can be appropriate for multiple reasons, giving the surgeon excellent exposure through one incision for anatomical reduction and stable fixation, with 68.75% achieving well-to-excellent functional outcomes. Lab models have also demonstrated that double plating is a stronger construct compared to single LISS plate, with less bend angles and reduced fracture gap.

Due to the more invasive nature of open reduction and internal fixation techniques for distal femur fractures, operative time can be longer compared to external fixation and MIPO. This is important to consider, as the technique may lead to complications such as surgical site infection (4% in one multicenter study, 3.6% in another observational case-control study).

Femoral Nail

The femoral nail can be performed via either an anterograde or a retrograde technique. There are a relatively small range of indications, including extra-articular fractures or simple intra-articular fractures. This technique has the benefit of being a closed technique and having a shorter operative time. An interfragmentary screw should first be utilized for simple intra-articular fractures to avoid fracture propagation during nail insertion.

The anterograde nail technique should be spared for metaphyseal/diaphyseal fractures, given that adequate distal fixation is paramount to the integrity of this relative stability construct. To highlight this further, the best fixation has been found to be an oblique proximal screw with two distal screws in the coronal plane. A proof-of-concept three-dimensional finite element model study identified anterograde nail to be the more stable construct for supracondylar distal femur fractures.

Conversely, the retrograde nail technique requires a parapatellar approach to sublux or evert the patella to allow retrograde femur reaming. Multiple complications can arise, including septic arthritis, knee stiffness, impingement, and hardware malpositioning or mal-fixation. Whilst studies show slightly less knee functional range postoperatively for retrograde nail compared to LISS plate, the infection rate, malalignment complications, and pain profiles postoperatively were comparable.

Distal Femur Replacement

Distal femur replacement is a final treatment option for comminuted intra-articular distal femur fractures in low-demand patients. It has the theoretical advantage of achieving early mobilization, which has been demonstrated at 1-year follow-up compared to ORIF.

56.2 Patellar Fractures

56.2.1 Introduction

The patella is the largest sesamoid bone in the body with the quadriceps tendon and fascia lata attaching to its anterosuperior margin and the patella tendon attaching to its anteroinferior margin. The patella functions as a pulley helping to shift the contractile force of the quadriceps muscle anteriorly.

The posterior articular surface of the patella is divided into medial and lateral facets. A thick layer of articular cartilage covers the superior three-quarters of the posterior surface whilst the inferior quarter is non-articulating. An anastomotic ring supplied by the geniculate arteries provides the vascular supply to the patella in a centripetal fashion.

56.2.1.1 Epidemiology and History

Patellar fractures make up 1% of all fractures, occurring most commonly in the 20–50-year age group. The incidence of patellar fractures in males is twice as high as the incidence in females.

Patellar fractures are caused by two main mechanisms of injury from direct and indirect forces. Direct trauma to the anterior knee commonly occurs from a fall onto the knee or a dashboard injury during a motor vehicle accident. This causes a failure of the patella bone in compression commonly resulting in a comminuted fracture pattern, usually with minimal displacement, and damage to the articular cartilage.

Indirect trauma to the patella occurs when an eccentric load is applied on the extensor mechanism of the knee. This most characteristically occurs when the knee is rapidly flexed against a maximally contracted quadriceps muscle. The patella fails under tension commonly resulting in a displaced transverse/avulsion-type fracture, usually with less damage to the articular cartilage compared to patellar fractures from direct trauma.

In the pediatric population (age 8–12), indirect trauma may result in a patella sleeve fracture, a rare injury where the cartilage "sleeve" of the patella separates from the ossified patella. A high index of suspicion is required in this patient cohort, and further imaging such as magnetic resonance imaging (MRI) scans or ultrasound may be indicated when clinical and radiographic findings are equivocal.

56.2.2 Classification System

Patella fractures present with a high degree of diversity and variability in fracture type and fracture pattern. Several classification systems have been described in the literature for patellar fractures. A holistic classification system linking the distinct fracture types with specific management options is currently still lacking.

Patellar fractures are classified descriptively based on the fracture morphology. Fractures with multiple fragments are considered comminuted. Fractures are classified as displaced when there is a separation of fragments greater than 3 mm or an articular step-off greater than 2 mm.

Fractures running in a medial-lateral direction are described as transverse, whereas fractures in a superior-inferior direction are described as vertical. Stellate fractures describe comminuted fractures in which the fracture lines radiate from a single point. Fractures involving the articular cartilage and underlying subchondral bone can be described as osteochondral.

Patellar fractures can also be classified according to the AO/OTA classification system based on the degree of articular involvement and comminution of the fracture. Type A fractures describe extra-articular fractures, type B fractures describe partial-articular vertical fractures, and type C describe complete articular, transverse fractures of the patella.

56.2.3 Assessment

Once again, assessment should involve a standardized approach in accordance with the ATLS principles to rule out any more immediate life-threatening injuries and confirm an isolated injury.

A thorough history and examination of the patient must be obtained, considering the mechanism of injury, patient risk factors, and detection of any other associated injuries. Suspicion for a patellar fracture should be raised when either direct trauma or an eccentric load involves the knee. High-energy mechanisms, such as dashboard, should raise concern for other associated injuries including femoral fractures, acetabular fractures, knee dislocations, ligamentous injuries, and neurovascular injuries.

Examination of a knee with patellar fracture may reveal a hematoma, hemarthrosis, and pain on palpation or palpable defect in the patella. Examination should involve a thorough inspection of the integrity of surrounding soft tissue and identify any open injury that may complicate surgical management. Straight leg raise examination should be performed to evaluate the integrity of the extensor mechanism.

Plain radiographs of the knee including standard anterior-posterior, lateral, and skyline views are usually sufficient. More sophisticated imaging modalities, such as CT or MRI scans, are rarely required but can be useful in the assessment of comminuted fractures and any associated ligamentous, meniscal, or osteochondral injuries.

Importantly, bipartite patella is present in 2–3% of the population. It occurs when a second ossification center for the patella fails to unite with the primary nucleus. They occur most commonly at the superolateral edge and are bilateral in 50% of patients. Bipartite patella should not be confused with an acute patella fracture.

56.2.4 Management

56.2.4.1 Nonoperative Management

Nonoperative management is indicated in nondisplaced and minimally displaced patellar fractures with an intact extensor mechanism and articular congruency. Around 30% of the force of extending the knee joint is transmitted through the medial and lateral retinaculum and ligamentous sheath overlying the patella. In subaponeurotic patellar fractures where the retinaculum is intact, these structures can provide fracture stability. Nonsurgical management may be considered in patients with displaced patellar fractures that have significant comorbidities or are poor surgical candidates.

Nonoperative management for patellar fractures involves early weight-bearing usually in a range-of-motion brace locked in extension or near extension. Active or active-assisted range of motion is started at 7–14 days and gradually increased to full range of motion over 4–6 weeks. Exercises against resistance typically begin at the 6-week mark. Delayed weight-bearing is rarely indicated except in patients unable to follow instructions or who have a high-fall risk (i.e., geriatric population). Early mobilization and range of motion are encouraged to prevent joint stiffness. A repeat radiograph of the patella 1 week after beginning range of motion can be used to evaluate the stability of the fracture. A further radiograph of the patella at 6 weeks can be used to confirm bone healing.

Nonoperative management of non-displaced patellar fractures with an intact extensor mechanism has shown good outcomes in terms of pain and function in 90–99% of patients. For displaced patellar fractures, outcomes of nonoperative management are poorer. Two-year follow-up of patients with nonoperatively managed displaced patellar fractures showed an extensor lag of >20% for all patients (n = 12), with 25% of patients considering their outcome to be poor.

56.2.4.2 Operative Management

Operative management is indicated in patellar fractures with associated extensor mechanism incompetence. Displacement of fracture segments, incongruence of the articular surface, intra-articular loose bodies, or osteochondral fractures are other relative indications for operative management. The principles of operative management for patellar fractures include a restoration of the extensor mechanism, articular congruency, and preservation of patellar bone. Ideally, operative methods should aim to achieve a stable fixation to allow for early mobility and rehabilitation.

56.2.4.3 Open Reduction and Internal Fixation

The preferred operative treatment for displaced patellar fractures is open reduction and internal fixation to provide stability, restoration of normal patellar anatomy, and function to the extensor mechanism. Numerous operative techniques using a variety of different materials have been described in the literature.

The patella fracture is approached commonly through a vertical midline incision. Soft tissue is dissected to achieve good exposure of the fracture. Small medial or lateral parapatellar arthrotomies can be performed for palpation or direct visualization of the posterior articular surface. Anatomic reduction is achieved, and provisional stabilization can be provided with the aid of Kirschner wires or bone reduction forceps. Definitive fixation can be achieved through the use of a combination of different materials including screws, plates, and wires, most commonly in a tension band construct.

56.2.4.4 Tension Band Wiring

Tension band wiring is most ideally suitable for transverse patellar fractures with minimal comminution. Comminuted portions of the fracture may first need to be secured with lag screw fixation to convert the fracture into a simple transverse pattern for more optimal results. The modified anterior tension band (MATB) construct is currently the most widely accepted technique. This technique involves two longitudinal Kirschner wires through the fracture reinforced by an 18-gauge wire in a figure-of-eight pattern over the anterior surface of the patella. The tension band construct converts the anterior force generated on the patella, by the extensor mechanisms and knee flexion, into a compressive force on the patella. Biomechanical studies have shown that screws offer more biomechanical stability than Kirschner wires when used in tension band constructs. In this technique, a tension band wire is passed through longitudinal cannulated screws in a tension band construct. Additional interfragmentary screws, small plates, and circumferential cerclage wiring can be useful in supporting fixation in comminuted fractures (Fig. 56.2).

Nonabsorbable sutures have been used as an alternative material to steel wire for use in the tension band construct. Outcomes of biomechanical and a limited number of small clinical studies have shown braided polyester sutures to be comparable to steel wire when used for tension band wiring.

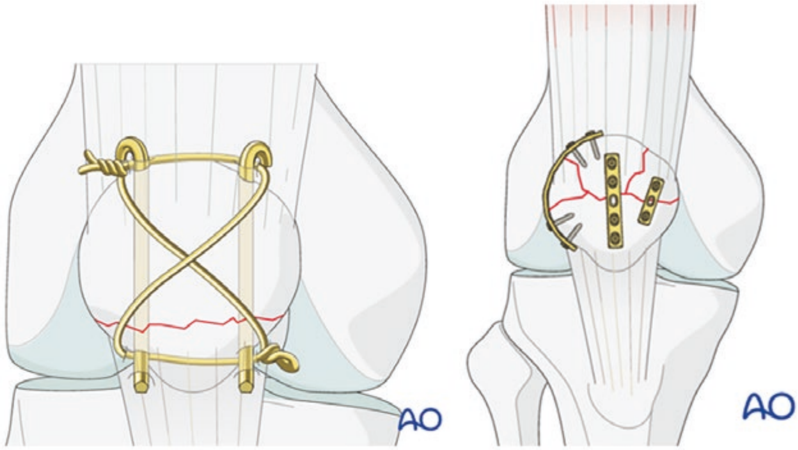

Fig. 56.2 Tension band wire construct for transverse patellar fracture, and fragment specific fixation with small plates for comminuted patellar fracture

56.2.4.5 Arthroscopic Assisted Percutaneous Fixation

More recently, less invasive procedures have been designed utilizing percutaneous fixation assisted by knee arthroscopy. Knee arthroscopy allows for the assessment of cartilage, ligaments, and fracture reduction from within the joint itself. Arthroscopic assisted percutaneous fixation techniques have shown promising results in simple, mildly displaced transverse fractures. Percutaneous fixation is also useful in the presence of soft-tissue injury in association with a patellar fracture.

56.2.4.6 Patellectomy

Patellectomy or partial patellectomy is reserved for rare cases of patellar fractures that are unable to be fixed with open reduction and internal fixation. The indications for partial or complete patellectomies have significantly diminished with improvements in surgical techniques and understanding of patella biomechanics and anatomy.

Partial patellectomy may be indicated in cases with significant cartilage loss and severe comminution. Even in these cases, all effort is made to preserve as much patella bone as possible. Preservation of even a portion of the patella can help to retain some patellar moment arm and improve strength of the knee. Severely comminuted fractures of the inferior pole or lateral margins of the patellar may be most amenable to partial patellectomy. After the excision of fragments, some fractures involving the inferior pole of the patella can be managed as patella avulsions and reattached to the patella body.

Complete patellectomy is rarely indicated except in rare cases of failed internal fixation, infection, tumor, or patellofemoral arthritis. Complete patellectomy is largely avoided due to poor outcomes and loss of quadriceps strength.

Take-Home Message

- The AO/OTA classification systems utilized are useful in succinctly communicating the degree of injury and the level of intervention thus required.
- Fracture of the knee can range from very minor injuries with minimal treatment required to potentially limb-threatening injuries requiring immediate and invasive intervention.
- Goals of treatment should involve restoration of knee function and stability, by either nonoperative or operative means, and pain control, to return patients to their premorbid level of function.

Summary

Orthopedic surgeons are constantly re-evaluating the approaches, techniques, and prostheses available for the treatment of distal femur fractures and patella fractures. Large randomized controlled trials are important to objectively determine the effectiveness of these techniques, yet the financial and ethical feasibility of these studies is a significant barrier. The growing availability of distal femur replacements and improvements in replication of the anatomical knee function will create exciting opportunities for current and future knee arthroplasty surgeons. All techniques will need to be further studied and utilized appropriately, given that the aging population as well as the high-energy motor vehicle patient cohorts will continue to present knee fracture challenges to the orthopedic community.

Questions

Multiple correct answers are possible. Answers available in the book back matter.

1. Distal femur fractures account for:
   (a) 3% of all femur fractures
   (b) 50% of all femur fractures
   (c) 0–1% of all femur fractures
   (d) 30% of all femur fractures
2. The AO/OTA type B1 is:
   (a) Partial articular fracture of the lateral condyle
   (b) Partial articular fracture of the medial condyle
   (c) Simple extra-articular fracture
   (d) Multifragmentary extra-articular fracture
3. Management of distal femur fractures includes:
   (a) Minimizing iatrogenic soft-tissue trauma, achieving articular congruity of the knee, absolute stability, restoration of limb length, and preservation of the normal knee joint function
   (b) Urgent reduction with external fixation
   (c) Urgent reduction with ORIF
   (d) Restoration of limb length and preservation of the normal knee joint function through percutaneous pinning, to avoid infections
4. Bipartite patella:
   (a) Is present in 2–3% of population and does not require treatment
   (b) Is present in 2–3% of population and requires treatment
   (c) Is present in 10% of population and is a risk factor for fractures
   (d) Requires urgent fixation with K-wires
5. Patellectomy:
   (a) Is reserved for rare cases of patellar fractures that are unable to be fixed with open reduction and internal fixation
   (b) Is required in case of transverse fractures
   (c) Is required in case of oblique fractures
   (d) Is never performed

Further Reading

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