13 Epidemiology and Classification of Patella Fractures

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13.1 Anatomy and Biomechanics

The patella has a triangular shape and is the largest sesamoid bone in the human body. It articulates with the femoral trochlea forming the patellofemoral joint, which is, next to the medial and lateral section, described as the third compartment of the knee.

On the proximal pole, termed the basis, three-quarters of the patella's articular surface are covered by a 1 cm or thicker layer of cartilage, while the distal pole, termed the apex, lies extra-articular not being part of the articular congruency. A prominent longitudinal ridge divides the proximal articular region into medial and lateral facets. A vertical ridge along the medial border defines the odd facet [1], while transverse ridges further subdivide the medial and lateral facets. Variations of patella morphology have been described and classified by Wiberg and Baumgartl and are delineated elsewhere [2, 3].

Ossification of the patella occurs between 4 and 7 years of age originating from a single ossification center. With an incidence of 2–6%, an additional ossification center does not merge resulting in a bipartite patella and should not be misdiagnosed as a patella fracture. The typical appearance of the described anatomical variation helps to distinguish between the former and the latter: a patella bipartite is mostly located laterally at the proximal pole and shows a smooth, sclerotic margin and shows no articular step-off. In 50% of cases it presents itself bilaterally. Even rarer is a multipartite patella with an additional dorsal defect. Normally bipartite or multipartite patellae remain asymptomatic.

The patella possesses a complex blood supply via the genicular anastomosis, which nourishes fragments even in comminuted fractures. Feeding arteries are the popliteal, femoral, and tibial arteries and their respective branches.

The patella is part of the extensor mechanism of the knee and is located between the quadriceps tendon and the infrapatellar ligament (patellar tendon), which inserts at the tibial tuberosity. The extensor mechanism is responsible for active knee extension and the ability to maintain an erect position as well as to realize the unassisted gait. The extensor mechanism further consists of medial and lateral retinacula, which in turn are formed by the fascia lata and deep transverse fibers of the patellofemoral ligaments. These fibers along with the iliotibial band act as a

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M. Hanschen et al. (eds.), *Knee Fractures*, Strategies in Fracture Treatments,
https://doi.org/10.1007/978-3-030-81776-3_13

reserve extensor mechanism: they allow to some extent active extension even in the setting of an isolated patella fracture.

Biomechanically, the patella increases the leverage and efficiency of the extensor mechanism. It serves as a hypomochlion for the quadriceps muscle amplifying its force up to 30% [4]. The principal purpose of the patella is linking and displacement [4]. During initial knee extension, the patella functions as a link allowing for transmission of torque generated by the quadriceps muscle to the proximal tibia [5]. In young, physically fit individuals, these forces can exceed 6000 N, which correlates with 2–3 times of the body weight [6]. The displacement function of the patella is most critical from 45 degrees of flexion to terminal extension: it 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 angel of knee flexion [4, 5].

Conversely by transforming tensile forces into compression forces, the patella decelerates knee flexion [7, 8]. This mechanism is also referred to as the "patella femoral joint reaction (PFJR)."

13.2 Etiology and Epidemiology of Patella Fractures

With a reported prevalence at 0.7%–1% of skeletal injuries, patellar fractures are relatively rare [9, 10]. These fractures are most prevalent within the age group of 20–50 years with an incidence ratio of 2:1 in favor of males [9, 11]. Newer studies show that there is a shift towards a more even distribution between the genders [10]. The incidence of patellar fractures in a representative study (10-year time period in northern Denmark) is 13.1/100,000 and increases with increasing age referring to incidence distribution [10]. This also marks patellar fractures as fragility fractures because of their high incidence especially in older females [10].

As a consequence of its anterior location, the thin overlying soft tissue envelope respectively subcutaneous position, the biomechanical function, and the high level of force transmission, the patella is very susceptible to injury. Benli et al. describe vehicle collisions (78.3%) as the most common cause of injury, followed by occupational accidents (13.7%) and domestic accidents (11.4%), respectively [12, 13]. In a *current epidemiological* study conducted by Larsen and colleagues, the frequency of high- and low-energy trauma and mode of injury were further investigated. According to their findings, fall from standing height (69%) was the major cause for patella fractures, followed by road traffic accidents (14%) and sport injuries (7%), while direct blows accounted for 4% [10]. Moreover, in 5% of all cases, patellar luxation is associated with osteochondral fractures [14]. Iatrogenic causes for patellar fractures are perioperative injuries in total knee joint arthroplasty (incidence of 0.68%–21% [13, 15]) and during anterior cruciate ligament reconstruction using autologous patellar ligament grafts [16].

Regarding the trauma mechanism, direct (blunt force) injuries may be low energy, such as after a fall, or high energy, as from a dashboard impact in a motor vehicle collision ("dashboard injuries"). These traumas more likely result in comminution, articular injury, anterior soft tissue damage, and thus open injury [17].

By contrast, indirect injuries typically result from forceful contraction of the quadriceps with the knee in a flexed position leading to exceeding stress in tension and subsequently to fractures of the patella. This substantial force may extend through the close-by retinaculum of the extensor mechanism. Indirect forces thus more likely lead to transverse fractures [18] with possible substantial displacement of fracture fragments.

In clinical reality, combinations of injury patterns are common: patellar fractures are likely caused by both direct and indirect forces: the culmination of a direct blow, quadriceps muscle contraction, and secondary joint collapse [5].

13.3 Fracture Patterns and Classification of Patella Fractures

In addition to anamnesis including injury mechanism and clinical findings, radiographs in anteroposterior, lateral, and axial view of the affected knee are usually sufficient to diagnose a patella fracture. If, in the acute situation, the axial view cannot be obtained due to avoidance of secondary dislocation and/or distress of the patient, alternative diagnostic options such as CT or MRI should be considered if necessary for further treatment.

A CT scan including multiplanar reconstructions is indicated in comminuted fracture patterns or suspected accompanying ligamentous, meniscal, or osteochondral defects, while a MRI can detect additional soft tissue injuries.

Fracture patterns are not only determined by injury mechanism but are also dependent on various other factors such as patient constitution regarding age and bone quality.

Most patellar fractures feature a transverse fracture pattern due to excessive forces generated by the extensor mechanism. Minor avulsion fractures pose the risk of quadriceps or patellar tendon injury and should be further investigated. Direct (blunt force) trauma to a partially flexed knee typically results in vertical fracture patterns. Depending on concomitant injuries to the retinacula and the extensor mechanism, they may not be displaced. Direct trauma mechanisms can also result in comminuted, stellate fracture patterns when impacting the patella against the femur leading to injuries of chondral surfaces of both the patella and the femur condyles.

Patellar fractures are usually classified according to the geometric configuration of fracture lines in conventional radiographs. Regarding fracture displacement Cramer et al. suggested that displacement of less than 3 mm should be considered non-displaced [19].

In principal, patella fractures are differentiated as transvers, vertical, comminuted, and osteochondral.

Rogge, Oestern, and Gossé classified patellar fractures according to fracture localization and fracture lines independent from dislocation level [20]. In their work they describe seven distinguished fracture types:

– Type 1: fractures of the proximal pole
– Type 2: fractures of the distal pole
– Type 3: transverse fractures
– Type 4a: medial vertical fractures
– Type 4b: lateral vertical fractures
– Type 4c: central vertical fractures
– Type 5: stellate fractures
– Type 6: multifragmentary
– Type 7: comminuted fractures

In trauma surgery, the AO (Arbeitsgemeinschaft für Osteosynthesefragen)—ASIF (Association for the Study of Internal Fixation) classification of patella fractures is commonly used. According to the findings of Müller et al. [21], it distinguishes extra-articular fractures (type A), partial articular fractures (type B), and complete articular fractures (type C). With increasing fracture severity, those types are further subdivided.

In 1994, Speck and Regazzoni modified the AO-ASIF classification: instead of focusing on the extent of articular involvement, it rather relies on fracture lines, localization, and extent of dislocation in regard to subsequent surgical management [22] (Table 13.1).

Osteochondral fractures are often associated with high-energy trauma mechanisms, stellate patellar fractures, or after patellar dislocation [5]. Fragments can be torn off the lateral femur condyle or medial patellar facet following patellar subluxation or dislocation [5]. While plain radiographs might not be able to show these injuries, a MRI can assist in detecting these lesions [5, 23].

"Sleeve fractures" are the most prevalent fracture pattern in children and adolescents. These injuries typically occur between 9 and 15 years of age [24].

In these cases a distal pole fragment with a large component of the articular surface avulses from the remaining patella. MRI and sonography are of crucial importance to detect these injuries. As in all patella fractures, the therapeutic aim is the sufficient reconstruction of the extensor mechanism.

Table 13.1 Classification of patella fractures according to Speck and Regazzoni [22]

Type A fractures (vertical fractures)	A1: Non-displaced vertical fractures
	A2: Displaced vertical fractures
	A3: Vertical fractures with additional fragment
Type B fractures (transverse fractures)	B1: Extra-articular pole fracture Proximal pole <5 mm Distal pole >15 mm
	B2: Simple transverse fracture
	B3: Transverse fracture with additional fragment, double transverse fracture
Type C fractures (multifragmentary fractures) mm	C1: Non-displaced multifragmentary fracture
	C2: Multifragmentary fracture, displacement <2
	C3: Multifragmentary, comminuted fracture, displacement >2 mm

13.4 Concomitant Injuries and Open Fractures of the Patella

In most cases concomitant injuries in association with patella fractures are related to higher-energy injuries [25]. These injuries typically include soft tissue damage, hemorrhage (disruption of the pre- and/or infrapatellar bursae), hemarthrosis, and ligamentous (retinacular tearing), meniscal, and osteochondral defects.

Accompanying fractures of the femur and/or the tibia are relatively rare. In high-energy traumas, fracture patterns may also include more severe injuries such as acetabular, femoral neck fractures and dislocation of the hip in terms of so-called chain injuries. Concomitant injuries could be demonstrated in 15–28% [9, 26]. They occurred even more frequently in association with open patellar fractures (up to 80%) [25, 27]. Moreover, associated injuries are most often found in the ipsilateral lower extremity: Melvin and Karunakar and Catalano et al. report 26% and 44% of those fractures, respectively [5, 27].

Open patellar fractures account for 9–13% of all patellar fractures [25, 27, 28]. As is the case for concomitant injuries, open fractures are also affiliated with high-energy injuries following high-energy trauma. Also they are frequently associated with multiple injuries to other bones or organ systems [25, 27, 28] and thus a significantly higher ISS (injury severity score). A greater degree of damage to the soft tissue, cartilage, and comminution has also been reported by Torchia and Lewallen [28].

Classification of open patellar fractures is based on the findings of Gustilo and Anderson according to the extent of soft tissue damage [29]. The treatment is following the same algorithm as in open long bone fracture and open joint fracture care, respectively [30, 31]. The results are comparable to patients with closed fractures [25].

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