6.7 Patella

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6.7 Patella

1 Assessment of fractures and soft tissues

1.1 Surgical anatomy

The patella is the largest sesamoid bone in the human body. It is located in the extensor apparatus of the knee. Anatomical features include the cranial base and the extraarticular caudal apex as well as the anterior extraarticular and the posterior articular surfaces. The rectus femoris and intermedius muscles insert at the base and the vastus medialis and lateralis muscles on either side. The patellar tendon originates from the apex patellae and inserts at the tibial tuberosity.

The articular surface has the thickest layer of cartilage in the body, up to 5 mm, rendering the patella susceptible to chondromalacia and degenerative patellofemoral arthritis.

1.2 History and examination

Patellar fractures make up about 1% of all fractures [1] and are mostly caused by direct trauma to the front of the knee, for example, a direct fall or a blow onto the flexed knee.

- Bone avulsions of the adjacent tendons or pure ruptures of the quadriceps and patellar tendons are caused by indirect forces.

Typical signs are swelling, tenderness, and limited or lost function of the extensor mechanism.

- Preservation of active knee extension does not rule out a patellar fracture if the auxiliary extensors of the knee—the medial and lateral retinacula—are intact [2].

If displacement is significant, the physician can palpate a defect between the fragments and hemarthrosis is present. The examination must include evaluation of the soft tissues, so as not to overlook an injury to the patellar bursa or to omit grading the injury if the fracture is open.

1.3 X-ray evaluation

In addition to the standard x-rays of the knee in two planes, a tangential view of the patella may be useful. In the AP view the patella normally projects into the midline of the femoral sulcus. Its apex is located just above a line drawn across the distal profile of femoral condyles. In the lateral view the proximal tibia must be visible to exclude a bone avulsion of the patellar tendon from the tibial tuberosity. A rupture of the patellar tendon or an abnormal position of the patella like patella alta (high-riding patella) or patella baja (shortening of the tendon) can be recognized with the help of the Insall-Salvati method [3]. This is the relationship of the length of the patella and the patellar tendon on the lateral x-ray. This ratio is normally $r = 1$. A ratio $r < 0.8$ suggests high-riding patella (patella alta) or patellar tendon rupture. The third important plane is the 30° tangential view, which is obtainable in 45° knee flexion. If a longitudinal or osteochondral fracture is suspected, the 30° tangential view is a helpful diagnostic adjunct.

Tomography is helpful in special cases, such as stress fractures, in elderly patients with osteopenia and hemarthrosis, and also in cases of patellar nonunion or malunion [4]. Computed tomography is recommended only for the evaluation of articular incongruity in cases of nonunion, malunion, and femoro-patellar alignment disorders. Scintigraphic examination can be helpful in the diagnosis of stress fractures; a leukocyte scan can reveal signs of osteomyelitis. MRI is helpful to diagnose cartilage defects and lesions. Tendon ruptures and patellar dislocation must be ruled out. Isolated rupture of the quadriceps or patellar tendon must be excluded by clinical evaluation (palpation) and ultrasound scan can be helpful. Dislocation, most commonly occurring in the lateral side, may result in
6  Specific fractures

Osteochondral shear fractures with lesions of the medial margin of the patella.

Bipartite patella results from lack of assimilation of the bone during growth. Located on the proximal lateral quadrant of the patella, the condition is without clinical relevance, is usually bilateral, and has a characteristic x-ray feature with rounded, sclerotic lines rather than the sharp edges and lines of a fracture.

1.4  Fracture classification

The major fracture types are illustrated in Fig 6.7-1.

Each fracture type has its own code consisting of three elements eg, 34-C1.3. The first element, 34, identifies the bone. The AO/OTA classification describes the different fracture types:

<table>
<thead>
<tr>
<th>Type A</th>
<th>Extraarticular, extensor mechanism disrupted</th>
<th>Operative treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type B</td>
<td>Partial articular, extensor mechanism intact, eg, vertical fracture</td>
<td>Nonoperative or operative treatment in case of intraarticular incongruity or danger of secondary dislocation</td>
</tr>
<tr>
<td>Type C</td>
<td>Complete articular disrupted extensor mechanism</td>
<td>Operative treatment</td>
</tr>
</tbody>
</table>

1.5  Decision making

The choice of treatment depends on the type of fracture. There are four possible treatment options:

- Nonoperative treatment is generally possible in the case of closed, nondisplaced fractures with an intact extensor mechanism (34-B).
- Simple fractures with gaps and steps in the articular surface may be stabilized by percutaneous screw fixation under arthroscopic control.
- Most types of fracture need open reduction and osteosynthesis.
- Patellalectomy is reserved for fractures that cannot be reconstructed (34-C3). The recommended therapy for each fracture pattern is included in Tab 6.7-1.
2 Surgical anatomy

The anterior surface is surrounded by an extraosseous arterial ring which receives inflow from branches of the genicular arteries. This anastomotic ring supplies the patella through midpatellar vessels, which penetrate the middle third of the anterior surface, and the polar vessels, which enter the apex. Avascular necrosis is rare but can occur when excessive bilateral incisions are made and the patella is injured.

The infrapatellar branch of the saphenous nerve crosses from medial to the ventrolateral aspect of the tibial head close to the apex of the patella. It runs in the subcutaneous tissue layer and may be at risk in transverse incisions.

2.1 Biomechanics

The patella serves as the fulcrum of the extensor mechanism within two lever arms: the quadriceps tendon (the largest muscle in the body) and the patellar tendon inserting at the tibial tuberosity. Enormous forces are transmitted across the patellafemoral joint. Maximal forces measured within the quadriceps tendon range up to 3,200 N, within the patellar tendon 2,800 N, and in young, physically fit men up to 6,000 N [5]. This corresponds to three to seven times body weight and indicates the load-bearing capacity required of an osteosynthesis. The high pressures created by knee flexion and especially by arising from a sitting position require intact cartilage with adequate gliding properties. The shape of the femoropatellar joint, and hence the posterior surface of the patella, varies widely. Patellar tracking also depends on the configuration of the extensor mechanism and on the balance of the quadriceps muscles. The congruity of the articulation of the patella with the femur changes considerably from extension to flexion. From full extension to 45° of flexion the articular surface of the patella is in contact with the anterior femur. In a knee flexed more than 45° the posterior surface of the quadriceps tendon is in contact with the patellar facets of the femur. This increases the lever arm.

- The increased lever arm of the extensor mechanism, due to the height of the patella, adds an additional 60% of the force needed to gain full (eg, the final 15°) extension.

This fact must be taken into account if patellectomy is performed, since full extension power will be markedly reduced postoperatively.

<table>
<thead>
<tr>
<th>Tab 6.7-1 Summary of surgical options.</th>
</tr>
</thead>
<tbody>
<tr>
<td>34-A Extraarticular pole fractures</td>
</tr>
<tr>
<td>Lag screw plus tension band wire or cerclage to tuberosity</td>
</tr>
<tr>
<td>Transosseous suture of avulsed tendon plus cerclage between patella and tibial tuberosity to protect suture (protection wire)</td>
</tr>
<tr>
<td>34-B Partial articular, vertical fracture</td>
</tr>
<tr>
<td>Nondisplaced: nonoperative</td>
</tr>
<tr>
<td>Displaced, simple: transverse lag screw, additional cerclage in osteoporotic bone</td>
</tr>
<tr>
<td>Multifragmentary (stellate): circumferential cerclage plus tension band</td>
</tr>
<tr>
<td>34-C Complete articular, transverse fracture</td>
</tr>
<tr>
<td>K-wires plus tension band wire</td>
</tr>
<tr>
<td>Plus third fragment: lag screw or K-wire plus tension band wire</td>
</tr>
<tr>
<td>Four or more fragments: K-wires, screws plus tension band wire</td>
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<tr>
<td>Partial or total patellectomy</td>
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</tbody>
</table>
3 Preoperative planning

3.1 Positioning and approaches

The patient is placed supine on a radiolucent table. A bump under the patient’s ipsilateral buttock is helpful to rotate the leg internally. A tourniquet around the thigh gives better visibility. The surgeon has to take into account that the inflated tourniquet can complicate the reduction of the fracture by fixing the quadriceps in a shortened position. To avoid this, the knee should be carefully flexed beyond 90° and the patella manually pushed distally to gain as much length as necessary before the tourniquet is inflated. In some cases it may be helpful to deflate the tourniquet while reducing the fracture. Clinical examination of the knee under anesthesia is of the utmost importance. Associated lesions, such as ligament damage, dislocation, and instability must be ruled out.

Either a longitudinal or a transverse incision can be used (Fig 6.7-2). We prefer the midline longitudinal incision over the patella, because it can be extended proximally or distally and it does not interfere in case of later revision. The transverse approach gives the best cosmetic result, since it lies within Langer’s lines, but may injure the infrapatellar branch of the saphenous nerve. Parapatellar incisions are also possible, especially in the case of an open fracture when one may be able to incorporate skin lesions into the approach. After incision of the superficial fascia, the extensor apparatus is exposed and tears in the auxiliary extensors can be identified. A medial parapatellar arthrotomy is made if it is necessary to inspect the knee joint and intraarticular surgery can be performed as needed. In the case of an open fracture or a preexisting chronic bursitis, the prepatellar bursa may be excised; this is normally not required in closed fractures.

3.2 Reduction techniques and tools

The knee joint and fracture lines must be irrigated and cleared of small debris to allow exact reconstruction. The larger fragments are reduced using a large pointed bone reduction forceps. In type A or C fractures, reduction is easier in a full or hyperextended position of the knee. Longitudinal type B fractures are better reduced with the knee flexed. Anatomical reduction of the articular surface is monitored by palpating the
joint from inside, as neither inspection nor the x-ray will reveal a minor step off. If an inside-out technique is planned, K-wires are inserted in an open manner before the reduction is done. The wires can also be used as joysticks to help in reducing the fragments. Reduction is held by one or two reduction forceps.

### 3.3 Choice of implant

Tension band wiring (chapter 3.2.3), being highly effective in transforming tension force into compression force, is most widely used. Single lag screws, if applied properly, will add to stability but should not be used without a tension band except in longitudinal type B fractures. Articular osteochondral flake fractures can be kept in place with biodegradable pins until healed. Heavy sutures may also serve to reduce important small bone and soft-tissue parts.

**Tension band wiring**
1.25 mm or, exceptionally, 1.0 mm stainless steel wire in combination with 1.6, 1.8, or 2.0 mm K-wires are the implants of choice.

**Lag screws**
The 3.5 mm cortex screw, used as a lag screw, is preferred. The 4.0 mm cancellous bone screw can also be used, but it has some disadvantages. Because of the high density of the patellar bone, reduction may be lost during screw insertion (high torque). Removal of a short threaded cancellous screw may be difficult or impossible.

**Biodegradable implants**
Osteochondral fragments can be fixed with biodegradable pins of 1.6–2.0 mm diameter instead of K-wires. These implants consist of polyglycolic acid (PGA), polydioxanone (PDS), or polylactic acid (PLA). PGA starts to lose stability after 1–2 weeks; while PLA holds for 6 months. These implants are useful only for adaptation of unloaded fragments and are not recommended in areas of high mechanical stress. The same applies to resorbable suture material, which cannot match the tensile strength of metallic wires. Nonresorbable heavy suture material may serve as an alternative in suitable cases. Different factors contribute to the biocompatibility of these implants, and local foreign-body reactions remain a matter of concern. Their advantage is that implant removal can be avoided.

### 4 Surgical treatment—tricks and hints

#### 4.1 Open fractures

Open fractures are emergency cases and require surgery as soon as possible (chapter 4.2).

- **Debridement of contused or contaminated soft tissue is essential and should be combined with irrigation.**

Soft-tissue stripping from the bone fragments must be avoided to maintain blood supply.

**Procedure**
First, the complete extent of the injury must be identified, since the preoperative x-ray may not always reveal all fracture lines. Any extraarticular fracture lines will be detected by clearing a very small amount of overlapping tissue (1 or 2 mm) at the fracture edges. Steps, gaps, and the amount of destroyed or impacted cartilage are noted and any loose fragments are removed from the knee. The joint is irrigated and the articular surface of the corresponding femoral condyle is examined.
4.2 Tension band wiring

The principle is to convert the tension force into compression as the knee is flexed (Fig | Animation 6.7-3). Reduction and fixation can be achieved in two ways, either by first reducing the fracture and then drilling the K-wires through the reduced fragments (outside-in technique) or by first drilling the wires into the unreduced fragments followed by reduction and completion of the fixation (inside-out technique).

Using the outside-in technique, the first wire is drilled in an axial direction, the second one parallel to the first, through the reduced fragments (Fig | Animation 6.7-3). It may be difficult to find the right direction and position for the wires. Alternatively, drilling the two wires from the fracture side inside out should be considered. Before reduction, the blunt ends of the wires must be cut obliquely to make them pointed. After this, the main fragments will be manually reduced and held with a pointed reduction forceps. The K-wires are then drilled forward through the opposite main fragment. (If the bone is very dense, the holes for the K-wires can be predrilled.) The ideal level for the pins lies in the center of the patella, approximately 5 mm below its anterior surface. Often the K-wires are closer to the articular than to the anterior surface. Nevertheless, the principle of tension banding is not disturbed.

A sufficiently long (e.g., 30 cm), 1.25 or 1.0 mm wire is pushed manually as close as possible to the edge between the bone and the protruding pin tips. The wire is placed in the form of a figure-of-eight. The wire should be as close as possible to the bone throughout its whole course. The use of a curved large bore injection needle may be helpful (Fig | Animation 6.7-3c). A cerclage (figure-of-zero) wire has more stability against torsion force. However, if the pins are located near the bone limits, the cerclage can cut into the retinacula and the principle of tension banding is lost. A figure-of-eight is therefore preferred by some authors.
To pass the cerclage wires through the ligamentous structures and around the K-wires close to the bone it may be helpful to use a curved large bore injection needle or suction drain.

The cerclage wire should lie anteriorly to the patella so as to act as a tension band. A figure-of-eight may also be used.

The lateral view demonstrates the tension band principle. With knee flexion, tensile force is converted into compression at the opposite cortex.
While tightening the cerclage with the knee in extension, the reduction is checked by palpating the retropatellar surface. After tightening the cerclage, the proximal pin ends are bent, shortened, and turned towards the quadriceps tendon and driven into the patella to prevent skin irritation and loosening. The distal pin ends are only trimmed, not bent, for easier removal.

**Additional cerclage**
Comminuted fractures can be reduced and stabilized with the tension band technique if they are not too badly displaced (B3 stellate fracture) ([Fig 6.7-4](#)). In such cases, with many small fragments, the tension band technique must be combined with an additional circumferential cerclage around the fractured patella. The placement of this cerclage should be the initial step of stabilization to avoid further displacement while tension band wiring is carried out. This may be more satisfactory with a heavy suture.

**Lag screws only**
Although most patella fractures have transverse fracture lines that require a tension band construction with either K-wires or lag screws, occasionally patella fractures consist of simple vertical splits. Patella fractures may also consist of a large corner piece. In either of these two scenarios, lag screw fixation alone following anatomical reduction provides absolute stability ([Fig 6.7-5](#)). The reason a tension band is not necessary is that the longitudinal integrity of the extensor mechanism is not disrupted by these fracture patterns. The fractures simply need to be repaired to restore anatomical congruity to the articular surface and prevent nonunion.

**Combined tension banding plus lag screws or K-wires**
In transverse fractures, the two main fragments are themselves often further fragmented. Tension band wiring is possible only if the two main fragments have been reconstructed with lag screws. After reduction of fragments and temporary fixation by a pointed reduction forceps, the screws are implanted. Lag screws are inserted closer to the retropatellar surface leaving enough space for the K-wires. For fragments too small to hold a screw, 1.6 mm K-wires are used.

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**Fig 6.7-4a–b**

- **a** Relatively nondisplaced stellate (34-B3) fracture. In the first step a circumferential 1 mm cerclage wire is placed around the “equator” of the patella.
- **b** In the second step the vertical K-wires and the standard anterior tension band configuration are added.
Lag screws plus an anterior band wiring
Fractures of a pole of the patella are best stabilized with lag screws (Fig 6.7-6). As implant pull-out or failure is inevitable, the bending forces must be neutralized by additional anterior tension band wiring. Upper pole fractures are stabilized in this manner, if necessary combined with additional transosseous sutures of the quadriceps tendon.

Transosseous sutures for tendon repair
Very small fragments should be excised and tendon repair is done with transosseous sutures alone. We prefer nonresorbable heavy suture material for the main adaptation and resorbable material for the additional fine sutures. A patellotibial protection wire is usually necessary.
4.3 Patellotibial cerclage

After the patella tendon has been repaired or if fixation of the patellar tendon origin is inadequate because of a multiple, small fragments, the transosseous sutures must be protected with a patellotibial cerclage wire between patella and tibial tuberosity [6] (Fig 6.7-7). The anchoring at the tuberosity can occur around a 3.5 mm cortex screw or through the hole of a cannulated screw. When tightening this, it is necessary to ensure that the knee is able to flex to 90°. This means that in full extension there will be some redundancy of the cerclage wire.

Fig 6.7-7  Transosseous sutures reattaching or repairing the patella tendon are protected by a figure-of-eight wire between patella and tibial tuberosity.

4.4 Partial patellectomy

Partial patellectomy is preferred to total patellectomy, whenever possible, as it keeps the lever arm intact (Fig 6.7-8). A comminuted upper or lower pole and even a comminuted zone in the middle of the patella can be managed best by taking out all small bone fragments. If the damaged zone is in the middle of the patella, a proximal and distal osteotomy with reduction of the main fragments, as in a transverse fracture, can be performed. If the comminuted area is marginal, the bone fragments should be removed in order to prevent osteophyte formation. To avoid tilting the patellar fragment and increasing patellofemoral contact forces, the patellar tendon should be attached near the anterior aspect of the remaining patellar fragment [7]. In poor quality bone, a patellotibial cerclage may need to protect the transosseous suture repair [8].

4.5 Patellectomy

In case of severe comminution and extensive cartilage damage, patellectomy may be the only way to manage the injury. All bone fragments and shredded tissue are removed by sharp dissection leaving as much extensor apparatus as possible. Tendinous reconstruction then follows. A defect zone of 3–4 cm can be bridged by direct repair. Shortening of the extensor apparatus is beneficial as it increases the muscle preload. If a direct suture proves impossible, then inverted V-plasty is recommended [9].

- One should always take into consideration the fact that retention of even one larger fragment will help maintain the lever arm of the patella.
4.6 Wound closure

The arthrotomy is closed and tears in the retinacula may be repaired by resorbable sutures. In open fractures, the small implants can usually be covered by adjacent soft tissue and the skin can be mobilized considerably, so even large skin defects do not pose any problems.

Fig 6.7-8a–d Severe central comminution of the patella. As a salvage procedure, the injured segment may be removed by osteotomy. The two remaining portions are joined together by two lag screws and a tension band wire.
Internal fixation of the patella is generally quite stable. The anterior tension band protects implants (K-wires, lag screws) against pull-out forces and compresses the fracture surface during knee flexion (Fig 6.7-9).

- Following tension band wiring, it is usually not necessary to use casts or braces: Motion allows the dynamic tension band to function by producing compression, which increases stability.

In addition, active motion is beneficial to articular cartilage health. The patient begins with isometric exercises and full weight-bearing mobilization: A knee brace may be helpful until quadriceps control is regained. With injuries of the patella tendon where a patellotibial cerclage has been used, weight bearing may be full with a knee brace that allows 90° of motion only.

**Implant removal**

Implants that do not bother the patient do not have to be removed. In many cases patients complain of discomfort around the patella and request implant removal. This can take place after a minimum of 9–12 months. A patellotibial cerclage should be removed at 12 weeks if 90° knee flexion is not obtained or after breakage if painful.

**Pitfalls and complications**

**Disturbed wound healing**

The optimal plane of tissue dissection lies between the subcutaneous fascia and the extensor apparatus. It is very important not to commit the common error of separating the tissue layers between skin and subcutaneous fascia. The result will be necrosis of wound margins. Improper use of wound hooks can also produce such problems.

**Deep infection**

Revision with debridement and irrigation is indicated every other day until wound healing is secured. With deep infection, long-term antibiotic administration is recommended.

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**Fig 6.7-9a–c** 34-C closed fracture.

a  Closed fracture of the patella.

b–c  After ORIF with tension band wiring (AP and lateral).
**Synovitis from biodegradable implants**
Crystalline decomposition products can create mild to severe sterile synovitis, which may be hard to distinguish from an infection. Arthroscopic intervention may be necessary.

**Late hardware removal**
The irritating end of a K-wire or a cerclage wire should be shortened before the skin is perforated or there is a risk of infection.

- **Hardware for patellar fractures should not be taken out for at least 9–12 months after injury. Dense cortical bone requires this length of time to heal before it can safely withstand high tensile force without protection.**

**Patella baja**
This complication must be avoided and can cause severe limitation of knee flexion. If there is need for a cerclage wire to protect the patella tendon, a patella baja can be produced by misjudging the exact length of the patellar tendon. The opposite knee will indicate the correct position of the patella as described under x-ray evaluation.

**Loss of motion**
In the case of limited flexion, intensive physiotherapy is indicated [10]. If the range of motion does not improve within months, an arthroscopic arthrolysis will be the next step, removing scar contractions from the upper recess. If patellectomy has been performed, tendon rupture is a late complication.

**Posttraumatic arthritis**
This can develop due to severe primary damage of the articular cartilage or if there is secondary damage due to joint incongruity, or a change in the force across the patellofemoral joint. This can occur if the patellar ligament is attached too anteriorly, positioning the distal pole posteriorly. In the first situation, arthroscopic debridement is indicated; in the second, the origin of the tendon should be corrected by transposing it.

### Bibliography


### Acknowledgment
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