Patella Fractures: Approach to Treatment

ABSTRACT

Patellar fracture morphology varies based on the mechanism of injury. Most fractures are either a result of direct impact or through an indirect eccentric extensor contraction injury. Each fracture pattern requires appropriate preoperative planning and individualization of the fixation method. Displaced fractures affect the extension apparatus, and often require surgical fixation. Surgical treatment is recommended in fractures with any of the following features: articular step-off > 2 mm, > 3 mm of fracture displacement, open fractures, and displaced fractures affecting the extensor mechanism. Meticulous handling of the soft-tissue envelope is of the utmost importance, given the patella’s tenuous blood supply and limited soft-tissue envelope. Incongruent articular surface can result in detrimental long-term effects; therefore, surgical treatment is directed toward anatomic reduction and fixation. The evolution of patellar fracture fixation continues to maximize options to balance rigid fixation with low-profile fixation constructs. Improving functional outcomes, minimizing soft-tissue irritation, and limiting postoperative complications are possible by using the therapeutic principles of rigid anatomical fixation and meticulous soft-tissue handling.

Anatomy

As the largest sesamoid bone in the body, the patella’s primary ossification typically occurs by the age of 5 or 6 years. The patella forms from a single ossification center in 97% to 98% of patients, whereas in 2% to 3% of the cohort, it develops as a bipartite patella. This usually occurs when the secondary ossific nucleus fails to unite with the primary nucleus. The superolateral aspect of the patella is the most common site of the secondary nucleus.

The patella is located anterior to the knee joint with musculotendinous insertions of the quadriceps tendon and tensor fascia lata into the anteromedial margin. The patellar ligament arises from the inferior pole attaching to the tibial tubercle. The lateral and medial retinacula are formed by the quadriceps aponeurosis, vastus lateralis, iliobial band, and vastus medialis, respectively. Posteriorly, the articulating surface is composed of a medial facet and larger lateral facet, separated by a median vertical ridge. The
medial facet contains a far medial portion known as the odd facet, which is in contact with the femoral condyle in full flexion. The thickest articular cartilage in the body covers this patellar articular surface. The ligamentous and tendinous insertions maintain the patellar articulation within the femoral trochlea while enhancing the biomechanical advantage of the knee extensor mechanism.\textsuperscript{1}

The vascular supply to the patella is primarily derived from an extraosseous and intraosseous blood supply arising from an anastomotic ring from the genicular and anterior tibial recurrent arteries and midpatellar vessels. Lazaro et al\textsuperscript{2} demonstrated that the inferomedial vessels were the most dominant vessel in 80\% of cadavers in their vascular evaluation of the patellar blood supply.

**Patella Biomechanics**

The patella serves as an articulating fulcrum to increase the moment arm of the extensor mechanism. In addition, it notably improves the efficiency of the quadriceps muscle by elevating the extensor mechanisms from the axis of rotation of the knee and increases the torque generated. It also aids in reducing frictional wear that would otherwise deteriorate the extensor mechanism tendon. When the knee is fully flexed, the patella is a link between the quadriceps and patellar ligament. Daily activities generate patellofemoral compressive forces of 3.3 times body weight while climbing stairs and 7.6 times body weight while squatting.\textsuperscript{3} The patella engages the femur from 45° flexion to full extension, and this displaces the extensor mechanism from the mechanical axis of the knee, increasing torque generation to allow for terminal extension.\textsuperscript{1,4}

**Mechanism of Injury**

Patellar fractures may result from either direct or indirect forces but usually involve a combination of the two forces. A direct blow to the patella usually results from a ground level fall or dashboard injury from a motor vehicle collision. This mechanism of injury typically results in a comminuted/stellate fracture pattern with articular injury. Indirect trauma typically occurs when the mechanical properties of bone are overcome by eccentric loading forces. The patella fails under tension by rapid knee flexion against a contracted quadriceps. These indirect injuries present as a transverse fracture pattern with larger displacement, retinacular injury, and less articular injury/impaction.\textsuperscript{5}

**Clinical History and Assessment**

A thorough history and physical examination must be done for patients presenting with anterior knee pain. High-energy dashboard knee injuries should be evaluated for associated femoral neck fractures, posterior wall acetabular fractures, and hip dislocations. Athletes presenting with indirect mechanisms or twisting mechanisms should also be assessed carefully for associated injuries. It has been reported that 95\% of patients with acute lateral patella dislocations have articular cartilage injuries to the patellofemoral joint.\textsuperscript{6}

A physical examination may reveal swelling, palpable defects, lacerations, or abrasions. Detection of traumatic arthrotomy of the knee can be accomplished with the detection of intra-articular air on CT as recent literature has demonstrated improved sensitivity and specificity compared with a saline load test.\textsuperscript{7} Competence of the extensor mechanism should be assessed using an active straight leg raise test. To avoid a false-positive secondary to pain, a knee aspiration and intra-articular injection of local anesthetic may be required.

**Imaging**

AP, lateral, and two oblique knee radiographs should be obtained for patella fractures. This four radiograph combination has been shown to notably improve sensitivity for fracture detection in comparison with conservative two radiographic views (AP, and lateral).\textsuperscript{8} Four views including the use of a flexed lateral view may provide additional information to guide surgical decision-making and help determine retinacular integrity.

Advanced imaging may be considered for comminuted, occult, or stress fractures. CT scan has been shown to affect surgical management plans in 49\% of patients and change fracture classification in 66\% of patients assessed.\textsuperscript{9} MRI is highly sensitive for the detection of occult fracture, cartilage damage, and subchondral fracture and provides additional information regarding the integrity of the extensor mechanism; however, this is not indicated for acute displaced patella fractures.

**Classification**

Patella fractures are commonly described by fracture pattern and amount of displacement. The Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification uses the long bone classification system described by Müller. In contrast, and the Orthopaedic Trauma Association is based on the degree of articular involvement and the number of fracture fragments.
Management

Optimal treatment of patella fractures includes restoration of a functional extensor mechanism, the reestablishment of articular congruity, and preservation of patella bone stock.

Nonoperative

Nonoperative management may be indicated for patella fractures with an intact/competent extensor mechanism, <1 to 4 mm of fracture displacement, and less than 2 to 3 mm of articular incongruity or articular step-off. Patient age, functional status, and bone quality must also be considered. Nonsurgical treatment regimens include weight-bearing as tolerated with long leg immobilization (cylinder cast, knee immobilizer, or hinged knee brace) for a duration of 4 to 6 weeks, followed by the initiation of range of motion. Previous evidence supported that nonsurgical management is associated with good-to-excellent outcomes, but recently, Cooper et al reported poor functional outcome scores with minimally displaced fractures. Further long-term clinical trials are needed to define appropriate nonsurgical treatment indications.

Nonoperative treatment for displaced patella fractures is reserved for those with limited functional status or contraindications to surgery. At the 2-year follow-up, Pritchett reported all 18 patients with displaced patella fractures developed a \( \pm 20^\circ \) extensor lag, but only three patients reported notable limitations in their activities. The natural history, as well as the implications and limitations of nonoperative treatment of non-displaced and displaced patella fractures, should be discussed with patients.

Surgical

Common indications for patella fracture fixation includes incompetent extensor mechanism, fracture separation greater than 2 to 4 mm or step-off greater than 2 to 3 mm, and intra-articular loose bodies. Active communication and patient/injury-specific discussions should occur regarding open reduction and internal fixation because of the myriad of treatment options and their associated risks and benefits.

Three common surgical approaches exist to patellar fracture fixation. The most common being a longitudinal midline extensile incision centered over the patella. Direct visualization of the articular surface is difficult and often requires palpation of the articular surface to assess articular reduction. This approach is most useful for the fixation of noncomminuted transverse fractures with large fracture fragments. Accessory fluoroscopic patellar views of \( 17^\circ \) of patellar external rotation (range \( 12^\circ -35^\circ \)) and \( 26.5^\circ \) of patellar internal rotation provide tangential views of the lateral and medial facets, respectively. This aids in confirmation of anatomic articular reduction.

The lateral parapatellar approach allows for visualization of the articular surface for comminuted articular fractures requiring direct reduction (Figure 1). This technique can be done with a midline skin approach or a more lateral skin approach. It preserves the major inferomedial blood supply of the patella while providing extensive visualization of the articular surface.

The median parapatellar approach has also been described, but it does include a risk to the inferomedial blood supply of the patella. However, retrospective evaluation of Yoon et al of this approach demonstrated no cases of osteonecrosis or weakening of the extensor mechanism with this approach.

Tension Band Construct Fixation

Tension-band construct is the most common surgical technique for patellar fractures. The technique converts the anterior tension forces produced by the extensor mechanism and knee flexion into compression forces at the articular surface. Two 2.0 mm K-wires are placed perpendicular to the fracture line along the subchondral surface after fracture reduction. A metal low-gauge wire tension band is applied in a figure eight-shaped manner to compress the fracture. The ends of the K-wires are bent...
and buried in the proximal and distal aspects of the patella. The tension band wires are then twisted and buried in the patella. Prominent hardware in tension band wiring has led to hardware removal rates reported as high as 31.6%.\(^\text{16}\) This has led to a progressive evolution in the fixation technique.

Improved longitudinal stabilization of the patellar fracture with the use of screw fixation rather than K-wires was the first advancement of the tension band. Screws provide greater rigidity and improved resistance against tensile loading when compared with K-wires. The modified tension band construct with cannulated screws has been shown to be superior in preventing fracture displacement and improving bending strength.\(^\text{17-19}\)

The tension-band technique has continued to evolve with the introduction of braided and nonabsorbable sutures. Replacement of low gauge wire with high strength sutures has demonstrated comparable strength and improved stress distribution while limiting soft-tissue irritation.\(^\text{20-22}\) Nonabsorbable braided suture or tape has also been used to replace wire for this construct and has been shown to display less creep, greater stiffness, and less extensibility than other sutures.\(^\text{23}\) Utilization of braided/nonabsorbable sutures has decreased the overall risk of revision surgery and wound compromise.\(^\text{24,25}\) In a recent retrospective report on fixation using headed cannulated screws with high strength nonabsorbable suture, Busel and colleagues showed high union rates at 96% and a low rate of symptomatic hardware at 8%. Three of the four cases of symptomatic hardware were due to screw prominence.\(^\text{26}\)

The ultimate goal of the tension band technique is a biomechanically superior construct with little hardware irritation that will allow for early rehabilitation and range of motion. Screw fixation has also evolved along with the high strength suture incorporation. Screw head prominence has been shown to reduce the constructs ability to resist gap formation during cyclic loading testing.\(^\text{27}\) Dual-pitched buried compression screws with suture tension band demonstrated superior biomechanical behaviors over standard headed screw fixation including increased construct rigidity, smaller interfragmentary motion, increased resistance to failure, and greater fixation strength. Martin et al\(^\text{28}\) showed that the mean clinical failure strength for the headless screws construct was almost double that of the headed screws construct. Alayan et al\(^\text{29}\) demonstrated comparable fixation; however, greater fracture gapping was found with buried compression screws and suture fixation compared with wire/cannulated screw constructs. Further clinical comparison of these techniques is still indicated.

### Plate Fixation

Patella fracture plating has increased in popularity for the treatment of displaced, comminuted stellate, and inferior pole type injuries with improvements in low-profile plating options.

A diverse selection of plating options exists to treat the various patella fracture morphologies. Dorsal 2.7 mm fixed-angle plates and dorsally based x-shaped plates have been compared with tension band wiring for transverse patella fractures with excellent results.\(^\text{19,30}\) Locking plate fixation has demonstrated increased ultimate strength of fixation when compared biomechanically with tension band fixation.\(^\text{30}\) Wurm et al\(^\text{31}\) demonstrated notably improved patellar fixation using an anatomically shaped locking plate with unicortical screws in comparison to cortical screws with tension-band wiring. During biomechanical testing, the tension band construct developed a 5 times larger fracture gap compared with plate fixation. In addition to biomechanical success, Wurm et al\(^\text{31}\) reported only a 6% complication rate in the study participants. This complication rate is considerably lower than the complication rate typically reported for patella fractures treated with tension band wiring, which is estimated about 20% to 30%.\(^\text{32}\) Their patients achieved 77% of full function, with patients complaints most commonly regarding kneeling or squatting.

Multiaxial longitudinal cortical and unicortical locked plating for comminuted fractures has been done with the use of a moldable low profile mini-fragment locked plate as well. This technique has demonstrated clinical and biomechanical superiority, with less fracture gap formation over tension band constructs.\(^\text{33-36}\) The low-profile plate allows for the use of 2.4 and 2.7 mm cortical and locking screws through a variable angle mesh. Each plate is custom cut and contoured to fit the fracture morphology (Figures 2 and 3). These provide excellent fixation options for comminuted fractures in patients with and without osteoporotic bone.

Mesh-type plating techniques have demonstrated successful radiographic union while limiting reoperations for nonunion, infection, and symptomatic outcomes.\(^\text{35,37-39}\) In addition, patients have reported improved subjective outcome scores, thigh circumference, strength with closed and open chain knee exercise programs, and 70% less anterior knee pain compared with tension band
Prominent hardware is still a concern with patellar plating, but hardware removal rates have been reported between 0 and 11%,16,33,39,40 that is improved over previously reported removal rates of 32% to 37% with metal tension band constructs.41

Management of Inferior Pole Patella Fractures (Including Partial Patellectomy)

Inferior pole patella fractures are complex injuries due to the degree of comminution that often limits standard fixation techniques. Heterogeneity of patients and patella fractures in the current literature limits definitive conclusions when comparing open reduction and internal fixation with partial patellectomy. Reconstructable inferior pole fractures may be addressed with plate fixation, suture fixation, and suture anchor fixation.

Matejčić et al42 evaluated the basket plate in the treatment of comminuted fractures of the distal pole of the patella. It showed excellent functional outcomes in 81% of patients and good results in the other 18%. In addition, minifragment fixation can be used for fixation of inferior pole fractures that are reconstructable (Figure 4). The goal of fixation is to restore inferior pole alignment while avoiding patellar baja, which may result with inferior pole patellectomy.

Suture fixation for management of inferior pole comminution uses nonabsorbable braided sutures passed through the patellar tendon in a Krakow fashion then passed through the inferior pole comminution.43 These sutures can then be passed through intraosseous tunnels in the patella and tied over the superior pole of the patella (Figure 5). When comparing this technique to tension band wiring for inferior pole comminution, 7.6% of patients required reoperation in the suture

Figure 2

Intraoperative photograph of comminuted patella fracture in a 59-year-old woman after fall from ladder demonstrating (A) low profile minifragment mesh plate contoured to the patient’s patella resulting in (B) anatomic reduction of the articular surface with a low-profile construct (C).

Figure 3

Preoperative (A) AP and (B) lateral radiographs of 45-year-old male cyclist after fall off bicycle demonstrating a comminuted patella intra-articular fracture. One-year postoperative (C) AP and (D) lateral radiographs after fixation with a moldable low-profile minifragment mesh plate construct.
fixation cohort compared with 30.6% of patients in the tension band wiring cohort. A similar technique using suture anchors was described by Kadar et al. They were able to demonstrate similar results to partial patellectomy. Inferior pole fixation is critical to appropriately align the inferior pole because malunion can result in impingement and anterior knee pain. Current literature favors the use of nonabsorbable suture compared with metal fixation to decrease the risk of hardware complications; however, future research remains warranted.

Partial patellectomy should be considered for highly comminuted inferior pole patella fractures where anatomic reduction cannot be achieved through the above mentioned techniques. Whether poor bone quality or complexity of fragmentation preclude fixation, the goals of treatment shift to the retention of a stable portion of the patella to maintain a well-functioning extensor mechanism. Partial patellectomy alters the extensor mechanism by decreasing the lever arm about the knee joint, resulting in up to 33% of patients with abnormal patellar tilting and 42% of patients with patella baja. Anterior reattachment of the patellar tendon to the patella remnant is recommended to minimize the patellofemoral contact stresses. Satisfactory clinical results have been shown with maintenance of at least 60% of the patella, with a notable increase in resulting patellofemoral contact forces. Partial patellectomy has dramatic effects on the patellofemoral mechanics, with up to 55% of patients developing osteoarthritic changes at the 2-year follow-up.

**Total Patellectomy**

As advances in fixation methods have increased, the indication for total patellectomy has notably decreased. A 50% reduction of quadriceps strength is seen with total patellectomy. Retention of any viable patella will result in improved clinical results. In the setting of tumor, infection, failed internal fixation, nonambulators, or severely comminuted fracture with no viable articular fragments, total patellectomy may be indicated.
Open Patella Fractures

Six to nine percent of presenting patella fractures are open injuries, most commonly as a direct result from a high energy vehicular trauma.47 Associated injuries have been reported as high at 80%.48 Anand et al47 showed that open patella fractures are associated with higher injury severity scores and a greater number of associated injuries. Most commonly, these fractures are classified as Gustilo Anderson type II injuries, with rates reported between 53% and 76% of presenting open fractures. Type III injuries have been reported as high as 32%, whereas type I injuries have been reported in 15% of open fractures. Immediate management of open patella fractures requires urgent antibiotics, irrigation, and débridement, followed by definitive fixation.48,49

Historically, open patella fractures are associated with higher incidences of complications compared with closed fractures especially when comparing the rates of infection and nonunion. The rates of infection and nonunion in closed patella fractures have been reported as 0% to 5% and 0% to 3%, respectively. In open fractures, the rate of infection can be as high as 10.7% with a nonunion rate of 7%.5,48,49 Catalano et al48 evaluated a series of open fractures and reported an incidence of deep infection of 10.7%, which correlated with the magnitude of soft-tissue injury. No infections were identified in type I and II fractures treated with immediate internal fixation or primary wound closure or both.

By contrast, a recent meta-analysis of 737 patella fractures found that modern treatment of open fractures, including prompt irrigation and IV antibiotics, decreased the risks of complications. In addition, open fractures did not notably influence the frequency of reoperation, infection, or nonunion.41

Authors’ Preferred Method of Treatment

We recommend determining the surgical approach based on fracture morphology. For midpole transverse fractures, a longitudinal midline incision with full-thickness medial and lateral subcutaneous flaps may be used. The articular surface is then exposed and visualized through the fracture site and along the retinacular rents. After the reduction of the fracture, the fracture reduction should be assessed through the retinacular rents by visualization, palpation, and fluoroscopic assessment using the accessory views. Based on the current literature of failure rates, complications, and patient outcomes, the authors’ preferred method of fixation for transverse fractures is with figure-of-8 tension-band construct with nonabsorbable braided sutures or tape passed through parallel cannulated screws.

For comminuted patella fractures, our preferred technique is a lateral parapatellar approach using interfragmentary screw fixation with minifragment locked neutralization plate. For all patterns, we supplement all fixation with anatomically approximated retinaculum closure.

For open fractures, we recommend urgent antibiotic administration, débridement, irrigation, and definitive fixation when indicated. Skin grafting or flap coverage should be completed within 7 days to reduce the risk of postoperative infection if the wound is not amenable to primary closure.

Postoperative Management and Rehabilitation

No standard postoperative protocol exists after the surgical treatment of patella fractures. Postoperative protocols allow for immediate weight-bearing in extension using a cylinder cast, knee immobilizer, or hinged knee brace locked in full extension. Initially, the knee range of motion is limited to 0 to 30 degrees for 4 to 6 weeks postoperative. After 4 to 6 weeks, the range of motion is slowly progressed. Early exercise programs should incorporate active flexion with passive extension to allow for motion while minimizing the tensile and bending forces on the repair. After 6 weeks, the patient is allowed to range the knee freely without restrictions.

Each rehabilitation program should be modified to fit each individual case, given patient age, bone quality, fixation type, and fixation stability. In cases of potential patient noncompliance, poor fixation, and partial patellectomy cases, a long leg cast in extension postoperatively should be considered.

It has been postulated that using multiplanar plate fixation may allow for the implementation of earlier ranges of motion, although no high-level clinical literature exists comparing postoperative protocols. Singer et al18 demonstrated success and no secondary fracture displacement with mesh plating and early range of motion at 2 weeks postoperatively in their series with a mean of 19.6 months follow-up. All study patients except one regained full knee range of motion.

We recommend a simplified approach, which may be modified pending fracture and patient variables. The protocol includes 4 weeks of weight-bearing as tolerated with immobilization in a hinged knee brace locked in extension. Early physiotherapy and initiation of isometric quadriceps exercise programs may begin 2 weeks...
postoperatively. At the discretion of the surgeon and fixation type, passive and active range of motion may be progressively increased starting at 4 weeks postoperatively. We recommend that a physiotherapist should supervise increases in range of motion. Patients should be allowed to range freely at 6 weeks. Clinical and radiologic signs of healing should be used to advance the patient through the postoperative protocol.

The subcutaneous location of the patella and the demand for early knee motion contribute to the complexity of patella fracture treatment. The reported rates in the literature for hardware removal after patella open reduction and internal fixation vary widely, ranging from 0% to 60%. A meta-analysis investigating the frequency of reoperation, infection, and nonunion after patella fracture fixation reported rates of 33.6%, 3.2%, and 1.3%, respectively.41 The rate of revision surgery is most commonly secondary to symptomatic hardware. This has led to the evolution in patella fracture fixation and management with suture fixation in tension band constructs. In an effort to decrease postoperative complications, low-profile plating techniques have also progressively improved, which has resulted in lower revision surgery rates reported between 5.9% and 11%.16,33,34

Hardware failure is rare after patella fixation, with reported rates from 8% to 12%, in cases managed with screw and Kirschner wire anterior tension band designs.24 The overall risk of breakage and migration of K-wires is low; however, case reports have been found describing the incident. The fragmented metal pieces can be benign or they can in rare cases migrate to the heart.50 Although this was one rare instance, generally, no distal or proximal migration exists of broken hardware.51

Substantial knee extensor weakness has been observed after osteosynthesis partial and total patellectomy. Bayar et al52 found that patients with >1 mm articular incongruity postoperatively had notably higher incidences of thigh atrophy, pain, and increased physical deficits. The weakness and deficits have been shown to last up to 12 months after surgical fixation. Lazaro et al40 series reported that 80% of patients treated with tension band fixation reported anterior knee pain during activities of daily living and objective weakness in strength (−41%), power (−47%), and endurance (−34%). 57% of the patients in that cohort had radiographic evidence of patella baja.

Knee arthrofibrosis and loss of knee range of motion is an established complication after patella fracture. Balancing early postoperative range of motion with fracture healing and fracture stability can be challenging and is patient specific. Patients with postoperative limitations in knee flexion may be considered for manipulation under anesthesia and/or arthroscopic lysis of adhesions after fracture union.53

The incidence of patellofemoral osteoarthritis is difficult to ascertain from the current literature. Patellofemoral osteoarthritis has been reported in 8.5% of cases treated with tension band wiring technique.44 The initial injury-related damage to the articular cartilage compared with the quality of reduction as the cause of early onset of post-traumatic osteoarthritis remains unclear.

Summary

Patella fractures are relatively common and are amenable to a variety of surgical fixation methods. Screws and a modified tension band technique using braided suture or metallic wire is the most frequently used technique for transverse fracture patterns. Advancements in low-profile locking plates have allowed fixation of more comminuted fractures that previously may have been treated with partial patellectomy. Open fractures must be managed with urgent débridement, intravenous antibiotics, and early fixation. Internal fixation methods must be tailored to the fracture pattern and patient profile considering preoperative functional status, bone quality, and soft-tissue envelope. A thoughtful approach to treatment is required, including selecting the surgical intervention that will preserve the most bone stock while providing stability and avoiding soft-tissue irritation. Using lower profile and suture fixation methods may reduce complications such as symptomatic hardware or need for additional procedures.

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References

Levels of evidence are described in the table of contents. In this article, reference 33 is a level II study. References 7, 9, 16, 21, 24, 32, 41, 44, and 47 are level III studies. References 4, 6, 8, 10-12, 15, 25, 26, 31, 33, 37-40, 42, 43, 45, 48, 49, and 51-54 are level IV studies.

References printed in bold type are those published within the past 5 years.


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