PATELLA FRACTURES AND EXTENSOR MECHANISM INJURIES

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INTRODUCTION TO PATELLAR FRACTURES

The treatment of patella fractures has evolved with improvements in both fracture fixation techniques and an improved understanding of patellar function. Until the 19th century, the vast majority of patella fractures were treated nonoperatively with extension splinting. The critical structural and biomechanical functions of the patella were not understood, such that excision of a “vestigial embryologic remnant” was felt to be a reasonable option. Brooke published results showing increased limb strength after patellectomy compared to normal controls, and advocated patellectomy as a viable surgical option. Hey-Groves and Watson-Jones believed that the patella inhibited quadriceps function, and concluded that the strength of the knee was improved after patellectomy. Blodgett and Fairchild, Thompson, and Seligo published additional clinical series describing excellent clinical results with partial or complete patellar excision for fracture.

The appeal of nonoperative treatment or total excision was tempered, however, by modest functional outcomes. Extension splinting was associated with high rates of residual pain, non-union, and permanent disability. Furthermore, laboratory and clinical studies raised concern regarding outcomes after patellectomy. Cohn and Kelly demonstrated degenerative changes on the femoral articular surface after patellectomy in a rabbit model. A high rate of patient dissatisfaction, decreased quadriceps strength, residual pain, and functional disability were also reported after total patellectomy.

In the 1940s, laboratory studies by Haxton and others demonstrated the critical biomechanical function of the patella and highlighted the importance of its preservation to optimize function of the extensor mechanism. With advances in aseptic surgery and techniques in fracture fixation, significant interest developed in identifying alternative means of treatment for these injuries. Malgaigne designed the “griffe metalldique” in 1843, a metal claw connected to sliding plates designed to reapproximate fragments in displaced patellar fracture patterns. Sir Hector Cameron of Glasgow, Scotland performed the first open reduction and internal fixation of a patellar fracture in 1877 with interfragmentary wiring. Lister and Trendelenburg performed similar procedures in Germany using drill holes and wire fixation. Numerous techniques of fracture reduction and fixation emerged, but stable fixation was difficult to achieve. Materials used for fixation included percutaneous pins, metal loops, kangaroo tendon xenografts, fascial strips, and screws. The greatest advance in patellar fracture fixation, however, occurred in the 1950s with presentation of the anterior tension band technique by Muller et al. The Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation (AO/ASIF) subsequently modified and advocated tension band fixation as a rigid construct that allowed for early range of motion and rehabilitation of patella fractures. Weber et al. demonstrated superior biomechanical strength with modified anterior tension banding and retinacular repair in a transverse patellar fracture model compared to cerclage or interfragmentary wiring techniques. Numerous clinical series have subsequently confirmed a high rate of success with tension band wiring techniques. Currently three forms of operative treatment for displaced patella fractures are most commonly utilized.

- Open reduction and internal fixation, usually with a tension band wiring technique or cannulated screw tension band technique
- Partial patellectomy
- Total patellectomy

The indications for each technique are individualized and depend on the fracture pattern, patient activity level, and functional expectations. Each procedure can achieve good to excellent results with proper patient selection and application. Regardless of the selected technique, the goals of surgical treatment include the following.

- Restoration of the functional integrity and strength of the extensor mechanism
- Maximizing articular congruity
- Preservation of patellar bone

ASSESSMENT OF PATELLAR FRACTURES

Patellar Fracture Injury Mechanisms

Fractures of the patella account for approximately 1% of all skeletal fractures and may result from direct, indirect, or combined injury patterns. The patella is prone to injury from a direct blow as a consequence of its anterior location and thin overlying soft tissue envelope. Direct injuries may be low energy, such as after a fall from a sitting or standing height, or high energy, as from a dashboard impact in a motor vehicle collision. Commnuted fracture patterns are often the result of high-energy, direct injuries. In these cases, it is critical to survey for associated injuries of the ipsilateral limb, including hip dislocation, proximal femur fractures, or fractures about the knee.

Indirect injuries occur secondary to the large forces generated through the extensor mechanism, and typically result from forceful contraction of the quadriceps with the knee in a flexed position. The substantial force generated by a violent quadriceps contraction fractures the patella and may propagate through the adjacent retinaculum of the extensor mechanism. As a result, indirect injuries frequently cause a greater degree of retinacular disruption compared with direct injuries and active knee extension is compromised in most cases. The degree of fragment displacement is generally representative of occult injury to the adjacent soft tissue envelope. While transverse fracture patterns are associated with an indirect injury mechanism, it is clear that fracture pattern is not solely determined by injury mechanism, and is also dependent on various other factors such as patient age, bone quality, and the degree of knee flexion. In reality, patellar fractures likely reflect a combination of both direct and indirect forces. The culmination of a direct blow, quadriceps muscle contraction, and secondary joint collapse.

The majority of patellar fractures have a transverse fracture pattern resulting from excessive tensile forces through the extensor mechanism. These may occur through the body, apex,
or distal pole of the patella. Small proximal or distal avulsion-type fractures should not be ignored, as they are often associated with substantial soft tissue injury to the quadriceps or patellar tendon. Vertical fractures are typically the result of a direct blow to a partially flexed knee, and may be nondisplaced if the retinaculum and extensor mechanism are intact. Comminuted, stellate fracture patterns are typically the result of a direct blow with impaction against the femoral condyles, and can be associated with substantial injury to both the femoral and patellar chondral surfaces.

**Injuries Associated with Patellar Fractures**

Concomitant injuries occur commonly in association with patella fractures and, as expected, occur more frequently in higher-energy injuries. Without stratifying according to injury mechanism, two large series of patella fractures reported by Bostrom[32] and Noble and Hakek[33] demonstrated associated injury rates of 15% and 28.1%, respectively. Associated injury occurred even more frequently with open patellar fractures with rates approaching 80%. Most often, associated injuries occur in the ipsilateral lower extremity. A recent investigation at the author's institution of 300 consecutive patellar fractures found ipsilateral distal femur or proximal tibia fracture to accompany 26% of patella fractures. Catalano et al. reported a 44% rate of ipsilateral lower-extremity fracture in a series of open patellar fractures. This contrasts ipsilateral with lower-extremity fracture rates of around 5% by Bostrom[32] and Gunal et al.,[34] and highlights the increasing rate of high-energy patella fractures encountered today. Less literature exists regarding extensor mechanism rupture and associated injuries. While these injuries are more frequently the result of low-energy trauma compared to patellar fractures, a similar association between increasing energy of injury mechanism and increasing rate of ipsilateral knee injury has been described.[33] Thus, knowledge of a high-energy mechanism should alert the surgeon to the increased probability of associated injuries, especially of the ipsilateral lower extremity.

**Signs and Symptoms of Patellar Fractures**

Patient history typically includes a direct blow to the patella, a fall from a standing height, or a near fall with forceful contraction of the quadriceps on a partially flexed knee. Correlation of the fracture with the mechanism of injury will help the surgeon to anticipate both the fracture pattern and the degree of soft tissue injury. Complaints of anterior knee pain, swelling, and difficulty ambulating after a fall are also common and may reflect an injury to the extensor mechanism. With high-energy injuries, the surgeon must have a low threshold of suspicion for associated musculoskeletal injuries.

On physical examination, displaced patella fractures typically present with an acute hemarthrosis and a tender, palpable defect between the fracture fragments. The absence of a large effusion in the presence of a palpable bony defect should raise concern for associated retinacular tears. Competence of the extensor mechanism must be assessed by asking the patient to perform a straight-leg raise or extend a partially flexed knee against gravity. A large hemarthrosis may be very painful, and limit the ability of the patient to comply with this part of the examination. In these situations, aspiration of the hemarthrosis followed by injection of a local anesthetic into the joint may be helpful. It is critical to note, however, that the patient's ability to extend the knee does not rule out a patella fracture, but rather it suggests that the continuity of the extensor mechanism is maintained via an intact retinacular sleeve.

Lacerations or abrasions to the skin overlying the patella are of particular concern, and may reflect an occult open fracture or communication with the knee joint. Any concern warrants further investigation with a saline load test.[36] A large bore, 18-gauge needle and syringe are used to perform a joint aspiration, followed by infusion of 150 mL of saline into the knee joint. Communication between the knee joint and the wound is marked by egress of the infused saline from the wound. Methylene blue may be added to the saline infusion to facilitate detection. Open fractures or traumatic arthrotones warrant urgent irrigation and debridement in the operating room.

After a careful examination is completed, the knee should be splinted, iced, and elevated. The knee is typically immobilized in a slightly flexed position for comfort until definitive treatment is rendered.

**Patellar Fracture Imaging and Other Diagnostic Studies**

**Plain Radiographs**

Plain radiography is typically sufficient to confirm the diagnosis of patellar fracture or injury to the extensor mechanism. Anteroposterior (AP), lateral, and tangential or axial views of the patellofemoral joint should be obtained (Fig. 54-1). Views of the contralateral knee are helpful for comparison and may prevent the erroneous diagnosis of a normal anatomical variant as a fracture.

In the setting of a patellar fracture, the AP view should be taken with the largest cassette possible (typically 14 x 17 in) placed behind the knee of the supine patient. If full knee extension is not possible secondary to pain, the x-ray beam trajectory must be adjusted accordingly. Leg rotation must be controlled, so that the patella is pointing straight up and will be centered on the film. The patella should lie within the midline of the femoral sulcus, and the distal pole should be no higher than 20 mm above a tangential line connecting the distal femoral condyles. Vertical and horizontal fracture lines should be carefully noted. Typically, the degree of fracture comminution is underestimated by the radiographically evident fracture lines. The distal femur and proximal tibia should not be ignored and must be carefully inspected for occult condylar or plateau fractures.

A bipartite or tripartite patella can often be mistaken for a fracture in the setting of a trauma history (Fig. 54-2). These anatomical variants reflect incomplete fusion of two or more ossification centers. The opposing edges are usually smooth and corticated on plain radiographs. The finding is typically bilateral, and contralateral knee radiographs often confirm the diagnosis. The most common bipartite pattern is located in the superolateral aspect of the patella, and is not associated with...
any pain, tenderness, or functional compromise of the extensor mechanism on physical examination. A true unilateral bipartite patella is extremely rare, and may represent an old avulsion-type patellar fracture.

The lateral radiographic view is critical to define fracture pattern and associated extensor mechanism disruption. Controlling limb rotation, however, is essential to obtain a true lateral view that allows for reliable determination of patellar height and identification of occult injuries. The distal patellar pole and tibial tubercle should be carefully inspected for subtle avulsion fractures. Patellar height should be assessed using the Insall–Salvati ratio, which compares the height of the patella to the length of the patellar tendon. In a normal subject, a ratio of 1.02 ± 0.13 is expected. A ratio of less than 1 suggests patella alta and disruption of the patellar tendon. A ratio of greater than 1 is associated with patella baja and quadriceps tendon

![Image](image_url1)

**FIGURE 54-1** Anteroposterior (A), lateral (B), and axial (C) views of a displaced transverse patella fracture.

![Image](image_url2)

**FIGURE 54-2** Anteroposterior (A) and lateral (B) radiographs of a bipartite patella. Note the superolateral fragment with well-defined cortical margins.
disruption. Other, less sensitive indices of patellar height can also be assessed on the lateral view. With the knee flexed 90 degrees, the proximal patellar pole normally rests at or below the level of the anterior cortex of the femur (Fig. 54-3). With the knee flexed 30 degrees, the inferior patellar pole normally projects to the level of Blumensaat line (the distal physeal scar remnant). Loss of this relationship is suggestive of extensor mechanism disruption. A tangential or axial view of the patellofemoral joint is also useful. With patellar fractures, vertical or marginal fracture lines and associated osteochondral defects may only be visualized on this view. Merchant et al. described their technique for obtaining an axial view of the patella. With the patient supine and the knees flexed 45 degrees over the edge of the table, the x-ray beam is angled 30 degrees below horizontal with the cassette placed approximately 6 to 12 in below the knees and perpendicular to the beam. This technique is easily performed in patients with knee trauma, as supporting the knee in a partially flexed position often confers maximal comfort in the setting of an acute hemarthrosis.

**Computed Tomography**

Computed tomography (CT) scanning is rarely necessary in the evaluation and treatment of isolated patellar fractures. Frequently, however, the patella may be incidentally imaged during the evaluation of an ipsilateral distal femoral or proximal tibial fracture. While CT allows for improved evaluation of articular congruity and fracture comminution, it rarely provides additional information that will alter the treatment plan that has been determined on the basis of physical examination and plain radiographs. CT scanning plays a more important role in the evaluation of patellar stress fracture, nonunion, or malunion. Apple et al. demonstrated a 71% sensitivity of tomography in detecting stress fractures in elderly, osteopenic patients, compared to 30% with bone scans and 0% with plain radiographs alone. CT is also useful to characterize trochlear anatomy and lower-extremity rotational alignment with patellofemoral tracking disorders.

**Magnetic Resonance Imaging**

Magnetic resonance imaging (MRI) has been used increasingly to evaluate suspected extensor mechanism injuries as well as...
chondral injuries associated with patellar dislocations. In addition, MRI may have a role in the evaluation of acute patellar fractures considered for nonoperative treatment in which suspicion exists for an osteochondral fracture. However, MRI for acute patellar fractures is not routinely utilized.

The normal quadriceps and patellar tendons have a laminated appearance with homogeneous, low signal intensity on MRI. Trauma to the patella or adjacent soft tissues results in hemorrhage and edema, and is associated with increased signal intensity on T2-weighted images. Furthermore, loss of continuity of patellar or quadriceps tendon fibers can be readily seen to define both partial and complete disruptions. Lateral patellar dislocations are associated with a characteristic edema pattern on MRI that allows for confirmation of the diagnosis even after spontaneous reduction following the injury. In addition to a traumatic effusion, contusion of the lateral femoral condyle and medial patellar facet with increased signal on T2-weighted images, disruption of the medial patellofemoral ligament, retinacular tears, and osteochondral loose bodies are frequently seen. In the absence of patella fracture on radiographs, blunt direct trauma to the patella such as with a dashboard mechanism has been found to be associated with subchondral microfracture on MRI in approximately 40% of cases. The long-term significance of these subchondral microfractures remains uncertain.

More sophisticated imaging techniques to evaluate the articular cartilage such as T2 mapping, T1rho or delayed gadolinium-enhanced imaging of articular cartilage (dGEMRIC) allow for the identification of chondral injuries that may not be visualized on plain radiographs, however, these sequences have most often been employed in the management of osteoarthrosis and sports injuries rather than acute traumatic patellar injury.

Patellar Fracture Classification

Patellar fracture classification is typically descriptive in nature, and can be based on fracture pattern, degree of displacement, or mechanism of injury. A formal classification has been proposed by the Orthopaedic Trauma Association (OTA) and is based on the degree of articular involvement and the number of fracture fragments. However, this classification has not been validated and the clinical utility of this system remains uncertain. Despite these deficiencies, the current OTA classification is important for standardizing the classification of patellar fractures for clinical research. Prior to the OTA classification, patellar fracture classification lacked standardization and thus most clinical series have reported outcomes based on the type of fixation rather than fracture pattern.

A useful approach in the clinical setting begins with classifying patellar fractures as displaced or nondisplaced. Displaced patellar fractures are defined by separation of fracture fragments by more than 3 mm or articular incongruity of more than 2 mm. After the fracture is classified as displaced or nondisplaced, the injury can be further categorized on the basis of the geometric configuration of fracture lines. Described patterns include transverse or horizontal, stellate or comminuted, vertical or longitudinal, apical or marginal, and osteochondral (Fig. 54-4). In addition, a special category of patellar sleeve fractures can occur in skeletally immature patients in which a distal pole fragment with a large component of the articular surface avulses from the remaining patella.

Nondisplaced Fractures

Transverse. As many as 35% of transverse patellar fractures are nondisplaced. While the mechanism may be multifactorial in nature, these injuries are typically associated with indirect, longitudinal forces that fracture the patella but are insufficient to tear the medial and lateral patellar retinacula. As a result, the extensor mechanism remains competent. The preserved integrity of the soft tissue envelope helps to maintain the reduction. Approximately 80% of these fractures occur in the middle to lower third of the patella.

Stellate. Stellate fractures typically result from direct blow injuries to the patella with the knee in a partially flexed position. Approximately 65% of these injuries are nondisplaced. Active knee extension is preserved, as the medial and lateral patellar retinacula are usually not torn with the injury. Damage to the patellar and femoral articular surface is not uncommon given the mechanism of injury, and careful evaluation on tangential views or MRI is necessary to identify occult osteochondral lesions.

Vertical. A vertical or longitudinal fracture pattern is not uncommon and has been reported to account for 12% to 22% of patellar fractures in several large series. The fracture line is most commonly seen involving the lateral facet and lying between the middle and lateral third of the patella. Different mechanisms of injury have been implicated. Bostrom reported that lateral avulsion was the most common mechanism in 75% of their series. Dowd, however, reported that direct compression of the patella in a hyperflexed knee is responsible for this pattern of injury. The patellar retinacula are intact, preserving active knee extension by the patient. The fracture pattern is easily missed on an AP radiograph, emphasizing the importance of an axial view to identify this injury.

Displaced Fractures

Transverse. Noncomminuted, transverse fractures account for approximately 52% of displaced patellar fractures.
Evaluation of the integrity of the extensor mechanism is critical with this pattern of injury. The fracture fragment separation (>3 mm) is suggestive but not diagnostic of retinacular and extensor mechanism disruption. A subset of these fractures with fragment displacement but intact retinacula exists, and is characterized by preservation of full active knee extension. These fractures may respond more favorably to nonoperative treatment. Boström3 has reported that preservation of the retinacula allows satisfactory healing without surgery. McMaster,36 however, has warned of a high risk of nonunion with nonoperative treatment in these patients.

Stellate. Displaced, stellate fractures usually result from a high energy, direct blow to the patella. These fractures typically demonstrate a high degree of comminution. Anterior soft tissue contusion and/or lacerations are not uncommon, and careful evaluation for an open fracture or traumatic arthropathy is warranted. Transverse fracture lines with extensive comminution may result in propagation into the retinaculum and disruption of the extensor mechanism. However, even if the extensor mechanism is preserved, the significant articular incongruity may warrant operative intervention.

Pole Fractures. Fractures at the proximal pole of the patella are typically bony avulsions of the quadriceps mechanism. Displacement is rare and has been reported to be approximately 4% in large clinical series.6,31 Active knee extension may be preserved if the medial and lateral retinacula remain intact. The lateral radiograph may demonstrate patella baja and a reduced Insall–Salvati ratio. Distal pole fractures are bony avulsions of the patellar tendon. Displacement is much more common with these injuries and has been reported to occur in up to 11.5% in large series.5,31 Retinacular disruption with loss of knee extension is virtually universal with distal pole fractures. A lateral radiograph will demonstrate patella alta and an increased Insall–Salvati ratio.31

Osteochondral Fractures. Osteochondral fractures of the femur or patella are also seen in association with high-energy, stellate patellar fractures or after patellar dislocation. Plain radiographs may not demonstrate these lesions. MRI with cartilage-sensitive sequences can improve the detection of these injuries.32 Osteochondral fracture fragments can shear from the lateral femoral condyle or medial patellar facet after patellar subluxation or dislocation, and may warrant surgical intervention. Kroner31 first reported on a series of these fractures after patellar subluxation in patients 15 to 20 years of age.

Fractures after Bone–Tendon–Bone Harvest. Patellar fractures have been infrequently reported after graft harvest for bone–tendon–bone anterior cruciate ligament (ACL) reconstruction. An incidence of 0.2% has been reported in one series of over 1,700 ACL reconstructions.56 While these may occur intraoperatively secondary to technical error, the majority of cases have been attributed to postoperative trauma from a fall or overly aggressive rehabilitation protocols. Both transverse and vertical fracture patterns have been reported. Rigid fixation of these fractures, even in the setting of minimal displacement, has been advocated to allow for early motion and avoid delayed rehabilitation of the ACL reconstruction.

Masqueraders. A bipartite or tripartite patella is a normal anatomical variant and should not be misdiagnosed as a displaced patellar fracture. A bipartite fragment typically presents as a well-corticated fragment in the superolateral aspect of the patella, and is the result of incomplete fusion of ossification centers. The incidence of a bipartite patella is approximately 8% and is almost always seen bilaterally.39,56 Radiographs of the contralateral knee will confirm the diagnosis.

Measures of Patellar Fracture and Extensor Mechanism Injury Outcomes

No validated outcome measure exists specifically for fractures of the patella or injuries to the extensor mechanism. Hence, a plethora of clinical outcome measures have been utilized to report results of patella fractures over the years. This has severely limited the ability to compare between studies. The most commonly reported scale has been that described by Bostman et al.52 This scale incorporates objective measures such as range of motion and thigh atrophy while evaluating subjective parameters such as pain and giving way. Catalano et al.54 modified the HSS knee score by excluding evaluation of varus and valgus instability to report outcomes of open patella fractures. A modified form of the Cincinnati Rating System, incorporating a subjective component as well as objective physical examination and radiographic assessments, was first employed by Saltzman and subsequently utilized by others.57 Validated knee scores such as the Lysholm, the Knee Osteoarthritis Outcome Score (KOOS), and the Knee Society score, have also been utilized, however, these scores were not specifically designed for use in isolated knee extensor mechanism injuries. Design and validation of an outcome score specific to the pathology and complaints of injuries to the extensor mechanism is needed and will improve future research.

PATHOANATOMY AND APPLIED ANATOMY RELATING TO PATELLA FRACTURES

Osseous Anatomy of the Patella

The patella is the largest sesamoid in the body, lying deep to the fascia lata within the tendon fibers of the rectus femoris. Its proximal margin is termed the basis, and the rounded inferior margin, the apex. Ossification centers typically appear at 2 to 3 years of age. While its shape can vary considerably, the patella is typically ovoid and flat anteriorly on its nonarticular surface.31

The proximal three-fourths of the patella is covered with thick articular cartilage, while the distal pole is entirely devoid of articular cartilage. For this reason, most distal pole fractures are extra-articular. The articular cartilage can be 1 cm or greater in thickness in a normal patella.54 The proximal articular region is divided into medial and lateral facets by a longitudinal ridge. A second, vertical ridge along the medial border of the patella defines a small medial region termed the odd facet.52 Small, transverse ridges further subdivide the medial and lateral facets into superior, intermediate, and inferior facets. While the
lateral facet is usually the largest, considerable variation in the size and shape of patellar facets has been observed. Wiberg\(^63\) classified patellar osteology into three major groups based on the size of the medial and lateral facets.

- **Type I**: Medial and lateral facets are both concave and approximately equal in size.
- **Type II**: The medial, concave facet is smaller than the lateral facet.
- **Type III**: The medial, convex facet is smaller than the lateral facet.

Varying degrees of medial facet dysplasia were further defined by Baumgartl\(^64\). Type II and III patellas have a small, flat medial facet, while Type IV patellas have a small, steeply sloped medial facet with a medial ridge. Type V, termed the Jaegerhut patella, is devoid of a medial facet or vertical ridge.\(^64\)

**Arterial Blood Supply in the Patella**

The patella is nourished by an extensive, dorsal plexus of blood vessels that can be separated into both an extraosseous and an intraosseous vascular system (Fig. 54-5). Six separate arteries contribute to this vascular plexus, and help to preserve fragment vascularity even in the setting of comminuted fracture patterns.\(^65\)\(^,\)^\(^66\) The supreme geniculate artery arises from the superficial femoral artery at the level of Hunter canal, while the four geniculate arteries take origin from the popliteal artery. The recurrent anterior tibial artery is a branch of the anterior tibial artery, taking origin approximately 1 cm below the proximal tibiofibular joint. The superior portion of the plexus lies dorsal to the quadriceps tendon, while the inferior aspect passes deep to the patellar tendon in the fat pad. Scapinelli\(^65\)\(^,\)\(^67\) has shown that the primary intraosseous blood supply of the patella enters through the middle third of the anterior body and the distal pole, and perfuses in a distal to proximal fashion. This pattern of retrograde perfusion is important in understanding the risk of osteonecrosis after patellar fracture.

The patellar tendon is nourished by deep vessels in the fat pad receiving contributions from the inferior medial and lateral geniculate arteries. The superficial surface of the tendon is supplied by retinacular vessels that arise from the inferior medial geniculate and recurrent tibial arteries.\(^66\)

**Soft Tissue Anatomy of the Patella**

The patella is firmly invested within the quadriceps tendon deep to the fascia lata. The extensor mechanism, however, collectively refers to the quadriceps tendon, medial and lateral retinacula, patella, and patellar tendon.

The quadriceps muscle complex is composed of the vastus lateralis, vastus medialis, rectus femoris, and vastus intermedius. The vastus lateralis originates from the femur and inserts on the patella at an approximately 30-degree angle relative to the longitudinal axis of the femur. Its most medial fibers insert on the superolateral patella, and its most lateral fibers run lateral to the patella to insert into the lateral retinaculum and the iliotibial tract.\(^3\)\(^6\)\(^62\) The vastus medialis consists of two distinct portions separated by fascia and innervated by distinct branches of the femoral nerve.\(^66\)\(^62\) The vastus medialis longus inserts on the patella proximally at an angle of 15 to 18 degrees relative to the long axis of the femur, while the vastus medialis obliqueus (VMO) inserts more distally on the patella at an angle of 50 to 55 degrees.\(^66\)\(^62\) The rectus femoris is a long, fusiform muscle that lies central and superficial in the quadriceps complex. The fibers run 7 to 10 degrees medially relative to the long axis of the femur in the coronal plane. The vastus intermedius lies deep to the rectus femoris and inserts directly into the superior base of the patella.\(^66\)\(^62\)

The anatomy of the quadriceps tendon has been variably described. Previous studies have reported a trilaminar organization, with the rectus femoris tendon superficial, the vastus medialis and lateralis tendons in the middle, and the vastus intermedius fibers deep.\(^3\)\(^9\) In reality, however, the insertion reflects an intricate blending of all tendon fibers at the insertion into the superior patella.\(^5\)\(^2\)

The patellar retinaculum and iliotibial band function as secondary extensors of the knee. The retinaculum is formed by the continuation of the deep investing fascia lata in the thigh, and reinforced by inserting aponeurotic fibers from both the vastus medialis and lateralis. Both the medial and lateral retinaculum insert directly into the proximal tibia, and can thereby provide active knee extension in the setting of an isolated patellar fracture.\(^3\)\(^4\)

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**FIGURE 54-5** Arterial blood supply of the patella. **A**: Extraosseous geniculate arterial system: \(S\), supreme geniculate; \(MS\), medial superior geniculate; \(MI\), medial inferior geniculate; \(ATR\), anterior tibial recurrent; \(LI\), lateral inferior geniculate; \(LS\), lateral superior geniculate. **B**: Intraosseous arterial supply.
The medial patellofemoral ligament is an extracapsular continuation of the deep retinacular surface of the VMO that extends from the superior medial border of the patella and attaches to bone just anterior to the medial collateral ligament on the medial epicondyle.67,68 The medial patellofemoral ligament is accepted to be the major restraint to lateral patellar displacement and contributes 50% to 60% of the total restraining force of the medial patellar stabilizers.67,68 It has a fan-shaped configuration that runs from the upper medial margin of the patella to a femoral insertion posteroinferior to the femoral condyle and just distal to the adductor tubercle. Cadaveric dissections have revealed the ligament to be 58.8 ± 4.7 mm in length, 12 ± 3.1 mm in width, and inclined 15.9 ± 5.6 degrees proximally.68

The patellar tendon originates from the apex of the patella proximally and inserts into the tibial tubercle distally. Its average length is 3 cm. The patellar tendon is formed primarily from a continuation of the central fibers of the rectus femoris tendon. The tendon is reinforced medially and laterally by the extensor retinaculum and the iliotibial tract as it inserts into the tibia.62

**BIOMECHANICS OF THE EXTENSOR MECHANISM**

The extensor mechanism is biomechanically responsible for active knee extension and the ability to maintain an erect position. Numerous activities of daily living, including walking, ascending stairs, or rising from a chair depend on the extensor mechanism to generate sufficient force to overcome gravity.69,70

The patella provides the critical biomechanical functions of both linking and displacement.69 During initial knee extension from a fully flexed position, the patella functions as a link between the quadriceps and the patellar tendon. In this capacity, it allows for transmission of torque generated by the quadriceps muscle to the proximal tibia. For young men, these forces can exceed 6,000 N and can approach up to eight times body weight.71 At 135 degrees of flexion, linking occurs via transmission of forces between the extensive contact area of the trochlea with the patellar facets and the posterior surface of the quadriceps tendon.72 From 135 to 45 degrees of flexion, the odd facet engages the femur. The odd facet is the only portion of the patella that articulates with the medial surface of the femoral condyle but not the trochlea.72 Albanese et al.73 studied knee extension mechanics after subtotal excision of the patella. The quadriceps force as a function of knee flexion angle was recorded for varying amounts of excision and compared with the results for total patellectomy.73 Excision of the proximal one-half or less resulted in lower force requirements when compared with total patellectomy. The effects of distal to proximal excisions indicate a biomechanical advantage to maintaining a fragment equal to at least three-fourths the length of the proximal patella.73

The displacement function of the patella is most critical from 45 degrees of flexion to terminal extension. Twice as much torque is required to extend the knee the final 15 degrees as is necessary to bring it from a fully flexed position to 15 degrees.76 The patella displaces the tendon away from the center of rotation of the knee, increasing the moment arm and providing a mechanical advantage that increases the force of knee extension by as much as 50% depending on the angle of knee flexion.69 It is this displacement action of the patella that provides the additional 60% of torque necessary to gain the last 15 degrees of terminal extension.

The high torques generated by the extensor mechanism can result in substantial patellofemoral contact forces. Compresive forces as large as three to seven times body weight have been recorded during squatting or climbing stairs.74,75 Given the small contact area of the patellofemoral articulation, it has been estimated that the contact stresses generated are greater than in any other weight-bearing joint in the body.75

The patellofemoral contact zones are dynamic and shift with varying degrees of knee flexion. The patella engages the trochlear sulcus at approximately 20 degrees of flexion. With increasing knee flexion, a horizontal band of contact area across the patellar facets moves proximally and reaches a maximum at 90 degrees of flexion. Beyond 90 degrees, the contact area on the patella shifts into two discrete locations on the medial and lateral facets. Corresponding with the proximal shift of contact on the patella, the contact zone on the femur shifts distally on the trochlea and separates into two discrete zones on the medial and lateral condyles with hyperflexion.72,76

**PATELLAR FRACTURE TREATMENT OPTIONS**

The management of patellar fractures is largely based on the fracture classification and findings on physical examination, with particular attention on the integrity of the extensor mechanism. Age, bone quality, patient expectation, and the presence of associated injuries may also influence surgical decision making. Regardless of the treatment strategy, the goals of surgical intervention are:

- Maximal preservation of the patella to maintain its linking and displacement functions
- Restoration of the articular congruity of the patella
- Preservation of the functional integrity and strength of the extensor mechanism

Currently, the main treatment options for patellar fractures are:

- Nonoperative management
- Open reduction and internal fixation, most commonly with a tension band wiring or cannulated screw tension band construct
- Partial patellectomy
- Complete patellectomy

**Nonoperative Treatment of Patellar Fractures**

*Indications and Contraindications*

Nonoperative treatment may be indicated for patellar fractures with <3 mm of fragment displacement or <2 mm of articular incongruity in which the extensor mechanism remains intact.
TABLE 54-1  Nonoperative Indication and Contraindications

<table>
<thead>
<tr>
<th>Indications</th>
<th>Contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact extensor mechanism</td>
<td>Extensor lag or incompetent extensor mechanism</td>
</tr>
<tr>
<td>&lt;2 mm articular incongruity</td>
<td>&gt;2 mm articular incongruity</td>
</tr>
<tr>
<td>&lt;3 mm fracture displacement</td>
<td>&gt;3 mm fracture displacement</td>
</tr>
<tr>
<td>Severe medical comorbidity</td>
<td>Open fracture</td>
</tr>
<tr>
<td>Severe osteopenia</td>
<td>Loose bone or chondral fragments</td>
</tr>
</tbody>
</table>

(Table 54-1). Almost any fracture pattern (transverse, stellate, or vertical) may be addressed with closed treatment if the above criteria are satisfied. Relative indications for nonoperative management, sometimes even in circumstances of greater fragment displacement, include medical conditions that are contraindications to anesthesia and elderly, debilitated patients with severe osteopenia that precludes the ability to achieve rigid internal fixation.

**Techniques**

Acute nonoperative treatment typically consists of 4 to 6 weeks of extension splinting or bracing. If patient compliance and reliability are a concern, however, long leg cylinder casting may be preferable with careful molding about the knee and above the ankle to help prevent displacement of the cast as edema resolves. Straight-leg raises and isometric quadriceps exercises are initiated early in the cast or brace to minimize atrophy. Range of motion is gradually initiated after there is evidence of callus formation and fracture consolidation on plain radiographs. Radiographs are obtained shortly after range of motion is initiated to evaluate for displacement. In regard to weight bearing, most modern protocols allow for some degree of early weight bearing in full extension. Takebe and Hirohata77 recommended early partial weight bearing as tolerated with crutches for support.

**Outcomes**

Nonoperative treatment of minimally displaced fractures has been found with good clinical outcomes. In a large series of 422 patellar fractures reported by Bostrom,11,219 minimally displaced fractures were treated nonoperatively, and 98% had good to excellent results at final follow-up. Only two failures occurred with nonoperative treatment. Other series have reported low failure rates of less than 5% with closed management of minimally displaced fractures.15,62

In a series of 18 patients with significant medical comorbidities and displaced patella fractures, Pritchett18 reported satisfactory outcomes in 12 patients at 2-year follow-up, with 9 of these 12 patients without significant limitations in activities of daily living. Furthermore, Klassen and Trousdale79 reported on a retrospective series of delayed union or nonunion of patella fractures and found that minimally symptomatic nonunions could be successfully managed conservatively. In addition, Nathan et al.80 showed that in a low-demand patient, patellar nonunion may be successfully managed nonoperatively despite the inability to achieve radiographic union with nonoperative care.

**Operative Treatment of Patellar Fractures**

**Indications and Contraindications**

Operative treatment is indicated for patellar fractures with >3 mm of fragment displacement, >2 mm of articular incongruity, osteochondral fractures with associated intra-articular loose bodies, and/or a compromised extensor mechanism with loss of active extension. Internal fixation or partial or total patellectomy with repair of the extensor mechanism are all surgical interventions performed with the goal of achieving stable fixation and a functional extensor mechanism that allows for early range of motion and rehabilitation.

**Surgical Procedure**

**Internal Fixation Background.** Numerous variations of internal fixation techniques for patellar fracture stabilization have been described in the literature (Fig. 54-6). The first description of cerclage wiring for patellar fracture fixation was made by Berger in 1892.81 Anderson81 discussed the use of an equatorial circumferential wire placed around the patella, and Magnusson and Paw52,83 described successful fixation with wires passed through vertical drill holes. Screw fixation for longitudinal and transverse fracture patterns with large fragments has also been described.10,26,84 The potential concern of these fixation strategies, however, has been (i) an inability to initiate early motion due to the risk of displacement with large tensile forces from quadriceps contraction, and (ii) lack of compressive forces at the articular surface. The AO/ASIF popularized the technique of tension band wire fixation for patellar fractures to address these concerns, based on biomechanical studies demonstrating increased construct strength with wires placed on the anterior, tension-side cortical surface of the patella.23

**Biomechanics of Tension Band and Modified Tension Band Fixation.** The principle of tension band wire fixation for patellar fractures is to convert the tensile forces generated from the quadriceps complex at the anterior cortical surface of the patella into compressive forces at the articular surface. With progressive knee flexion, the passive tensile forces in the extensor mechanism in addition to the pressure of the femoral condyles against the patella increase interfragmentary compression at the articular surface.

Biomechanical testing has been performed on a variety of internal fixation constructs. Weber et al., in a cadaver study, found Magnusson wiring and modified anterior tension banding to perform better than cerclage wiring or standard tension banding. Their study also demonstrated that repair of the retinaculum increased the strength of the constructs.45 A study by Benjamin et al.85 compared the strength of four different fixation strategies (tension band wiring, modified tension band wiring over Kirschner wires [K-wires], Lotke and Ecker longitudinal
anterior banding, and circumferential cerclage wiring) in a transverse patellar fracture and retinacular disruption model. Cerclage wiring provided the weakest fixation strength with up to 20 mm of gapping at the fracture site with tensile stress. The modified anterior tension band technique of transosseous K-wire fixation with anterior banding demonstrated superior strength to all other constructs.\(^8\) John et al.\(^8\) found that utilizing a horizontal figure-of-eight with four strands crossing the fracture rather than the more common vertical tension band improved interfragmentary compression. Isolated screw fixation with 3.5-mm or 4.5-mm screws may be sufficient, particularly in the setting of simple transverse or longitudinal fractures in patients with good bone stock. Burvant et al\(^8\) investigated tension banding with screws and found them to perform biomechanically superior to five other techniques of transverse patellar fracture fixation, including screw fixation alone, however, placing tension band wires around the screw tips and heads are often difficult in the clinical setting. Carpenter et al.\(^8\) compared a modified tension band, parallel 4.5-mm interfragmentary lag screws, and 4-mm cannulated lag screws augmented with a tension band passed through them in a transverse patellar fracture cadaver model. The highest load-to-failure was seen with the modified tension band and the cannulated lag screw technique.\(^8\) Regardless of which tension band construct is selected, Baran et al.\(^8\) used MRI in a knee cadaveric model to advocate for placement of the tension band wire as close to the bone as possible with minimal interposing tendinous tissue.

Due to the frequent soft tissue irritation from stainless steel wire as well as its difficult handing properties, alternative such as braided cable or suture has been investigated. Sciliaris et al.\(^9\) compared anterior tension banding with 1-mm wire versus 1-mm braided cable. The braided cable allowed for less fragment displacement with cyclical loading. In addition, tightening of the wire by twisting at two different sites compared to a single site has been shown to provide greater interfragmentary compression.\(^9\) John et al.\(^8\) demonstrated improved stability

**FIGURE 54-6 A-L**: Illustrations of patellar fracture fixation constructs.
with cyclic loading if wire twists were placed at the corners of the figure-of-eight loop.

McGreal et al. demonstrated that braided polyester suture was 75% as strong as wire and performed equivalent to cerclage wire with cyclical loading. Braided No. 5 Ethibond has also been shown to be comparable to wire fixation with anterior tension banding or Lotke and Ecker anterior longitudinal banding procedures for displaced, transverse fractures. Wright et al. investigated the properties of FiberWire, a reinforced braided polyblend suture, in comparison to stainless steel wire. Chen et al. demonstrated that braided polyester suture compared to stainless steel wire.94 Small clinical series have reported favorable outcomes with alternatives to stainless steel cable. Chen et al. demonstrated equivalent clinical outcomes with wire versus biodegradable tension band fixation of patellar fractures at a mean of 2-year follow-up. Gosal et al. found a reduced reoperation rate for fractures treated with a modified anterior tension band utilizing braided polyester suture compared to stainless steel wire.

Preoperative Planning. When planning for internal fixation of a patellar fracture, it is important to have a good understanding of the fracture pattern and the location of fragments (Table 54-2). Scrutinizing the injury radiographs often provides enough information about the fracture to formulate a detailed plan for location of the fixation construct as well as the order of reduction and insertion of internal fixation. Often, the fracture will consist of more than two fragments or the fragments will be oriented in an oblique direction. In these cases, the “textbook” descriptions of tension band constructs may need to be customized or combined with other techniques to fit the unique fracture pattern. Consideration should be given to “simplifying” the fracture pattern, which involves reducing and fixing minor fragments to create a fracture pattern that is amenable to an anterior tension band construct. Lag screws, K-wires, and bioabsorbable pins all may be utilized to hold smaller fragments together and their need should be anticipated preoperatively.

Positioning. The patient is positioned supine on a radiolucent operating table. A small bump under the hip is useful for controlling external rotation of the limb. In addition, a small bump of towels that can be moved from beneath the knee and ankle and vice versa, helps in providing slight knee flexion and extension, respectively, during the case. A tourniquet is rarely needed; however, one may be placed in nonsterile fashion and only inflated if uncontrollable bleeding is encountered.

Surgical Approaches. Numerous skin incisions have been utilized for the treatment of patellar fractures. However, a midline longitudinal extensile skin incision centered over the patella is most often recommended. This incision allows for extension both proximally and distally in the acute and revision fracture setting and provides the most versatility for future knee procedures, especially knee arthroplasty. After incising skin and subcutaneous tissues, the articular surface is typically exposed by either working through the fracture site or retinacular rents. The medial and lateral retinacular rents may be extended if needed to allow finger access to the articular surface. If the retinaculum is not damaged or visual exposure of the articular surface is desired, Gardner et al. developed a technique for exposure and fixation of comminuted patellar fractures using a lateral arthrotomy and inversion of the patella. This approach provides direct visualization for articular reduction.

Modified Tension Band with Vertical Figure-of-eight Wire Technique. The patient is positioned supine on a radiolucent table (Table 54-3, Fig. 54-6C). A longitudinal midline incision is typically performed except in the case of an open fracture or a traumatic arthrotomy in which the laceration may be incorporated into the incision if possible. Superficial

**TABLE 54-2** Preoperative Checklist Operative Treatment of Patellar Fractures

- OR table
- Radiolucent OR table
- Position/postioning aids
  - Supine positioning
  - Often a small bump under the hip is helpful in controlling external rotation of the limb
  - A small towel bump that can be moved below the knee for slight flexion or under the ankle for knee extension is useful
- Fluoroscopy location
- Positioned perpendicular to the extremity on contralateral side of bed
- Equipment
  - Small and large pointed reduction clamps
  - K-wires
  - 18-gauge wire or heavy braided nonabsorbable suture
  - 3.5, 4, or 4.5 cannulated screws
  - Mini-fragment screws
  - Suture passer
  - Dental pick
  - Power drill
  - Tourniquet
  - Nonsterile if desired

**TABLE 54-3** Modified Anterior Tension Band—Surgical Steps

- Anterior longitudinal midline incision
- Avoid unnecessary undermining of tissue
- Expose fracture and clear of debris
- Assess degree of injury and define fracture pattern
- Simplify fracture pattern with K-wires or screws when able
- Reduce fracture
- Place two 1.8-mm K-wires perpendicularly across fracture, 5 mm below anterior cortical surface
- Pass 18-gauge wire beneath patellar tendon posterior to K-wires
- Cross limbs of wire over anterior patella
- Pass wire through quadriceps tendon posterior to K-wires
- Tighten wires by twisting both limbs of the wire simultaneously
- Bend ends of K-wires 180 degrees posteriorly
- Impact bent ends of K-wires into patella
dissection should be avoided regardless of incision orientation to preserve the blood supply and the viability of skin flaps. After exposure of the fracture lines, all clots and devitalized debris should be cleared. Prior to any fixation, the degree of injury should be carefully assessed. The articular surfaces of the femur and patella should be inspected, and any intra-articular loose bodies flushed out of the joint. In addition, the integrity of the medial and lateral retinaculum as well as the proximal and distal soft tissue attachments of the patella must be evaluated. The fracture pattern should be generally defined. Complex fracture patterns with moderate comminution may be simplified with the use of interfragmentary lag screws to create a transverse pattern that is then amenable to tension band fixation. With the knee slightly flexed, the fracture should be reduced and maintained with a pointed reduction forceps. The quality of the articular reduction should be palpated through the defect in the retinaculum. Occasionally, extension of the arthrotomy or retinacular tear may be necessary to allow palpation of the fracture. Gardner et al.97 have developed a technique for exposure and fixation of comminuted patellar fractures using a lateral arthrotomy and inversion of the patella. This allows for direct visualization and reduction of articular surfaces without soft tissue interposition and allows for confirmation of articular congruity, compared to more traditional techniques that rely on palpation alone. Intraoperative fluoroscopy with imaging in multiple planes may also be utilized to confirm an anatomic reduction.

Two parallel 1.6-mm K-wires are placed perpendicularly across the fracture line to maintain the reduction and anchor the tension band wire. The K-wires can be placed in an antegrade or retrograde fashion. Using the antegrade technique, the wires are advanced from proximal to distal at a level 5 mm below the anterior cortical surface and parallel to it. The wires are spaced apart to divide the patella longitudinally into thirds. When using the retrograde technique, the reduction is taken down and the proximal fracture fragment is flexed 90 degrees to expose the fracture surface. Starting 5 mm below the anterior cortical surface and dividing the patella longitudinally into the thirds, the K-wires are advanced proximally through the fracture site, exiting at the locations of the starting points for the antegrade technique. The reduction is then re-established and held with a pointed reduction forceps. The K-wires are subsequently advanced from proximal to distal across the fracture site until they exit distally at the inferior patellar margin.

Next, the tension band wire is passed and tightened to complete the construct. The limbs of the wire are crossed over the tension band wire both proximally and distally. They are placed across the reduced fracture. This allows for lagged interfragmentary compression, and has been shown to be biomechanically stronger than the K-wire construct.88 In this technique, guidewires are placed in an identical fashion to K-wires as described above. This is followed by drilling and cannulated lag screw advancement across the fracture over the wires. Use a depth gauge to measure screw lengths. Take care to avoid having the screw tips protrude from the patellar bone as this can lead to rapid wire failure. Two individual 18-gauge wires are then passed; one wire through each cannulated screw. The wires are then passed anteriorly over the patella in a figure-of-eight fashion with interrupted, figure-of-eight nonabsorbable sutures. The wound is closed in a standard, layered fashion (Table 54-3).

### Cannulated Screw Tension Band Technique

The positioning, exposure, and reduction technique are identical to that for the modified anterior tension band (Table 54-4, Fig. 54-6). However, rather than K-wires, 4-mm cannulated screws are placed across the reduced fracture. This allows for lagged interfragmentary compression, and has been shown to be biomechanically stronger than the K-wire construct.88 In this technique, guidewires are placed in an identical fashion to K-wires as described above. This is followed by drilling and cannulated lag screw advancement across the fracture over the wires. Use a depth gauge to measure screw lengths. Take care to avoid having the screw tips protrude from the patellar bone as this can lead to rapid wire failure. Two individual 18-gauge wires are then passed; one wire through each cannulated screw. The wires are then passed anteriorly over the patella in a figure-of-eight fashion and tightened simultaneously to the adjacent wire end after anatomic reduction of the fracture has been confirmed.88

#### Longitudinal Anterior Banding and Cerclage Wiring—The Lotke–Ecker Technique

Stellate fracture patterns that are not amenable to a modified anterior tension band technique may be treated with longitudinal anterior banding plus cerclage wire fixation (the Lotke–Ecker technique) (Fig. 54-6).13 The positioning, exposure, and reduction technique is identical to that for the modified anterior tension band. Minimally displaced fractures are fixed in situ, while severely comminuted and displaced stellate fractures are reduced through indirect techniques.13 In these cases, a cerclage wire is first placed around the circumference of the patella immediately adjacent to the bone with the assistance of a 14- or 16-gauge

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**TABLE 54-4** Cannulated Screw Tension Band—Surgical Steps

- Refer to modified anterior tension band for exposure and reduction
- Place two cannulated screw guidewires perpendicularly across fracture 5 mm below anterior cortical surface
- Drill with cannulated drill over guidewires
- Use depth gauge for screw lengths
- Insert screws
- Pass a single 18-gauge wire separately through each cannulated screw
- Cross limbs of wire over anterior patella
- Tighten wires by twisting both limbs of the wire simultaneously
- Bend wire twists posteriorly into deep soft tissue
angiocatheter or pulled through with a hemostat. Gross manual reduction is performed without clamps, followed by articular surface reduction with progressive tightening of the cerclage wire.

Longitudinal anterior banding is then performed by drilling two parallel tunnels, 1 cm from the medial and lateral edges of the patella respectively, with a 2-mm drill bit in an antegrade fashion. A large gauge wire (18- to 22-gauge) is then inserted into both drill holes, preserving a closed loop distally. The distal loop is brought anteriorly and one free proximal end of the wire is passed through this anterior loop. The wire is then secured to its other end and tightened with progressive twisting. This fixation results in a hybrid of anterior tension banding and intraosseous wire fixation.

Postoperative Care. No specific postoperative protocols have been scientifically evaluated; however, most recent authors have recommended early knee range of motion and protected weight bearing. Prolonged immobilization in the presence of stable fracture fixation has generally been discouraged. In addition, postoperative continuous passive motion (CPM) has been suggested to help reduce postoperative stiffness and improve articular cartilage healing.

Potential Pitfalls and Preventative Measures. There are numerous potential pitfalls that can be encountered during internal fixation of patellar fractures (Table 54-5). The limited anterior soft tissue over the knee and its frequent injury from a direct blow makes it important to avoid elevating unnecessary subcutaneous flaps. This will minimize soft tissue healing problems and hematoma formation.

| Pitfall #1 – Wound breakdown |
| Pitfall #2 – Intraoperative loss of reduction |
| Pitfall #3 – Early tension band wire failure |
| Pitfall #4 – Protrusion of cannulated screw tips from patella |
| Pitfall #5 – Asymmetric wire tension |
| Pitfall #6 – K-wire migration |
| Pitfall #7 – Prominent Hardware |

Another common pitfall results from soft tissue irritation from prominent hardware. Bending K-wires posteriorly and impacting them into the patella to prevent migration and placing wire twists superiorly where more abundant soft tissue exists may help avoid soft tissue irritation. Alternatively, braided non-absorbable suture can be used rather than stainless steel wire for a tension band.

Avoid hardware failure by tensioning the tension band wire in two places to apply equivalent tension to both sides of the construct. Moreover, do not overtension the wires as this may lead to articular gapping or wire failure. Lastly, avoidance of prominent cannulated screw tips will prevent rapid wire breakage as the wires are tensioned over the edge of the patella rather than the sharp screw tips when this method is used.

Treatment Specific Outcomes. The lack of a uniform surgical technique or a standardized assessment scale limits the utility of reported outcomes after operative fixation of patellar fractures. As a result, the literature provides generalizations about “good” or “excellent” outcomes based on subjective patient complaints of pain, loss or motion, or limitations in daily activities. Moreover, these subjective results may not correlate with articular damage. Haklar et al. found Grade II or III cartilage irregularities of the patella and/or trochlea in 73% of patients who underwent arthroscopy at the time of anterior tension band hardware removal despite all patients in the series having good to excellent Lysholm Knee Scores at follow-up. The authors felt these findings may predict future symptomatic patellofemoral arthritis. Despite the likely presence of articular irregularities, the combined results of many small series for open reduction and internal fixation have produced a good to excellent result in most cases (Table 54-6). The results of operative repair of patella fractures need to be interpreted with some caution; however, as series are more often reported by repair construct rather than fracture pattern. Modified anterior tension band wiring has produced the best results, with 86% good to excellent outcomes reported. Bostman et al. reported significantly better results with anterior tension banding compared to cerclage wiring, partial patellectomy, or interfragmentary screw fixation. While small series have reported excellent outcomes with cerclage wiring, a review of the combined results reveals inferior performance to tension band wire fixation, with only 70% good to excellent results. However, a more recent report by Yang et al. reported 100% good to excellent results in 21 comminuted patellar fractures treated with braided titanium cerclage cable. The anterior longitudinal banding technique of Loske and Ecker can also be effective, with 81% excellent results reported in their small series. Results of cannulated screw tension band constructs are still emerging. This technique is now commonly employed and early series demonstrate favorable results with 96% good to excellent outcomes (Fig. 54-7).

Minimally Invasive and Arthroscopic-assisted Fixation. The use of arthroscopy to assist with patellar fracture reduction and fixation has been described. Appel and Siegel presented a series of cases with arthroscopic-assisted reduction of displaced patellar fractures followed by percutaneous screw and wire fixation with satisfactory outcomes. Theoretical
advantages include direct visualization of the articular surface during internal fixation, limited dissection and soft tissue stripping, and the ability to address associated intra-articular pathology in the knee including osteochondral fractures. Concerns include fluid extravasation and a limited ability to repair the retinacular tissues. While this technique may have a role in selected cases, we do not feel that it supplants open techniques for closed, displaced transverse patellar fractures. In the PPOS group, a special device was secured via four percutaneous portals in order to maintain the reduction while an anterior tension band was placed. In the group of patients treated with PPOS, 53 patients treated with percutaneous patellar osteosynthesis (PPOS) versus standard open reduction and internal fixation for closed, displaced transverse patellar fractures. In the PPOS group, a special device was secured via four percutaneous portals in order to maintain the reduction while an anterior tension band was placed. In the group of patients treated with PPOS, the authors reported shorter surgical times, less pain, less complications, and improved functional outcome scores by the Knee Society Clinical Rating Scale (KSCRS) at 1-year follow-up. Clinical outcome scores were not statistically different between the two groups by 2-year follow-up.

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Patients</th>
<th>Technique</th>
<th>Outcomes (Excellent or Good Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seligo et al. 1971</td>
<td>35</td>
<td>Cerclage</td>
<td>80%</td>
</tr>
<tr>
<td>Nummi 1971</td>
<td>112</td>
<td>Tension band wire/cerclage</td>
<td>32%; 11% complications; 18 cases of bone necrosis after cerclage</td>
</tr>
<tr>
<td>Boström 1972</td>
<td>75</td>
<td>Stainless steel wire through longitudinal drill holes</td>
<td>81%</td>
</tr>
<tr>
<td>Böstman et al. 1983</td>
<td>48</td>
<td>Tension band wire/cerclage</td>
<td>79%</td>
</tr>
<tr>
<td>Ma 1984</td>
<td>107</td>
<td>Percutaneous suture</td>
<td>91%</td>
</tr>
<tr>
<td>Levack et al. 1985</td>
<td>30</td>
<td>Tension wire/cerclage</td>
<td>63%</td>
</tr>
<tr>
<td>Catalano 1995</td>
<td>76 open fractures</td>
<td>Open reduction internal fixation</td>
<td>77%; 4% fixation failure; no deep infection</td>
</tr>
<tr>
<td>Torchia and Lewallen 1996</td>
<td>44 open fractures</td>
<td>Open reduction internal fixation 50%</td>
<td>Partial patellectomy 50%</td>
</tr>
<tr>
<td>Smith et al. 1997</td>
<td>51</td>
<td>Modified tension band wire</td>
<td>Loss of reduction &gt;2 mm in 22%</td>
</tr>
<tr>
<td>Berg 1997</td>
<td>10 transverse fractures</td>
<td>Parallel screws/tension band wire</td>
<td>70%</td>
</tr>
<tr>
<td>Yang et al. 2010</td>
<td>21</td>
<td>Cerclage (titanium braided cable)</td>
<td>100%</td>
</tr>
<tr>
<td>Qi et al. 2011</td>
<td>15</td>
<td>Bioabsorbable parallel screws/absorbable tension band suture</td>
<td>100%</td>
</tr>
<tr>
<td>Tian et al. 2011</td>
<td>101</td>
<td>51% tension band wire 49% Parallel screws/tension band cable</td>
<td>87% tension band wire 100% parallel screws/tension band cable</td>
</tr>
<tr>
<td>Chang and Ji 2011</td>
<td>10 (inferior pole fractures)</td>
<td>Parallel screws/tension band wire</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Partial Patellectomy**

**Biomechanical Background.** As mentioned previously, by elevating the extensor mechanism and increasing the lever arm, the patella increases the force of knee extension by as much as 50% depending on the angle of knee flexion. In addition, Albanese et al. demonstrated lower force requirements for knee extension with increasing amounts of retained patella. Thus, preserving any portion of the patella likely improves knee extensor function.

While the value of retaining maximal patellar length and height is rarely debated, the location of drill holes for tendon reattachment after partial patellectomy has been controversial. Studies have suggested that the holes be placed near the articular surface to avoid abnormal tilting of the patella and increased patellofemoral contact forces. In 1958, Duthie and Hutchinson reported tilting of the patella in five of seven patients with postoperative arthritis, and attributed these changes to malalignment from attachment of the patellar tendon to the anterior cortex. In contrast, Marder et al. completed contact pressure studies demonstrating improved mechanics with anterior tendon reattachment for 20% and 40% partial patellectomy models. Furthermore, Zhao et al. have reported an increase in the force required to extend the knee with tendon attachment to the articular surface compared to the anterior cortex. With these conflicting results, further investigation is warranted.

**Indications and Contraindications.** Partial patellectomy may be indicated when comminution of the distal pole or a fragment of the patella is extensive and cannot be stabilized with internal fixation. In addition, fragments that are dysvascular or free with limited soft tissue attachments and likely to become loose bodies within the knee joint should be removed. Partial patellectomy should be avoided when the entire patella is salvageable or a tendon repair can be performed without removal of bony fragments.
Surgical Procedure

Preoperative Planning. Most frequently the final decision to perform partial patellectomy is made during the surgical procedure, however, operative planning should prepare for the possibility of partial patellectomy. Heavy braided nonabsorbable suture, suture passers, and mini-fragment fixation should be available.

Positioning. Refer to the positioning description for internal fixation.

Surgical Approach. The surgical approach is the same as for open reduction and consists of a longitudinal midline exposure.

Technique. Care is taken to preserve as many large, viable fragments as possible (Table 54-7). Retained fragments are anatomically reduced and secured to one another with screws or K-wires. If the comminution primarily involves the central patella with preserved proximal and distal fragments, the central

<table>
<thead>
<tr>
<th>TABLE 54-7 Partial Patellectomy — Surgical Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Anterior longitudinal midline incision</td>
</tr>
<tr>
<td>• Expose fracture</td>
</tr>
<tr>
<td>• Assess degree of injury and determine which fragments are salvageable</td>
</tr>
<tr>
<td>• Remove nonviable patellar fragments</td>
</tr>
<tr>
<td>• Reduce and internally fix retained fragments</td>
</tr>
<tr>
<td>• Place grasping stitch in tendon</td>
</tr>
<tr>
<td>• Reattach patellar or quadriceps tendon through three parallel drill holes</td>
</tr>
<tr>
<td>• Secure suture over bone bridges in full extension</td>
</tr>
<tr>
<td>• Assess strength of repair with controlled flexion</td>
</tr>
<tr>
<td>• Consider adding cerclage wire from quadriceps tendon to tibial tubercle</td>
</tr>
<tr>
<td>• Perform multilayer closure</td>
</tr>
</tbody>
</table>

FIGURE 54-7 Modified tension band wiring through cannulated screws. Lateral view (A) of injury. AP (B) and lateral (C) view of internal fixation.
comminution can be excised and the remaining fragments secured as congruously as possible with screw fixation.

With severe inferior pole comminution, resection of fragments with patellar tendon reattachment can be performed. Most of these fractures are extra-articular, as the distal pole is devoid of articular cartilage. Three longitudinal drill holes are then placed through the remaining patella to serve as tunnels for suture passage. A tendon-grasping, woven or locking nonabsorbable suture (such as a Krackow suture) is placed in the patellar tendon, and the sutures are passed with a ligature passer through the tunnels and firmly tied over bone bridges with the knee in hyperextension. Tantamount to the tendon repair, however, is a meticulous repair of the associated medial and lateral retinacular injury.26 Based on the energy of the injury and strength of the repair, the construct may be protected with a cerclage wire, a tendon graft, or a Mersilene tape that is passed immediately proximal to the superior pole of the patella and inferiorly through the proximal tibia posterior to the tibial tubercle. The cerclage should be tightened with the knee flexed to 90 degrees, as tightening in extension may constrain the postoperative flexion that is achievable by the patient. The strength of the repair should always be evaluated intraoperatively, with the surgeon observing for interfragmentary motion and the integrity of the tendon–bone interface with progressive knee flexion. Rigid constructs may allow for early, controlled motion of the knee.

Postoperative Care. An extension brace is applied and partial weight bearing with crutch assistance is maintained for 6 weeks postoperatively. Gradual active and active-assisted range of motion is implemented at 6 weeks from surgery. If the surgeon obtains excellent fixation, early gradual range of motion in a hinged brace, not to exceed 90 degrees, may begin prior to 6 weeks from injury.

Distal Pole Osteosynthesis—Basket Plate. Traditionally, comminuted fractures of the distal pole have been managed with partial patellectomy with satisfactory outcomes. Recently, a technique for osteosynthesis of these fractures using a novel basket plate device has been described.114-117 The basket plate is contoured to fit the geometry of the patellar apex and is augmented with several anterior and posterior flanges to collect the comminuted fragments. Fibers of the proximal patellar tendon are spread apart by the flanges to allow positioning at the inferior pole without detachment. Four holes are provided to place parallel and oblique screws that engage the proximal fragment and resist both tensile and shear forces.115,116 Biomechanical studies have demonstrated an ultimate load-to-failure of approximately 420 N for this construct, approximately 70% higher than that of a separate vertical wiring fixation construct.115,116

Preliminary clinical outcomes with the basket plate osteosynthesis technique have been favorable. Matejec et al.116 reported 90% good to excellent outcomes at a mean 5-year follow-up for 51 patients who underwent basket plate osteosynthesis of comminuted distal pole fractures. These data must be approached with caution, however, as 61% of the included patients were lost to follow-up.116 A retrospective cohort study by Kastelec and Veselko114 compared 11 patients who had internal fixation of a distal pole avulsion fracture to 13 patients who had

<table>
<thead>
<tr>
<th>TABLE 54-8 Outcomes after Partial Patellectomy</th>
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<tbody>
<tr>
<td>Author/Year</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>Selig 1971</td>
</tr>
<tr>
<td>Nummi 1971</td>
</tr>
<tr>
<td>Mishra 1972</td>
</tr>
<tr>
<td>Boström 1972</td>
</tr>
<tr>
<td>Saltzman 1990</td>
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<tr>
<td>Hung et al. 1993</td>
</tr>
</tbody>
</table>

a pole resection. At an average follow-up of 4.6 years, average patellofemoral scores were significantly better in the osteosynthesis compared to the resection group.114 Furthermore, there was a significantly greater incidence of patella baja in the pole resection group as assessed radiographically by the method of Kastelec and Veselko.114 Sample sizes were small, however, and randomized control trials are necessary to further define potential advantages of osteosynthesis compared to resection in the surgical management of comminuted distal pole fractures.

Treatment Specific Outcomes. When appropriate selection criteria are utilized, partial patellectomy can yield functional outcomes that are equivalent to open reduction and internal fixation (Table 54-8).6,28,31,61,119 Multiple authors have reported nearly normal functional outcome when large fragments of the patella and articular congruity are preserved. Retention of small, nonviable fracture fragments or those devoid of cartilage did not improve function, while retention of large fragments provided a lever arm for improved extensor mechanism function. Combined results in 138 cases have shown good to excellent outcomes in 72% of cases. With extensive inferior pole comminution, superior results have been reported with partial patellectomy compared to internal fixation.31 Boström reported 88% good to excellent results with partial patellectomy for transverse patellar fractures with inferior pole comminution, compared to only 74% good to excellent results with internal fixation.

Total Patellectomy

Indications and Contraindications. Total patellectomy is occasionally performed for highly displaced, comminuted fractures in which stable fixation cannot be achieved and when no large fragments can be retained (Table 54-9). We have reserved this as a salvage procedure in the rare setting of failed internal fixation or patellar osteomyelitis. Retention of even a single fragment is usually possible, and can substantially help to preserve the biomechanical function of the extensor mechanism.73
Techniques for Extensor Mechanism Deficiency. In certain situations, there may be an inadequate amount of soft tissue available for primary repair of the extensor mechanism. In general, the absence of prepatellar soft tissues is addressed with quadriceps turnover procedures. Absence of the quadriceps tendon, however, usually requires fascia or tendon weaving procedures. Shorbe and Dobson described the inverted V-plasty quadriceps turnover procedure. The quadriceps tendon is exposed for approximately 3 in, and a full-thickness V-shaped incision is made into the tendon with the apex of the “V” located 2.5 in proximal to the former superior pole of the patella. The V-limits extend distally for 1 in, creating a base that preserves approximately ½ in of tendon that is continuous with the retinaculum on both the medial and lateral sides. The V-lip is folded inferiorly, inserting it through the proximal patellar tendon and suturing it in place with several interrupted sutures. The quadriceps tendon defect is then closed in a side-to-side fashion with multiple interrupted sutures.

If the quadriceps tendon is deficient, Gallie and Lemermier have described a free fascia or tendon weave procedure. After nonviable tendon remnants have been debrided, the length of the defect is measured with the knee in full extension. This length is doubled and 2 in added to harvest the appropriate size fascial graft. Through a separate lateral incision, a 1.5-cm wide graft of fascia lata or iliotibial band of appropriate length is harvested and tubularized along its long axis. Alternatively, allograft tissue of appropriate length can be utilized. The graft is then woven through the quadriceps tendon and/or muscle, passed through the patellar tendon, and sewn back on itself. Tension should be evident on the repair at 90 degrees of flexion when length has been adequately restored. Excess tissue is excised and all edges firmly sutured down.

Potential Pitfalls and Preventive Measures. The most important pitfall is performing total patellectomy in a case in which a portion of the patella can be salvaged. Careful assessment of the fracture at the time of surgery will most often reveal a portion of the patella that can be retained and total patellectomy avoided. When total patellectomy is performed, extensor lag is one of the most common complications. As the patella is removed, the extensor mechanism is effectively lengthened, thus imbricating sufficient redundant tissue so that the repair under tension at 90 degrees of flexion will limit this complication.

Treatment Specific Outcomes. The outcomes of total patellectomy are generally inferior to those reported after internal fixation or partial patellectomy for fracture. However, these results are difficult to interpret as fractures treated with total patellectomy likely reflect higher-energy, comminuted injuries. Before the introduction of anterior tension band techniques, poor methods of achieving rigid internal fixation may have justified total patellectomy in these early series. Recent studies, however, have reported a higher rate of fair-to-poor outcomes with total patellectomy (Table 54-11). Bostman et al. recommended total patellectomy only in the setting of severely comminuted fractures. Sutton et al. evaluated quadriceps strength and functional abilities in patients who had undergone partial

<table>
<thead>
<tr>
<th>TABLE 54-9</th>
<th>Total Patellectomy Indications and Contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Patellectomy</strong></td>
<td><strong>Indications</strong></td>
</tr>
<tr>
<td>Severe comminuted fractures unable to accept internal fixation or suture repair</td>
<td>Ability to retain any portion of the patella</td>
</tr>
<tr>
<td>Failed internal fixation</td>
<td>Patellar osteomyelitis</td>
</tr>
</tbody>
</table>

Surgical Procedure

Preoperative Planning. Often the final decision to perform total patellectomy is made during the surgical procedure, however, operative planning should prepare for the possibility of total patellectomy. Heavy braided nonabsorbable suture should be available.

Positioning. Refer to positioning for the modified anterior tension band.

Surgical Approach. Refer to approach for the modified anterior tension band.

Total Patellectomy Surgical Technique. If a total patellectomy is required, all bony fragments are removed, with care being taken to preserve the retinacula and restore the integrity of the extensor mechanism (Table 54-10). Removal of the patella effectively lengthens the extensor mechanism, such that end-to-end repair will result in an increased slack distance and extension lag after surgery. This is avoided by imbrication or use of a purse-string suturing technique that shortens the tendinous repair. Tension should be evident on the repair at 90 degrees of flexion when length has been adequately restored.

For additional extensor mechanism strength, the VMO can be used to extend the quadriceps tendon. The VMO is excised and all edges firmly sutured down.

Total Patellectomy—Surgical Steps

- Anterior longitudinal midline incision
- Expose fracture
- Assess degree of injury and determine if patellar salvage is possible
- Remove patellar fragments
- Imbricate redundant extensor mechanism tissue with heavy braided nonabsorbable suture
- Check extensor mechanism tension at 90 degrees of flexion
- Perform multilayer closure
- Advance VMO

Potential Pitfalls and Preventive Measures. The most important pitfall is performing total patellectomy in a case in which a portion of the patella can be salvaged. Careful assessment of the fracture at the time of surgery will most often reveal a portion of the patella that can be retained and total patellectomy avoided. When total patellectomy is performed, extensor lag is one of the most common complications. As the patella is removed, the extensor mechanism is effectively lengthened, thus imbricating sufficient redundant tissue so that the repair under tension at 90 degrees of flexion will limit this complication.

Treatment Specific Outcomes. The outcomes of total patellectomy are generally inferior to those reported after internal fixation or partial patellectomy for fracture. However, these results are difficult to interpret as fractures treated with total patellectomy likely reflect higher-energy, comminuted injuries. Before the introduction of anterior tension band techniques, poor methods of achieving rigid internal fixation may have justified total patellectomy in these early series. Recent studies, however, have reported a higher rate of fair-to-poor outcomes with total patellectomy (Table 54-11). Bostman et al. recommended total patellectomy only in the setting of severely comminuted fractures. Sutton et al. evaluated quadriceps strength and functional abilities in patients who had undergone partial
or complete patellectomy, with the contralateral normal knee serving as a control. Total excision was associated with a 49% reduction in strength of the extensor mechanism and a mean loss of 18 degrees in range of motion. Functionally, there was a high incidence of instability, with an inability of the patients to support their weight on the loaded knee with stair climbing. Einola et al.11 reported on 28 patients with a mean 7.5 years of follow-up, and reported a good result in only 6 patients. Quadriceps power was within 75% of the contralateral knee in only 7 patients. Scott14 similarly reported a good outcome in only 4 of 71 patients, with 90% complaining of chronic pain. Quadriceps atrophy, pain, and instability in the knee during running or stair climbing were common complaints of patients in both series. Wilkinson124 evaluated 31 patients with up to 13 years of follow-up, and reported an excellent outcome in less than 25% of patients. Furthermore, Sorensen127 noted that no patients regained full quadriceps strength after patellectomy, and that none of their operative reconstructions would have fared better with primary excision. For these reasons, it is our recommendation to avoid total patellectomy whenever possible. We have not encountered a patella so comminuted that a single fragment could not be preserved acutely. Maintaining even a single fragment provides a lever arm that substantially improves the function of the extensor mechanism. If a total patellectomy is performed, consideration should be given to augmenting the repair with VMO advancement. Günal et al.128 in a prospective randomized trial compared the results of 16 traditional total patellectomy procedures with 12 cases augmented by VMO lateral and distal advancement. Strength, limitation of activity, and subjective functional assessment were significantly improved with VMO advancement. Lastly, the decision to operate acutely compared to a delayed fashion remains controversial. Muller et al.126 retrospectively reviewed their results of early (<4 weeks) versus delayed patellectomy, and identified no differences in range of motion or clinical outcome scores between the groups.

### Open Fractures

Open patellar fractures constitute a surgical urgency and warrant timely irrigation, debridement, and stable fixation. A thorough debridement includes removal of all devitalized fragments and soft tissue, followed by serial debridement, skin grafting, and the use of local or free tissue flaps if necessary for wound closure. Appropriate antibiotic coverage is also essential.

Catalano et al.134 reported on a series of 79 open patella fractures with a mean of 21-month follow-up. Almost all fractures were displaced, with 22% transverse patterns and 39% comminuted, stellate injuries. The majority (53%) were Gustilo and Anderson Grade II injuries. Surgical intervention consisted of a thorough irrigation and debridement followed by open reduction and internal fixation in 57% and partial patellectomy in 32% of cases. Outcomes were satisfactory in most cases with only case of revision internal fixation for failure and no cases of deep infection. The Mayo Clinic’s retrospective review of open patellar fractures also reported 77% good to excellent results, with no infections in type I or II open injuries that were treated with immediate internal fixation after irrigation and debridement.112 Anand et al.132 recently presented long-term outcomes of 16 open patellar fractures and compared their results to a

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Number of Patients</th>
<th>Follow-up (yrs) Mean</th>
<th>Outcome (Excellent or Good Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seligo1971</td>
<td>44</td>
<td>NR</td>
<td>89%</td>
</tr>
<tr>
<td>Nummi1971</td>
<td>24</td>
<td>1–8</td>
<td>38%</td>
</tr>
<tr>
<td>Boström1972</td>
<td>5</td>
<td>8</td>
<td>20%</td>
</tr>
<tr>
<td>Mishra1972</td>
<td>26</td>
<td>4</td>
<td>69%</td>
</tr>
<tr>
<td>Einola11</td>
<td>28</td>
<td>7.4</td>
<td>21%</td>
</tr>
<tr>
<td>Sutton1976</td>
<td>33</td>
<td>5.3</td>
<td>Complete patellectomy associated with reduction in stance-phase flexion during walking and stairs; Loss of quadriceps strength and atrophy</td>
</tr>
<tr>
<td>Wilkinson1977</td>
<td>31</td>
<td>7.7</td>
<td>61% Maximal recovery up to 3 yrs</td>
</tr>
<tr>
<td>Peeples1978</td>
<td>14</td>
<td>4.6</td>
<td>85% Partial superior to total patellectomy</td>
</tr>
<tr>
<td>Böstman1985</td>
<td>10</td>
<td>Not specified</td>
<td>79% Mean quadriceps strength 66% of normal side</td>
</tr>
<tr>
<td>Jakobsen1985</td>
<td>28</td>
<td>20</td>
<td>80% Mean hospital for Special surgery score 68.4 (primary 71; delayed 63.8); primary group better range of motion (123 degrees vs.114 degrees)</td>
</tr>
<tr>
<td>Levack1985</td>
<td>34</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>Muller2003</td>
<td>12 acute patellectomy</td>
<td>9 delayed patellectomy</td>
<td></td>
</tr>
</tbody>
</table>
matched group of closed injuries. The injury severity score (ISS) and the incidence of associated musculoskeletal injuries were significantly higher in the open patellar fracture group. At a mean of 45-month follow-up, patients with open patellar fractures had a higher incidence of complications, a lower KOOS, and a higher visual analog score for pain.32

**AUTHOR’S PREFERRED METHOD OF TREATMENT FOR PATELLA FRACTURES**

**Patients with an Intact Extensor Mechanism, Vertical Fractures, and Minimal Articular Displacement or Patients Unfit for Anesthesia**

In these situations, we employ nonoperative care (Fig. 54-8). The exception is the patient with normal extensor mechanism function, but with significant articular incongruity or fracture gap. In patients with a large traumatic hemarthrosis, we will consider aspiration of the joint and injection of a local anesthetic to facilitate physical examination.

With compliant and reliable patients, we use a hinged knee brace locked in full extension. The brace is lightweight, allows for patient hygiene and monitoring of any abrasions or associated soft tissue injuries. Furthermore, controlled range of motion may be initiated once fracture callus is radiographically confirmed. In patients with questionable compliance or elderly patients who are at significant risk for falls, we prefer to utilize a fiberglass cylinder cast applied from the groin to just above the ankle, molded with the knee in full extension. Care must be taken, particularly in elderly or diabetic patients, to pad carefully to avoid iatrogenic soft tissue injury from a poorly molded cast. In patients with lower-extremity venous stasis ulcers or compromised circulation, an Unna boot can be applied prior to cast molding to protect the soft tissues.

Isometric quadriceps exercises with straight-leg raises are initiated 1 week after immobilization to minimize quadriceps atrophy. Partial weight bearing with crutch assistance is allowed immediately with advancement to full weight bearing in extension as tolerated. Follow-up radiographs are obtained at regular intervals to confirm that reduction has been maintained. If fracture displacement occurs early, surgical stabilization should be considered. After fracture consolidation is radiographically confirmed, controlled range of motion of the knee is initiated.

Marginal or small nonarticular fractures of the patella are often stable due to the preserved integrity of the soft tissues. In these cases, cast or brace immobilization is often unnecessary, and early, controlled range of motion with activity modification is initiated as tolerated.

**Displaced Fractures**

Preoperative planning is often difficult with patellar fractures as the fracture lines and comminution are not always clearly visualized using standard imaging. It is imperative to have all of the necessary equipment available in the operating room to perform either internal fixation or a partial patellectomy. At minimum, small and mini-fragment implant sets with 3.5- and 2.7-mm cortical screws for interfragmentary fixation, 1.6- and 2-mm Kirschner wires, 18-gauge wire, and 14- or 16-gauge angiocatheters for wire passage are needed. A 4-mm cannulated screw set can be made available as well to fix transverse fracture patterns. Small and medium pointed reduction forceps are helpful for maintaining a provisional reduction. A power drill with wire driver attachment and wire twisters should be available. If significant distal pole comminution is encountered, a
CHAPTER 54  Patella Fractures and Extensor Mechanism Injuries

Partial patellectomy may be necessary. A Hewson suture passer may be helpful for passing suture through bone tunnels if a partial patellectomy is performed.

In the case of open injuries, immediate irrigation and debridement of the fracture is performed followed by rigid internal fixation for Type I and II open injuries without gross contamination. Appropriate antibiotic coverage is selected, and serial debridement and/or soft tissue coverage are performed based on the contamination of the wound and the status of the soft tissues. If there is a question of an open fracture or traumatic arthroscopy, a saline load test should be performed in the emergency department. For closed fractures, the status of the skin and soft tissues helps guide the timing of operative intervention. Typically, we will wait 1 to 2 weeks in the setting of significant soft tissue swelling or superficial abrasions to minimize the risk of postoperative wound complications.

We perform the procedure with the patient supine on a radiolucent table. Intraoperative fluoroscopy is used to obtain true AP and lateral images. A high nonsterile thigh tourniquet is placed, but rarely inflated. The fracture is approached through a longitudinal midline incision with full-thickness skin flaps and minimal superficial dissection. This extensile approach provides excellent exposure of the fracture as well as the medial and lateral retinacular tears.

The fracture lines are carefully defined by debridement of clot and devitalized debris. In the setting of transverse fracture patterns (OTA C1.1), we prefer a cannulated screw tension band construct (Fig. 54-7). With more complex fractures in which the larger fragments have additional fracture lines (OTA C2.1), we attempt to simplify the fracture into a transverse pattern by securing the smaller fragments together with interfragmentary screws or K-wires. Screws of various sizes may be necessary based on fragment size and bone quality. Purely longitudinal fractures (OTA B1.1, B1.2, B2.1, B2.2) can often be secured with interfragmentary screws alone.

Provisional reduction of the fracture is obtained with the assistance of a pointed reduction forceps and manual manipulation. The reduction is assessed by both direct palpation of the articular surface through the retinacular tear and multiplanar fluoroscopy. If the retinacular tissues are intact, we create a small arthroscopy in the medial retinaculum to allow direct palpation of the articular surface. Guidewires for cannulated screws are placed in a retrograde fashion via the fracture line into the proximal pole. We prefer this technique to assure a depth 5 mm posterior to the anterior cortical surface. After drilling, the parallel screws are placed over the guidewires, conferring compression and rotational stability to the construct. The screw lengths are confirmed under fluoroscopy to avoid leaving the screw tips proud. The 18-gauge wire is then passed in a figure-of-eight fashion through the cannulated screws and the free limbs are twisted to achieve appropriate tension. The screw tips are left proud. The 18-gauge wire is then passed in a figure-of-eight fashion through the cannulated screws and the free limbs are twisted to achieve appropriate tension. The screw tips are left proud. The 18-gauge wire is then passed in a figure-of-eight fashion through the cannulated screws and the free limbs are twisted to achieve appropriate tension. The screw tips are left proud.

In the setting of a displaced, stellate fracture pattern in which anterior tension banding is not feasible (OTA C3.1, C3.2), we will utilize indirect reduction with cerclage wiring followed by the longitudinal anterior banding of technique.

Lotke and Ecker13 With severe inferior pole comminution that is not salvageable (OTA C1.3, C2.3), we perform a partial patellectomy while attempting to preserve as much of the remaining patella as possible. Interfragmentary screws may be utilized to stabilize large salvageable independent fragments. Two locking Krackow sutures are then run in the patellar tendon, resulting in four core strands which are passed through three tunnels in the residual patella. The drill holes are placed at the articular margin to avoid iatrogenic patellar tilt. A burr or rongeur is used to make a small trough at the inferior margin of the patella to allow tendon apposition against bleeding, cancellous bone. We typically protect the partial patellectomy with an 18-gauge cerclage wire passed superior to the patella across the quadriceps tendon and through the proximal tibia.

Postoperative Management

For fractures with stable internal fixation, we recommend early physiotherapy and weight bearing as tolerated while limiting flexion to 30 degrees for 4 weeks at which time range of motion is progressed. When fixation is tenuous, partial patellectomy is performed, or when the patient is noncompliant, full weight bearing in a cylinder cast in extension for 6 weeks is instituted prior to progression to a hinged knee brace. Isometric quadriceps exercises and straight-leg raises are encouraged as soon as pain subsides. Range of motion may be delayed in any situation in which the soft tissue envelope, wound closure, or fracture fixation is tenuous.

INTRODUCTION TO EXTENSOR MECHANISM INJURIES

Patients with a loss of active knee extension as a result of trauma without signs of a patellar fracture may have a disruption of the extensor mechanism. Injuries to the extensor mechanism can include quadriceps or patellar tendon ruptures, patellar dislocations, or tibial tubercle avulsions. Demographic data suggest a difference in the occurrence of quadriceps and patellar tendon ruptures based on age.13 Patellar tendon ruptures occur more commonly in patients less than 40 years old while quadriceps tendon ruptures occur more commonly in patients greater than 40 years of age.

ASSESSMENT OF EXTENSOR MECHANISM INJURIES

Extensor Injury Mechanisms

Quadriceps and patellar tendon ruptures are typically low-energy injuries. A thorough history and physical examination is helpful in diagnosing a patellar or quadriceps tendon rupture. Typically, the patient sustains a forceful quadriceps contraction against a fixed or sudden load of full body weight with the knee in a flexed position resulting in eccentric loading.

Injuries Associated with Extensor Mechanism

Quadriceps and patellar tendon injuries most often occur as low-energy injuries in isolation. However, ACL tears have
accompanied up to 12.5% of high-level sporting injuries resulting in patellar tendon rupture and should be sought during the initial evaluation or with MRI.129

**Signs and Symptoms of Extensor Mechanism Injuries**

Patients may often note prodromal signs and symptoms including pain, atrophy, and tenderness around the distal or proximal patellar pole and/or a history of Osgood-Schlatter disease or jumper knee.130 Quadriceps tendon ruptures occur more commonly in patients with systemic disease or degenerative changes.46,131 Numerous reports of simultaneous bilateral quadriceps tendon rupture have been published and include patients with systemic illness and obesity.132–135 Bilateral rupture of the patellar tendon can occur but is less frequent.136–138

Pain with an associated tearing or popping sensation is typical, as is the inability to bear weight. The key to diagnosing an extensor mechanism rupture is the lack of active knee extension or the inability to maintain the passively extended knee against gravity. Most commonly, patellar tendon ruptures extend completely through the retinacular tissue resulting in complete loss of knee extension. Quadriceps tendon ruptures may not involve as much of the retinacular tissue, and as a result some extension still may be possible. Typically, however, some degree of extensor lag is almost always present when compared with the uninjured limb. Immediately after injury, a defect may be palpable at the level of the rupture. However, when the diagnosis is delayed, the tendon defect may not be palpable secondary to consolidation of the hematoma and early scar formation.

A traumatic hemorrhrosis is common after extensor mechanism injuries. Ice, compression, elevation, and anti-inflammatory medications can be used to treat local symptoms. Although no studies have shown a benefit for knee aspiration in these injuries, aspiration of a tense hematoma may be considered to reduce pain and promoting recovery.

**PATHOANATOMY AND APPLIED ANATOMY RELATING TO EXTENSOR MECHANISM INJURIES**

In general, healthy tendons do not rupture. Under normal conditions, tensile overload of the extensor mechanism usually leads to fracture of the patella which is considered the weakest link in the extensor mechanism.139 McMaster140 studied the tensile strength and location of tendon ruptures in a rabbit model. Between 50% and 75% of the tendon fibers had to be transected to result in a rupture under forces greater than those seen under physiologic conditions. Patellar tendon ruptures secondary to indirect trauma have been considered the end stage of longstanding chronic tendon degeneration secondary to repetitive microtrauma. Biopsy specimens of spontaneously ruptured tendons reveal pathologic findings that are degenerative in nature, including hypoxic tendinopathy, mucoid degeneration, tendinolipomatosis, and calcifying tendinopathy; however, ruptures may occur in the absence of pathologic tendon degeneration.141 The frequent prevalence of prodromal symptoms associated with tendon failure seems to support the finding of tendon degeneration prior to rupture. Kelly et al.130 reviewed 13 athletes with chronic jumper knee that resulted in tendon rupture. In this series, younger patients had more severe symptoms than older patients leading him to conclude that more advanced degeneration is required to weaken younger healthier tendons. Prodromal symptoms were present in 46% of NFL players prior to patellar tendon rupture.129

**Extensor Mechanism Injury Imaging and Other Diagnostic Studies**

An AP and lateral plain radiograph should be obtained in all patients with suspected injury to the knee extensor mechanism. Plain radiographs are the most cost-effective radiographic means to diagnose a patellar tendon rupture. The unopposed pull of the quadriceps muscle will result in proximal migration of the patella. Patella alta, defined as the position of the patella superior to Blumensaat line on the lateral radiograph, is consistent with rupture of the patellar tendon. In addition, if bone fragments are identified an avulsion injury may be suspected. Radiographic findings suggestive of a quadriceps tendon rupture include obliteration of the quadriceps tendon shadow, a suprapatellar mass, suprapatellar calcific densities, or an inferiorly displaced patella. A study of 18 patients with known quadriceps tendon ruptures identified at least three of these abnormalities in 17 of the 18 patients.142

High-resolution ultrasonography has been recognized as an effective method of examining the patellar and quadriceps tendons in both acute and chronic injuries.143,144 Raatikainen et al.145 reported on the successful use of ultrasound in diagnosing partial quadriceps tendon ruptures. MRI is also an effective, albeit expensive, method of diagnosing extensor mechanism injuries.9,146,147 It is not recommended in the evaluation of most suspected extensor mechanism injuries, but may be helpful in patients with neglected tears or partial tendon injuries.

**EXTENSOR MECHANISM INJURY TREATMENT OPTIONS**

**Historical Perspective on Extensor Mechanism Injury**

The first known description of a patient with an extensor mechanism injury is found in the translated writing of the Greek physician Galen ca. 80 to 87 AD.147 In 1887, McBurney148 published their techniques and results. Increasingly accepted and numerous surgeons have subsequently published their techniques and results. In 1927, Gallie and LeMesurier122 described a review of 26 cases treated surgically and recommended operative repair. In 1927, Gallie and LeMesurier122 described a technique utilizing a fascia lata strip to repair a quadriceps tendon rupture. Following these reports, surgical management became established until the end of the 19th century when Quenu149 published a review of 26 cases treated surgically and recommended operative repair. In 1927, Gallie and LeMesurier122 described a technique utilizing a fascia lata strip to repair a quadriceps tendon rupture. Following these reports, surgical management became increasingly accepted and numerous surgeons have subsequently published their techniques and results.

**Nonoperative Treatment of Extensor Mechanism Rupture**

**Indications and Contraindications**

Incomplete ruptures are usually managed conservatively without surgical intervention if full active extension is present on physical examination (Table 54-12). In addition, nonoperative...
Surgical Procedure

Preoperative Planning for Quadriceps and Patellar Tendon Ruptures. Inspection of the soft tissues for abrasions, lacerations, or prior incisions should occur prior to surgery and may influence the placement of the skin incision (Table 54-13). Equipment considerations for repair are relatively straightforward. Heavy nonabsorbable suture, a suture passer, and a drill are typically required.

Positioning for Quadriceps and Patellar Tendon Ruptures. The patient is positioned supine on a standard operating table. A small bump under the hip is often useful for controlling external rotation of the limb. In addition, a small bump of towels that can be moved from beneath the knee and ankle and vice versa helps in providing slight knee flexion and extension, respectively, during the case. A tourniquet is rarely needed, however, one may be placed in a nonsterile fashion and only inflated if uncontrollable bleeding is encountered.

Surgical Approaches for Quadriceps Tendon and Patellar Tendon Repair. An extensile straight midline incision is most often employed to expose the knee from the inferior patella to 5 cm proximal to the quadriceps tendon rupture and from the superior patella to the tibial tubercle for patellar tendon ruptures. Full-thickness flaps are elevated medially and laterally to identify the apex of the retinacular tears, if present. The joint is irrigated to remove hematoma, allow identification and assessment of the tear, and examination of the patella and distal femoral articular surfaces.

Technique for Acute Quadriceps Tendon Repair. Avulsion of the quadriceps tendon from the superior pole of the patella can be treated by debridement of the tendon, followed by the passage of two heavy nonabsorbable sutures into the tendon (Table 54-14). Three parallel drill holes are then created from superior to inferior through the patella. The sutures are passed through the drill holes and tied at the inferior patella and the retinacular tissue is repaired (Fig. 54-9).

A midsubstance rupture can be repaired with end-to-end approximation of the tendon rupture. If the repair is tenuous, the Scuderi150 technique or quadriceps turndown flap has been

<table>
<thead>
<tr>
<th>TABLE 54-12 Nonoperative Treatment of Extensor Tendon Rupture—Indications and Contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contraindications</td>
</tr>
<tr>
<td>Open injury</td>
</tr>
<tr>
<td>Extensor lag</td>
</tr>
<tr>
<td>Loss of knee extensor function</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 54-13 Extensor Tendon Repair Case Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>• OR table</td>
</tr>
<tr>
<td>• Standard table</td>
</tr>
<tr>
<td>• Position/positioning aids</td>
</tr>
<tr>
<td>• Supine positioning</td>
</tr>
<tr>
<td>• Often a small bump under the hip is helpful in controlling external rotation of the limb</td>
</tr>
<tr>
<td>• A small towel bump that can be moved below the knee for slight flexion or under the ankle for knee extension is useful</td>
</tr>
<tr>
<td>• Equipment</td>
</tr>
<tr>
<td>• Heavy braided nonabsorbable suture</td>
</tr>
<tr>
<td>• Suture passer</td>
</tr>
<tr>
<td>• 18-gauge wire</td>
</tr>
<tr>
<td>• Power drill</td>
</tr>
<tr>
<td>• Tourniquet</td>
</tr>
<tr>
<td>• Nonsterile if desired</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 54-14 Extensor Tendon Repair Surgical Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Anterior longitudinal midline incision</td>
</tr>
<tr>
<td>• Expose tendon rupture</td>
</tr>
<tr>
<td>• Remove nonviable tendon edges</td>
</tr>
<tr>
<td>• Place grasping stitches in tendon</td>
</tr>
<tr>
<td>• Reattach patellar or quadriceps tendon through three parallel longitudinal drill holes in the patella</td>
</tr>
<tr>
<td>• Secure sutures over bone bridges in full extension</td>
</tr>
<tr>
<td>• Assess strength of repair with controlled flexion</td>
</tr>
<tr>
<td>• Consider adding a cerclage wire from quadriceps tendon to tibial tubercle for patellar tendon injury</td>
</tr>
<tr>
<td>• Perform multilayer closure</td>
</tr>
</tbody>
</table>
described as a method to reinforce the surgical repair. A partial-thickness triangular flap is developed from the anterior surface of the proximal tendon that is 2 in along the base and 3 in along each side. The flap is folded distally over the rupture/repair and sutured into place.

Several authors have suggested techniques for reinforcing the repair using wire, Dacron tape, or suture. Recently, no complications and 100% good and excellent results were reported with use of a braided nonabsorbable relaxing suture tensioned at 30 degrees of flexion in 20 quadriceps repairs. The authors felt the relaxing suture reinforced the repair and allowed early active motion and brace-free ambulation at 6 weeks. However, most repairs for tendon avulsions are sufficiently strong that secondary stress-relieving devices are not required.

**Technique for Acute Patellar Tendon Repair.** The site of the tear (proximal, midsubstance, or distal) will dictate...
the preferred surgical repair technique. Most patellar tendon ruptures occur at the insertion on the inferior pole of the patella as an avulsion. This is believed to be the result of a relative decrease in the collagen fiber stiffness at the insertion site and the greater tensile strain occurring at the inferior pole fibers than in the midtendon.140

Avulsion of the patellar tendon from the inferior pole of the patella can be treated by debridement of the tendon, followed by the passage of two heavy nonabsorbable sutures into the tendon. Three parallel drill holes are then created from inferior to superior in the patella. The sutures are passed through the drill holes and tied at the superior pole of the patella. The medial and lateral retinacular tears are identified and repaired. A cerclage or reinforcement suture or wire is recommended for most cases (Fig. 54-10). This is performed by drilling a transverse tunnel 1 cm posterior to the tibial tubercle and passing heavy

![Diagram of patellar tendon repair](image)

**FIGURE 54-10** Suture technique of patellar tendon repair. **A:** A suture passer is used to guide the core sutures through the drill holes. **B:** The suture is retrieved and tied at the superior margin of the patella. **C:** Direct repair to the inferior pole of the patella through three parallel drill holes. **D:** Addition of a cerclage wire through the tibial tubercle for protection of the tendon. **E:** Use of hamstring tendons placed through bone tunnels for repair of a chronic rupture.
Postoperative Care for Acute Patellar and Quadriceps Tendon Repair. The postoperative rehabilitation regimen is based on the surgeon’s assessment of the repair strength. A repair with poor quality tissue should be immobilized for 4 to 6 weeks in a cylinder cast with weight bearing as tolerated restrictions. This is more often the case in quadriceps tendon repair. However, a sturdy repair with reinforcement may be placed in a hinged knee brace locked in extension and can be started on early range of motion within 7 to 10 days postoperatively with active and active-assisted exercises.  

Chronic or Neglected Quadriceps Tendon Repair Techniques. Chronic or neglected tendon ruptures may present significant treatment challenges. When the tendon end can be approximated to the patella, a primary repair can be performed. However, a large defect may be present between the ends of the tendon and the patella preventing tendon apposition. Patients with a quadriceps tendon rupture older than 2 weeks may have muscle retraction of up to 5 cm. If the tendon has retracted proximally resulting in a gap, the quadriceps muscle can be elevated from the femur and adhesions released in an attempt to gain length. If the tendon ends still cannot be opposed, a Codivilla lengthening procedure should be considered. In this procedure a full-thickness inverted V is created in the proximal segment of the quadriceps tendon. The lower margin of the V should be 1.3 to 2 cm proximal to the site of the rupture. The ends of the ruptured tendon are approximated and repaired with heavy nonabsorbable suture. The triangular flap is turned down distally and sutured into place. The open upper portion of the V is then repaired in a side-to-side fashion. Scuderi described a variation of this technique for delayed reconstruction. After the tendon is exposed, a Codivilla or Bennett lengthening is performed. An inverted V-cut is made through the tendon proximal to the rupture. The triangular flap is then divided into two flaps. One half thickness flap is incorporated into the Y-plasty and the other is folded distally to reinforce the tendon repair.

Chronic Patellar Tendon Repair Techniques. Siwek and Rao described a technique of preoperative traction used in the treatment of three of five chronic patellar tendon ruptures. Preoperative traction was used in the following circumstances: Neglected rupture of the patellar tendon with marked radiographic or clinical displacement with an inability to move the patella manually distally. A Steinmann pin was placed transversely through the proximal portion of the patella and 5 lb of traction was applied from 4 days for up to 2 weeks preoperatively. Knee range of motion was initiated after the traction procedure. All repairs were augmented with a fascial graft or Bunnell wire. They reported 90% good to excellent results in five patients.

Kelikian et al. was the first to describe a case using the semitendinosus tendon to augment chronic patellar tendon rupture (Fig. 54-10E). In this technique, a staged surgical procedure was performed with skeletal traction applied until the patella descends to a level 1 in proximal to the tibial articular surface. Through a proximal incision the semitendinosus tendon was divided at its musculotendinous junction. A longitudinal paramedian incision was performed and drill holes made in the tibial tubercle and the distal patella. The free end of the tendon was passed from medial to lateral through the tibial tunnel and then from lateral to medial through the patella. The tendon was then brought down and sutured on itself. A cylinder cast was applied for 6 weeks.

Ecker et al. reported on four patients who underwent late reconstruction of the patellar tendon with semitendinosus and gracilis tendons. Preoperative traction was not used in this series. Intraoperatively, a Steinmann pin was placed transversely through the patella and distal traction was applied. The Insall–Salvati ratio was used to determine the correct height of the patella. The semitendinosus and gracilis were harvested leaving the distal insertion at the pes anserinus intact. Three large drill holes were made to accommodate the tendons. An oblique drill hole was made through the tubercle beginning proximally on the lateral aspect and extending distally to the medial aspect and two parallel transverse holes through the patella. The semitendinosus tendon was then inserted from medial to lateral through
the oblique hole in the tibial tubercle and then from lateral to medial through one of the transverse holes in the patella. The gracilis tendon was then passed from medial to lateral through the remaining transverse hole in the patella. A heavy gauge wire was placed through the tubercle and the distal hole of the patella. While the patella was maintained in a normal position with the traction pin, the wire was tightened to hold the position of the patella. The tendons were then sutured to each other. The wound was closed and a cylinder cast was applied for 6 weeks. The knee was manipulated and the wire removed at 6 weeks. Satisfactory results were reported with all four patients returning to work and achieving full active extension and 100 degrees of flexion.

**Postoperative Care for Chronic Patellar and Quadriceps Tendon Repair.** Repairs of chronic ruptures are protected more vigorously and for longer duration than acute repairs. Generally, weight bearing as tolerated is allowed in a cylinder cast for 6 weeks. Straight-leg raises may be performed. The patient is then transitioned to a hinged knee brace and allowed to move the knee from 0 to 45 degrees and then advanced 20 to 30 degrees every 2 weeks until full motion is regained. At that time, gentle active and active-assisted range of motion as well as light eccentric resistance training is started.

**Potential Pitfalls and Preventative Measures.** With repair of extensor mechanism ruptures, the integrity and strength of the suture repair is paramount (Table 54-15). Using tapered needles and carefully placing sutures to avoid cutting previously placed sutures is important. In addition, all slack should be removed from the suture lines before securing the knots. The addition of a relaxing suture or wire should be considered for all repairs in which tissue quality is questionable. When drilling transosseous tunnels, care should be taken to avoid violation of the articular cartilage with the drill. Finally, the repair should be taken through a 90-degree range of motion under direct visualization in the operating room prior to closure to ensure its security.

### Treatment Specific Outcomes

**Acute Quadriceps Tendon Repair.** Several authors have reported good to excellent results in 80% to 100% of operatively treated quadriceps tendon ruptures (Table 54-16). Many different techniques of primary repair have been described and no single technique has demonstrated superiority. In early series, primary end-to-end repair was performed with cast immobilization while in more recent series heavy nonabsorbable sutures have been passed through bone tunnels and early rehabilitation undertaken. The only factor that has been associated with inferior results is delay in timing of surgical repair of greater than 2 to 3 weeks. Scuderi\(^{150}\) reported good to excellent results in 85% of patients treated using the turndown flap. Siwek and Rao\(^{15}\) evaluated 36 ruptures and found that the 30 patients who underwent early treatment obtained good to excellent results while the three patients treated after 4 weeks all had unsatisfactory results. Larsen and Lund\(^{153}\) reported good to excellent results in 15 of 18 patients. This study attempted to correlate radiographic patellofemoral congruence with clinical outcome. Thirteen of the 18 patients demonstrated incongruence when

### TABLE 54-15

**Extensor Tendon Repair Potential Pitfalls and Preventative Measures**

<table>
<thead>
<tr>
<th>Pitfall #1</th>
<th>Prevention #1</th>
<th>Pitfall #2</th>
<th>Prevention #2</th>
<th>Pitfall #3</th>
<th>Prevention #3</th>
<th>Pitfall #4</th>
<th>Prevention #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting grasping suture with suture needles</td>
<td>Use tapered needles and carefully place sutures</td>
<td>Slack in suture repair</td>
<td>Apply tension to grasping suture with each throw to avoid slack</td>
<td>Patellar tendon repair failure</td>
<td>Consider placing a relaxing suture or wire through the tibial tubercle when there is questionable tissue quality</td>
<td>Suture repair failure</td>
<td>Gently flex the knee after repair to test repair integrity</td>
</tr>
</tbody>
</table>

### TABLE 54-16

**Outcomes after Acute Quadriceps Tendon Repair**

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Ruptures/ Patients</th>
<th>Technique</th>
<th>Postoperative</th>
<th>Outcomes (Excellent or Good Results [%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scuderi(^{150}) 1958</td>
<td>20/18</td>
<td>Suture with turndown flap</td>
<td>Cylinder cast 6 wks</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weight bear as tolerated</td>
<td></td>
</tr>
<tr>
<td>Siwek and Rao(^{15}) 1981</td>
<td>30/30</td>
<td>Suture end-to-end</td>
<td>Cylinder cast 6–10 wks</td>
<td>100</td>
</tr>
<tr>
<td>Larsen and Lund(^{153}) 1986</td>
<td>19/17</td>
<td>Suture end-to-end</td>
<td>Cast 6 wks</td>
<td>83</td>
</tr>
<tr>
<td>Rasul and Fischer(^{150}) 1993</td>
<td>17/17</td>
<td>Suture with drill holes</td>
<td>Cast 6 wks</td>
<td>100</td>
</tr>
<tr>
<td>Rougraff(^{151}) 1996</td>
<td>38/29</td>
<td>Primary suture or drill holes</td>
<td>Cast 6 wks</td>
<td>80</td>
</tr>
<tr>
<td>Konrath(^{152}) 1998</td>
<td>51/39</td>
<td>Suture through drill holes</td>
<td>Early motion with brace</td>
<td>92</td>
</tr>
<tr>
<td>Ramsieier et al.(^{153}) 2006</td>
<td>15/15</td>
<td>Primary suture or drill holes</td>
<td>Cast 6 wks</td>
<td>100</td>
</tr>
<tr>
<td>O’Shea et al.(^{154}) 2002</td>
<td>19/19</td>
<td>Primary suture, screw or wire augmentation</td>
<td>Cast 6 wks</td>
<td>100</td>
</tr>
<tr>
<td>West et al.(^{154}) 2008</td>
<td>20/20</td>
<td>Suture through drill holes with relaxing suture</td>
<td>Hinged knee brace, progression to ROM at 7 d</td>
<td>100</td>
</tr>
</tbody>
</table>
Most series have reported between 70% and 100% good to excellent results (Table 54-17). The majority of patients who undergo early primary repair achieve a functional range of motion and normal quadriceps strength. Persistent quadriceps muscle atrophy commonly occurs, but has not been correlated with loss of strength. Most series have reported good to excellent results in patients treated with early primary repair. Patients treated with delayed repair have lower success rates.

**TABLE 54-17 Outcomes after Acute Patellar Tendon Repair**

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Ruptures/Patients</th>
<th>Technique</th>
<th>Postoperative</th>
<th>Outcomes (Excellent or Good Results [%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siwek and Rao15 1981</td>
<td>25/25</td>
<td>Suture with Bunnell wire reinforcement</td>
<td>Cast extension 6-11 wks</td>
<td>96</td>
</tr>
<tr>
<td>Kelly10 1984</td>
<td>10/10</td>
<td>Suture through bone tunnels</td>
<td>Not specified</td>
<td>80</td>
</tr>
<tr>
<td>Larsen and Lund130 1986</td>
<td>10/10</td>
<td>Suture with reinforcement cerclage</td>
<td>Cast 6 wks</td>
<td>70</td>
</tr>
<tr>
<td>Hsu167 1994</td>
<td>41/35</td>
<td>Suture with wire cerclage</td>
<td>Cylinder cast 6 wks</td>
<td>86</td>
</tr>
<tr>
<td>Marder and Timmerman100 1999</td>
<td>14/14</td>
<td>Primary repair without cerclage</td>
<td>Hinged knee brace early motion</td>
<td>85</td>
</tr>
<tr>
<td>Ramsie162 2006</td>
<td>14/14</td>
<td>Primary suture or drill holes</td>
<td>Limit flexion to 60 degrees for 6 wks</td>
<td>100</td>
</tr>
<tr>
<td>West et al.144 2008</td>
<td>30/30</td>
<td>Suture through drill holes with relaxing suture</td>
<td>Hinged knee brace, progression to ROM at 7 d</td>
<td>100</td>
</tr>
</tbody>
</table>

**Chronic Quadriceps Tendon Repair Outcomes.** Overall, the reported results for chronic quadriceps tendon repairs are less satisfactory than those reported after repair of an acute tear with residual functional deficits present in most patients. Scuderi and Schrey158 reported good to excellent results in seven patients treated with their modification of the Codivilla lengthening technique. Omi159 described the medial transposition of a 2- to 5-cm strip of vastus lateralis to bridge a large defect in five chronic quadriceps tendon ruptures. Ramsey and Muller160 reported that four of seven delayed repairs lost between 10 and 20 degrees of full active extension at final follow-up.

**Acute Patellar Tendon Repair.** Most series have reported between 70% and 100% good to excellent results (Table 54-17). The majority of patients who undergo early primary repair achieve a functional range of motion and normal quadriceps strength. Persistent quadriceps muscle atrophy commonly occurs, but has not been correlated with loss of strength. Most series have reported good to excellent results in patients treated with early primary repair. Patients treated with delayed repair have lower success rates. Larsen and Lund151 performed a radiographic analysis of patellar congruence in a series of patients who underwent operative repair of acute patellar tendon ruptures. Seven of 10 patients demonstrated incongruity on the Merchant and lateral radiographs. Patients with residual patellofemoral symptoms all had incongruity but the majority were asymptomatic. They concluded that articular incongruity may not be the only cause of persistent knee pain in patients who undergo patellar tendon repair. Recently, West et al.164 demonstrated no complications and excellent results in 30 patellar tendon ruptures treated with transosseous sutures and a braided nonabsorbable relaxing suture placed through the quadriceps tendon and retinaculum and around the distal patella tensioned at 30 degrees of flexion. The authors then instituted range of motion from 0 to 55 degrees at 7 days and weaned the patient to brace-free ambulation at 6 weeks.
Chronic or Neglected Patellar Tendon Rupture. Chronic or neglected patellar tendon ruptures present significant operative challenges. The unopposed pull of the quadriceps muscles can result in significant contraction of the extensor mechanism. Early series recommended preoperative traction to overcome the contracted quadriceps muscle so that the tendon ends could be reaproximated.11,12 To our knowledge there have been no large series evaluating the outcomes after reconstruction of a chronic patellar tendon rupture. Isolated case reports have described different techniques and grafts including autogenous or allogenic grafts when local tissue is unavailable.37,112,129,130,169–172 Results have generally been less satisfactory compared to acute repair.

AUTHOR’S PREFERRED TECHNIQUE FOR QUADRICEPS TENDON REPAIR

The most common method of repair we use employs two grasping stitches passed through three longitudinal drill holes in the patella and tied over bone bridges. To begin, the edges of the quadriceps tendon are sharply debrided of grossly degenerated tissue providing a fresh surface to approximate to the patella. Absorbable sutures are placed into the medial and lateral retinacular tissues, but left untied until after the tendon repair has been completed. Two heavy nonabsorbable sutures (No. 5 Ticron or Fiberwire) are placed using a running Kessler or Krackow configuration leaving four strands of suture at the distal quadriceps stump. A trough is then created in the superior patella using a small burr or rongeur.

Three 2-mm drill holes are made parallel to each other along the longitudinal axis of the patella from superior to inferior. A Hewson suture passer is passed from the proximal patella through the drill hole. A No. 2 nylon suture is looped and placed into the suture passer which is then pulled out distally. The technique shuttles the nylon suture through the hole so that the core suture sutures can be easily and retrieved proximal to the patella. The two central sutures are passed through the middle drill hole and retrieved at the superior margin of the patella. The two peripheral sutures are each passed through a drill hole in a similar manner. Each of the central strands is then passed under the quadriceps tendon so that the knots when tied will lie close to the patella and not on top of the quadriceps tendon. Tension is applied to the sutures which are clamped but not tied. A lateral radiograph is obtained to assess the patellar height in relation to Blumensaat line and in comparison to the contralateral knee. Suture tension can be increased or decreased to control the patellar tendon length. The sutures are then tied. A deep drain is placed and the retinacular tissue sutures are tied. Reinforcement is often necessary with a patellar tendon repair to counteract the force of the quadriceps muscle contraction. A transverse 2.5-mm drill hole is made 1 cm posterior to the tibial tubercle. An 18-gauge wire is passed through the hole, brought proximally, and passed under the quadriceps tendon close to the superior border of the patella and twisted until it is tight. The reinforcement wire is tightened with the knee in some flexion in order to avoid shortening the tendon. The knee is flexed to 90 degrees to test the integrity of the repair. The patellar tendon suture line is then reinforced with absorbable sutures. The wound is closed in layers and a well-padded dressing is applied. A hinged knee brace is applied with the knee in full extension. Active flexion and passive extension are begun by 2 weeks postoperatively starting at 0 to 45 degrees and advancing 20 to 30 degrees every 2 weeks. Active knee extension is permitted at 6 weeks. Weight bearing is allowed immediately and crutches are used for at least 6 weeks. The hinged knee brace and crutches are discontinued when the patient is able to ambulate with good quadriceps control.

Tibial Tubercle Avulsions

Tibial tubercle avulsions represent an uncommon variant of extensor mechanism injuries. Treatment concepts are similar to those employed in the treatment of distal pole patellar avulsions. If the bone fragment is large enough, internal fixation with 3.5-mm or 4.5-mm screws should be performed with the addition of a stress-relieving cerclage wire to the protect repair.
If the tubercle fragment is too small for screw fixation, the tendon should be reapproximated to the proximal tibia through bone tunnels similar to the treatment used in other tendon avulsion injuries.

**Acute Patellar Dislocations**

Acute traumatic patellar dislocations occur with an average annual incidence of 5.8 per 100,000 increasing to 29 per 100,000 in the 10- to 17-year age group.\(^{173}\) Lateral patellar dislocations occur most commonly and conservative treatment is usually recommended.\(^{67,177-175}\) The majority of patients experience no further instability with reported recurrence rates after conservative treatment of 15% to 44%.\(^{173}\) Following a knee injury, osteochondral fractures at the medial inferior edge of the patella are highly suggestive of this injury pattern. Treatment of an acute lateral patellar dislocation typically consists of reduction and the use of an extension brace or cast for 3 weeks with immediate weight bearing. Range of motion in flexion is increasingly permitted over the following 3 to 4 weeks. Akin et al.\(^{174}\) prospectively studied 74 patients with primary acute patellar dislocations treated initially with a knee immobilizer for comfort allowing them to bear weight as tolerated with crutches. As soon as patient comfort allowed, a patellar stabilizing brace was used and resisted close-chain exercises and passive range of motion in the brace were permitted. Return to sports was allowed when full passive range of motion was regained, when no effusion was present, and when quadriceps muscle strength achieved 80% of the contralateral side. No recurrences were seen at 6 months with this protocol.

Despite the low recurrence rate there remains much controversy regarding the management of these injuries particularly with respect to operative indications. Most authors support operative fixation of a large displaced osteochondral fracture.\(^{57,173-175}\) The presence of a hemarthrosis increases the likelihood that a significant osteochondral fracture has occurred. Articular cartilage injuries are common and have been reported to occur in up to 95% of first-time dislocators.\(^{68}\) This reported high rate of articular cartilage injury has led some authors to advocate routine arthroscopy to evaluate this injury.\(^{67,176}\) However, a consensus statement issued by the International Patellofemoral Study Group in 2007 recommended that patients at high risk (i.e., those with a large hemarthrosis) undergo MRI to detect osteochondral fractures.\(^{173}\) MRI is also helpful in determining medial soft tissue injuries specifically injury to the medial retinaculum, the medial patellofemoral ligament, and/or the VMO.\(^{173}\) This recommendation was made based on the observation that while articular injuries are common not all require treatment. A second controversy is whether primary patellar dislocators should undergo acute surgical management to decrease the risk of future instability. While there are many reports in the literature, there are only three studies that directly compare operative and nonoperative management.\(^{173,178,179}\) None of these studies were able to identify any difference in outcome between the two treatment groups. Therefore, relative indications for early surgical treatment have included concurrent osteochondral injury, palpable disruption of the medial patellofemoral ligament-VMO-adductor mechanism, MRI findings of a large complete avulsion or midsubstance tear of the medial patellofemoral ligament, patellar subluxation on a Merchant view, and early failure of nonoperative management with subsequent redislocation.\(^{173}\)

**AUTHOR’S PREFERRED TECHNIQUE FOR ACUTE PATELLAR DISLOCATIONS**

Patients sustaining a first-time patellar dislocation are treated with closed reduction and immobilization of the knee in extension for 1 to 2 weeks. Radiographs are obtained after reduction. Patients are permitted to fully weight bear in the immobilizer. If a large hemarthrosis is present or plain-film evidence of osteochondral fracture exists, an MRI scan is obtained. At 1 to 2 weeks, the patient is transitioned to a patellar stabilizing brace and begins therapy focusing on range of motion and quadriceps, especially VMO strengthening. Patients may return to athletics when range of motion and strength approach the uninjured side.

**MANAGEMENT OF EXPECTED ADVERSE OUTCOMES AND UNEXPECTED COMPlications IN EXTENSOR MECHANISM INJURIES**

**Loss of Knee Motion**

The most common reasons for a suboptimal outcome after an extensor mechanism injury are the loss of knee flexion and quadriceps weakness (Table 54-18).\(^{20}\) In general, these complications are more closely associated with the injury itself than with the technical aspects of the surgical procedure. An aggressive postoperative program emphasizing early range of motion and quadriceps strengthening is recommended. In order to achieve this goal, it is paramount to achieve an operative repair that is strong enough to allow early postoperative rehabilitation. Most patients will ultimately be able to achieve 90 degrees of flexion. This is critical as it allows for sitting in tight places and also helps with arising from a sitting position. If 90 degrees of flexion is not obtained by 8 weeks postoperatively, a closed manipulation under anesthesia may be considered. However, caution should be used to avoid iatrogenic rerupture of the

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**TABLE 54-18** Common Adverse Outcomes and Complications following Extensor Mechanism Injury

- Loss of knee range of motion
- Quadriceps weakness
- Extensor Lag
- Painful hardware
- Infection
- Wound breakdown
- Loss of fixation
- Refracture
- Tendon rupture
- Nonunion
- Knee arthritis
tendon or refracture. Arthroscopic debridement and manipulation may also be considered to treat a flexion contracture or more severe flexion loss.180

**Extensor Mechanism Weakness**

Persistent quadriceps atrophy is noted in many patients but may not compromise final function. Siwek and Rao113 reported that 75% of their patients who underwent acute quadriceps tendon repair had persistent quadriceps atrophy ranging from 2 to 4 cm. However, despite the marked atrophy most had strength which was adequate for normal knee function. In regard to patellar fracture, persistent articular step-off has been correlated with decreased quadriceps strength.181 The treatment for an extensor lag secondary to weakness or atrophy is a vigorous rehabilitation program.

**Symptomatic Retained Hardware**

The subcutaneous location of the patella and extensor mechanism results in a high incidence of prominent or symptomatic hardware. The problem is more common with the addition of a cerclage or tension band wire. Symptoms are related to irritation of the capsule and tendons by the implants. Up to a 40% incidence of soft tissue irritation from hardware that necessitated removal was reported in three series.29,103,182 Removal of prominent cerclage or K-wires usually alleviates symptoms and can be performed on an elective basis. The use of nonabsorbable suture in place of metal wire has become more popular in an attempt to avoid this complication and comparatively fewer reoperations for symptomatic hardware have been reported.32,93,96

**Infection and Wound Complications**

Infection and wound complications are infrequent in closed injuries and often are related to patient-specific conditions and the subcutaneous positioning of heavy sutures or wires used in surgical repair. Sutures should not be placed directly in line with the incision to minimize the risk of delayed wound healing. Placing the skin incision lateral to the tibial tubercle may provide better soft tissue coverage. A postoperative hematoma can result in pain and an increased risk of wound dehiscence and infection. The use of closed suction drainage is recommended to avoid hemarthrosis formation. While infection after surgical management of closed injuries is relatively uncommon, the rate of postoperative infection following open patella fractures has been reported to be as high as 10.7%.102 Surgical debridement of nonviable tissue (soft tissue or bone) and evaluation of the stability of fixation remain the standard tenets of care. After thorough irrigation and debridement, stable fixation can be retained. Intraoperative cultures should be used to guide an organism-specific, 6-week course of intravenous antibiotics. Suppressive oral antibiotics can be considered until fracture union is secured and hardware removal can be undertaken. In the vast majority of cases, early recognition of infection and aggressive debridement of nonviable tissue will allow for preservation of the patella. A total patellectomy, however, rarely may be necessary in situations of intractable osteomyelitis and secondary nonunion.

**Loss of Fixation/Refracture/Rerupture**

The rate of loss of reduction after open reduction and internal fixation of patellar fractures has been reported to range from 0% to 20% in clinical series.28,29,103 Inadequate fixation, severe comminution, early aggressive rehabilitation, and patient noncompliance have all been implicated as risk factors. Smith et al.103 noted 11 cases of lost reduction in a series of 51 patients. Five cases were attributed to technical errors in tension band wire placement, five to patient noncompliance, and one to sequelae of infection. Nine cases had symptomatic hardware that ultimately required removal. Nonoperative management with a period of immobilization may be acceptable with minimal displacement (≤2 mm) or incongruity of the fracture fragments after loss of reduction. However, reoperation is warranted if the extensor mechanism is compromised or separation of fragments or incongruity of more than 3 to 4 mm has developed.

Reoperation after tendon repair can be seen in patients who return to activities too early before the bone–tendon junction has healed. Timely diagnosis and revision is usually successful in re-establishing knee motion and strength. Competitive sports should not be allowed for 4 to 6 months to allow time for sufficient tendon healing and remodeling. Isokinetic strength should be regained before resuming high-risk activities.

**Delayed Union and Nonunion**

Nonunion occurs infrequently in patellar fractures with an incidence ranging between 1% and 12.5%.26,51,74 Factors associated with nonunion include transverse fractures, open fractures, and nonoperative treatment.80 Elderly patients may tolerate a nonunion well with minimal functional deficits even with persistent muscle weakness and an extensor lag. However, reoperation should be considered in young, active patients as a recent systematic review reported no cases of successful union in conservatively treated patellar nonunions.80 Revision surgery with rigid internal fixation and autogenous bone grafting provides better opportunity for union. Weber et al.26 achieved a 100% union rate in their series of patellar fracture nonunions using these techniques. Uvaraj et al.183 recently presented outcomes of surgical management of 22 patellar nonunions treated with a median of 3 months from injury to surgery. Nineteen cases were treated with tension band wiring +/- cerclage and three cases were managed with patellectomy. At a median of 5.5-year follow-up, 91% good to excellent results were seen.183 Intraoperatively, if extensive cartilage injury is noted or the fragment appears to have a poor blood supply, a partial patellectomy may be considered. Whether revision internal fixation or partial patellectomy is undertaken, reconstruction of the extensor mechanism should be performed whenever possible. For long-standing nonunions, a shortened and contracted quadriceps tendon may necessitate tendon mobilization and quadricepsplasty.184,185

**Post-traumatic Arthritis/Pain**

Post-traumatic osteoarthritis can be the sequela of patellar fractures. The etiology is likely multifactorial, and may include (i) articular cartilage damage at the time of injury; (ii) inadequate reduction and restoration of articular congruity, and
(iii) excessive callus formation and secondary articular incongruity. Nummi reviewed more than 700 patellar fractures and found radiographic evidence of patellofemoral arthritis in 56.4% of the patients. Sorensen reviewed more than 700 patellar fractures and found that 56.4% of the patients. Sorensen at 10 to 30 years follow-up reported a 70% rate of radiographic signs of arthritis after patellar fracture. Despite its frequency, most patellofemoral pain can be managed conservatively with rest, physical therapy, and nonsteroidal anti-inflammatory medications. Severe debilitating patellofemoral arthritis can be treated with a patellectomy or patellofemoral arthroplasty. Nonanatomic attachment of the patellar tendon to the patellar remnant after partial patellectomy can lead to abnormal patellar tilt, and has been implicated as a cause of patellofemoral arthritis. In 1958, Dauthie and Hutchinson reported tilting of the patella in five of seven patients with postoperative arthritis, and attributed these changes to malalignment from attachment of the patellar tendon to the anterior cortex of the patella.

SUMMARY, CONTROVERSIES, AND FUTURE DIRECTIONS

Extensor mechanism injuries encompass a wide array of injury patterns. Good to excellent outcomes can be achieved in the treatment of acute injuries with numerous treatment strategies; however, close attention to the specific injury pattern and careful nonoperative and surgical technique is paramount in the successful treatment of these injuries.

In the event of complete extensor mechanism disruption, the indications for operative intervention are rarely debated; however, the treatment constructs and postoperative rehabilitation remain somewhat controversial. The paucity of high-quality literature contributes to this ongoing debate. Continued research on alternatives to stainless steel wire in tension band constructs holds promise in minimizing soft tissue irritation and subsequent reoperation, while limited reports of suture anchor fixation for quadriceps or patellar tendon ruptures as well as partial patellectomy indicate this technique may be a less invasive alternative with similar outcomes. In addition, validation of a patellar fracture classification and development of a validated outcome score specific to extensor tendon ruptures and patellar fractures will increase the quality of future research.

REFERENCES

64. Wiberg G. Roentgenographic and anatomic studies on the fractures by partial patellectomy.
65. Oetterling B. Anomalous patellae.
AU1: Head levels H1 and H2 have been updated according to the template (in text also). Please check and confirm the change made in local toc and text.

AU2: As per layout received, “Author’s Preferred Treatment Method” was in box format. But in the sample approval chapter they were set in local TOC also. Please check and confirm.

AU3: “Bruce and Walmsley” have been changed to Kelly et al. as per reference list. Please check and confirm.

AU4: The author name “Pauwel” has been changed to “Muller et al.” as per the reference list. Please check and confirm.

AU5: “Nummi” has been changed to “Gunal et al.” as per reference list. Please check and confirm.

AU6: The heading “Patellar Fracture and Extensor Mechanism Injury Imaging and other diagnostic Studies” has been changed to “Patellar Fracture Imaging and Other Diagnostic Studies” as per template. Please check and confirm.

AU7: Please check whether the unit provided in “inch” can be converted to “unit in centimeters” (similar for units in “pound” can be changed to unit in “kg”).

AU8: The heading “Patellar Fracture and Extensor Mechanism Injury Outcome Measures” has been changed to “Measures of Patellar Fracture and Extensor Mechanism Injury Outcomes” as per template. Please check and confirm.

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AU10: Please check whether the heading “Technique” can be changed to “Partial Patellectomy Surgical Technique.”

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AU16: As per table caption please confirm whether we can change Indications and Contraindications in the first and second columns, respectively.

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AU19: Author for Figure 3 - the label for the ratio was changed per the note from the editor – was unsure if there were any other changes needed to the figure. If so please mark up the proof and either the typesetter or publisher will make the change and send you a revised proof for review and approval.

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