(i) Comminuted patellar fractures

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Summary

Purpose of review: This article reviews current best practice for the diagnosis and treatment of comminuted patellar fractures.

Recent findings: Patellar fractures make up about 1% of all fractures. As a rule, fractures of the patella are caused by direct trauma to the knee. A transverse fracture is the most common fracture type.

Open reduction and internal fixation is the treatment of choice for the majority of displaced patellar fractures. Treatment must achieve anatomic reduction of the articular surface and reestablish the continuity of the extensor mechanism. Tension-band wiring, interfragmentary screw fixation and a combination of cerclage wiring and screw fixation are the most accepted techniques for stabilisation. Partial or total patellectomy is generally indicated when the patella is so severely comminuted that an accurate reduction and reconstruction of the retropatellar joint surface cannot be achieved.

Summary: Different methods of stabilisation for patellar fractures are used, depending mainly on the fracture pattern and the amount of displacement. The aims of operative treatment are basically accurate reduction and stable fixation that allows early mobilisation.

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Introduction

The patella is the largest sesamoid bone of the human skeleton. It is integrated into the extensor apparatus and with its articular surface, it is also a component of the patellofemoral joint.

The patella serves as the fulcrum for the extensor mechanism between the quadriceps tendon and the patellar tendon. Forces transmitted across the femoropatellar joint can reach up to three to seven times body weight. In 1985, Kapandji reported that maximal forces within the quadriceps tendon could be as high as 3200 N, and up to 6000 N in the patellar tendon in young, physically fit men.

Patellar fractures represent 0.5–1.5% of all skeletal injuries. Typically, patients are between 30 and 60 years old. As a rule, the mechanism for this injury is direct trauma, such as an impact onto the knee (“dashboard injury”). Indirect trauma mechanisms may produce bony avulsions of the adjacent tendons, and occur infrequently. Fractures can also occur as complications after total knee replacement surgery or after patellar tendon graft transplantation for ACL rupture.
Classification systems

There are different classification systems for patellar fractures: based on the trauma mechanism in direct or indirect injuries, on the grade of displacement in displaced or non-displaced fractures and on the basis of the configuration of the fracture lines in transverse, vertical, marginal, osteochondral or comminuted fractures. These systems are too imprecise for scientific use. The OTA classification, similarly to the AO classification, \textsuperscript{1,4} describes the different fracture types in extra-articular (A), partial articular (B) and complete articular fractures (C) (Fig. 1). Each fracture type has its own code, consisting of three elements, e.g., 45-C1.3. The first element, 45, identifies the bone: the patella. The second element describes the fracture type:

- (A) extra-articular, extensor mechanism disrupted,
- (B) partial articular, extensor mechanism intact, for example, often vertical fractures,
- (C) complete articular, disrupted extensor mechanism.

The classification of Speck and Regazzoni\textsuperscript{5} also differentiates the fracture in three types (A, B, C), with three subgroups for each fracture type. The classification of Rogge et al.\textsuperscript{6} differentiates seven fractures types.

Diagnosis

The medical history is the first step of the diagnostic work-up. Information on the mechanism of trauma helps for estimation of the severity of injury and the fracture pattern. The activity level of the patient and his/her current medical problems are also important for decision making on further treatment.

The clinical examination should include an inspection of the whole extremity. Clinical signs of a patellar fracture are swelling and pain in the knee joint. Fracture blisters, skin lacerations, abrasions or contusions are signs of direct trauma and should be documented. Wounds should be checked to confirm whether the fracture is open or closed. In displaced patellar fractures, a defect zone between the fragments may be palpable. Often there is a hemarthrosis of the knee. Flexion and extension in the knee joint is limited and painful. Active extension and lifting of the leg is usually impossible. However, the ability to extend the knee does not rule out a patellar fracture, because the medial and lateral retinacula may be still intact.\textsuperscript{3} The stability of the knee joint should be carefully examined. Of course a check of the peripheral pulses, the compartments of the leg, and a neurological examination should always be performed. Special interest should be paid to potential ipsilateral concomitant injuries, e.g., acetabular fractures, femoral fractures or tibial fractures, which are signs of serious trauma.

For radiographic examinations, a standard X-ray of the knee in two planes as well as a 30° tangential view of the patella should be performed. In the anteroposterior (AP) view, the patella is normally centred on the medullary axis of the femur. In the lateral view, the patellar fracture is best visible: displacement, intra-articular involvement and degree of comminution can be assessed. Vertical patellar fractures are best seen on the axial view. With the Insall\textsuperscript{7} method of relating the greatest diagonal lengths of the patella and the patellar tendon, abnormal position of the patella, e.g., patella alta or patella baja or a rupture of the patellar ligament are recognisable.

Evaluation of the true degree of damage of the patellar fracture in the conventional radiographic examinations is not always possible due to the cancellous bone structure of the patella. An additional CT-scan is seldom necessary.

![OTA classification for patellar fractures](J Orthop Trauma, 1996).\textsuperscript{4}
However, a CT-scan can be helpful for the evaluation of articular incongruity in cases of non-union, malunion and patellofemoral alignment disorders. Special attention should be paid to bipartite or tripartite patellae, which occur due to a lack of convergence of the bone during growth. Bipartite and tripartite patellae have characteristic signs on the radiographs, with rounded, sclerotic lines in contrast to the sharply edged lines of a fractured patella. For differentiation it can be helpful to compare the radiographs with the contralateral side. Magnet resonance imaging is only recommended in special cases, for example in stress fractures.

Differential diagnoses for patellar fractures are contusion of the knee, tendon ruptures (rupture of the quadriceps tendon or the patellar ligament), injuries of the capsular ligament of the knee and patellar dislocation or growth abnormalities.

Non-operative versus operative treatment

Operative management is the treatment of choice for the majority of patellar fractures, especially those with displacement and intra-articular involvement. The AO recommends the following treatment method, depending on the fracture type (see Table 1).

Displacement of more than 3 mm or articular incongruity of more than 2 mm is considered an indication for surgical treatment. The grade of dislocation can be checked in the radiographic examination whereas stability can be proven by clinical examination. The extensor apparatus is intact if the patient can lift up the extended leg. A secondary loss of position is unlikely.

Contraindications and relative contraindications for surgical treatment include non-displaced or minimally displaced stable fractures. These fractures can be treated non-operatively. Contused or injured skin areas, which preclude a safe surgical approach to the fracture, active infection on the extremity or medical conditions of the patient, which do not permit safe surgical intervention, are contraindications. Open fractures of the patella are treated as other open joint injuries. Open fractures are surgical emergencies; other lesions are best treated as soon as possible, depending on the condition of the local soft tissues.

Therapy

The aim of the therapy is an anatomic reduction and stable fixation of the fracture, which allows early mobilisation.

Stable fractures without dislocation or minimally displaced stable fractures can be treated conservatively. We prefer immobilisation in a semicircular plaster cast, with the knee extended. In longitudinal fractures, full weight bearing is allowed. In transverse fractures, in the first 4 or 6 weeks, only half weight bearing is allowed because of the risk of secondary loss of reduction. Physiotherapy should be performed out of the plaster cast. Active and passive knee mobilisation are limited in the beginning up to 60° of flexion, later on up to 90° of flexion. After 6 weeks, increased weight bearing and free knee motion are allowed. The immobilisation in the plaster cast should be not longer than 6 weeks.

Surgical technique

The patient is positioned supine on a radiolucent operation table. To avoid external rotation of the leg, a cushion is used under the ipsilateral hip. With cushioning below the lower leg, a knee flexion of 30–40° is achieved. This is the optimal position for Kirschner-wire drilling. A tourniquet can be placed high around the involved thigh and inflated to about 300 mmHg, depending on the size of the leg and on the patient’s blood pressure. Use of a tourniquet is not absolutely necessary. The surgeon should take into account the fact that the inflated tourniquet can complicate the reduction of the fracture, as under tourniquet pressure the patella can be displaced proximally due to contraction of

<table>
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<th>Table 1</th>
<th>Recommended therapy from the AO for each fracture pattern.</th>
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<td>Patella #45-</td>
<td>Therpay</td>
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<tr>
<td>45-A</td>
<td>Extra-articular Pole fractures</td>
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<tr>
<td>45-B</td>
<td>Partial articular Vertical fractures</td>
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<td>45-C</td>
<td>Complete articular Transverse fractures</td>
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the quadriceps muscle. Therefore, the knee should be carefully flexed and the patella manually pulled distally before inflating the tourniquet.

The incision can either be longitudinal or transverse. We prefer the longitudinal incision over the patella, because, if necessary, it can be enlarged distally and proximally and does not interfere in case of later revision. For the best cosmetic result, the transverse incision is preferable because it lies within the Langer’s lines. However, one should consider that this approach may injure the infrapatellar branch of the saphenous nerve.

Care should also be taken of the vessels of the geniculate arteries, and an en-bloc preparation of the fasciocutaneous layers under the bursa prepatellaris should follow. Under direct vision, an anatomical reconstruction is performed with the aid of one or several bone reduction forceps. By reducing smaller fracture fragments to each other, we convert a complex fracture pattern into a simple one. Anatomical reduction of the articular surface is checked by digital palpation of the patellofemoral joint inside the knee.

The most common osteosynthesis technique is tension-band wiring. The principle of this technique is to transform distraction forces into compression forces. Two different techniques of tension-band wiring are in use: the outside-in technique and the inside-out technique. In the outside-in technique, the fracture is first reduced and then fixed with two Kirschner wires (1.6 mm stainless-steel wire), which are drilled in the axial direction through the reduced fragments. In the inside-out technique, first the Kirschner wires are drilled into one of the unreduced fragments, and then reduction and completion of the fixation follows. We prefer to drill the Kirschner wires from the distal to the proximal pole because it is easier to find the optimal entry portal in the distal patellar pole for Kirschner-wire drilling. Following Kirschner-wire fixation, a 30 cm segment of a 1.25 mm wire should pass adjacent to and behind the Kirschner wires. Close approximation of the wire to the proximal and distal pole of the patella is recommended. The cerclage wire is placed in the form of a figure-zero or figure-of-eight fashion. The figure-zero fashion in comparison seems more resistant to torsion forces. Nevertheless, both the figure-zero and the figure-of-eight wire enhance total stability and compress the superficial parts of the fracture fragments. Especially the frontal wire changes distraction into compression during knee flexion. For symmetrical tensioning of the wire, a double-loop technique is recommended. (Figs. 2-5 show examples of tension-band wiring). Then, the ends of the two cerclage wires are hand-tightened by lifting them up on the clamp. The proximal pins of the two Kirschner wires are bent, shortened and turned towards the quadriceps tendon and put into the patella to avoid skin irritation and loosening. The distal pins are cut at short length so that they are not prominent within the patellar tendon. Finally, the quality of reduction should be checked again and the knee gently flexed to assess the stability of the fixation.

Before wound closure, the tourniquet is deflated and haemostasis is achieved with electrocoagulation. A suction drain is placed into the knee joint and closure of the wound can be performed in layers. First, closure of the prepatellar bursa with 2–0 resorbable sutures is performed. Then the subcutaneous tissues are closed with simple inverted 2–0 resorbable sutures, and finally skin closure is performed.

With the tension-band wiring technique even comminuted fractures can be reduced and stabilised. In these fractures, the first step of internal fixation after fragment reduction is the placement of the circumferential cerclage wire in order to avoid recurrent displacement of the fragments. An additional figure-of-eight cerclage wire must be combined with the tension-band wiring technique. Screw osteosynthesis is an alternative to the tension-band wiring technique. Depending on the thickness and bone quality of the patellar bone, 6.5 mm cancellous bone screws or 3.5 mm cortical screws can be used. Also, fractures of the superior or inferior pole of the patella or fractures with small fragments can be stabilised by lag screws (see Fig. 6).

In vertical patellar fractures, transverse lag screw fixation in combination with a cerclage wire is a sufficient fixation technique (see Fig. 7).
Another variation of the tension band technique in combination with screws is the use of 4.0 mm cannulated screws with the tension-band wire passed through the cannulated screws and tightened in a double-loop technique. Berg described equivalent clinical results for transverse patellar fractures for fixation with a tensioned anterior...
figure-of-eight wire placed through parallel cannulated screws in comparison to reports of fixation with modified tension-band wiring.

Burvant et al.\textsuperscript{11} and Carpenter et al.\textsuperscript{12} showed, in biomechanical studies, a significantly higher stability for osteosynthesis with screws only or for the combination of cannulated screws with a tension-band wire compared to a single tension-band wire. Scilaris et al.\textsuperscript{13} described, in a biomechanical comparison in transverse non-comminuted patellar fractures, a better fixation with two Kirschner wires and a 1.0 mm braided cable tension loop as opposed to a monofilament wire tension loop.

Fortis et al.\textsuperscript{14} demonstrated in an experimental investigation that tension-band wiring is highly effective for the fixation of the fractured patella but is improved by an additional circular wire.
Osteochondral fragments can be fixed with biodegradable pins. There are implants of polyglycolic acid (PGA), polydioxanone (PDS) or polylactic acid (PLA). These implants are only recommended for adaptation of unloaded fragments and not in areas of high mechanical stress. Their advantage is that implant removal is not necessary.

A new stabilisation technique for comminuted patellar fractures is described by Yammis et al. Instead of the tension-band technique, they used a circular external fixator, which is placed under arthroscopic control. The authors suggested that this treatment can provide enough stability to allow active knee motion in the early postoperative period. In addition, arthroscopic examination of the knee allows assessment of other intra-articular lesions.

With a comminuted patellar fracture, a partial patellectomy may be necessary if adequate anatomic reduction of the displaced fragments is not possible. Whenever possible, partial patellectomy is preferred to total patellectomy because it keeps the fulcrum function of the patella intact. A comminuted upper or lower pole or a comminuted zone in the middle of the patella can be managed by removing the small fragments. Non-resorbable transosseous sutures have to be used after resection of the upper pole for fixation of the quadriceps tendon and after lower pole resection for fixation of the patellar tendon, securing the suture with a tension-band wire. A tilt of the remaining patella should be avoided in all cases.

In cases of severe comminution and extended cartilage damage a patellectomy may be the only option. However, one should be aware that this always means a decrease in muscle strength of the quadriceps muscle. All bony fragments and the damaged tissue should be removed leaving as much extensor apparatus as possible. If the defect zone is more than 4 cm wide and a direct adaptation is not possible, an inversion of the quadriceps tendon in accordance to Miyakawa may be necessary.

Postoperative treatment

The postoperative treatment depends on the fracture type and the stability of surgical fixation. In patients with stable fractures, knee motion exercises begin immediately. Knee flexion is most important for transforming distraction forces into compression forces, and this supports bone healing. Continuous passive motion (CPM) is helpful in the early days after surgery. Drains are removed on the second postoperative day or depending on the amount of wound drainage. The patient begins with isometric exercises and out of bed mobilisation with the help of a physiotherapist. For protection of the osteosynthesis, we prefer mobilisation with a semicircular plaster cast. Normally, full weight bearing is allowed. Walking exercises begin with partial weight bearing of 15–20 kg or half body weight bearing and the help of two crutches for a 6-week duration. Actively assisted motion of the knee is allowed from full extension to 90° of flexion. Total weight bearing without the plaster cast and free motion are allowed after the seventh postoperative week, provided that the patient has a good clinical feeling and that X-rays show ongoing bony healing. Implant removal is possible after 1 year, on average.

Complications and prognosis

Feared complications are disturbed wound healing and deep infection. Careful soft tissue debridement, spared resection and secondary wound closure are recommended to reduce wound healing disturbances. In cases of larger skin defects, split skin grafting or gastrocnemius rotation flaps covered with split skin grafts may be necessary. Infection should be treated aggressively with radical debridement with drainage and with antibiotics.

Bowing of the Kirschner wires or failure of the figure-zero or figure-of-eight fashion wire may happen in patients who perform unlimited and aggressive early active mobilisation. When fracture displacement occurs in relation to the above, re-osteosynthesis is mandatory. Sometimes, rupture of the wire is discovered later on. There is no need for intervention when the patellar fracture is already healed.

Another possible complication after surgical treatment of patellar fractures is loss of fixation and reduction. If there is a loss of fixation without loss of reduction, the leg should temporarily be immobilised. If there are signs of loss of fixation and reduction, a revision of internal fixation should be performed.
Delayed union and non-union are usually the result of a failure of fixation or inadequate initial reduction. This can be avoided by anatomical reduction and good fixation techniques during primary surgery as well as close postoperative follow-up. If there is a delayed union, it can be treated with repeated cerclage-wire techniques. Significant mal-unions may require revision osteosynthesis or patellectomy. Klassen and Trousdale showed in a retrospective study that patients with minimal symptomatic delayed union or non-union of the patella can be successfully treated non-operatively with the knowledge that the fracture will not unite. Operative management of symptomatic patients can be expected to achieve union and increased function of the knee.

Especially in comminuted fractures, arthrofibrosis and loss of knee function are relatively common complications. An aggressive and persistent physical therapy regimen is necessary to avoid these complications or to treat them. For arthrofibrosis, an arthroscopic debridement may be beneficial.

Post-traumatic osteoarthrosis is the consequence of traumatic cartilage damage or suboptimal surgery with remaining steps or gaps. Nevertheless, an unsatisfactory outcome is also possible when the radiographic examination shows an anatomical healing.

As with other articular lesions, there is evidence that optimal reduction will give the best long-time results. Steps and gaps in the articular surface will be responsible for knee complaints such as swelling, pain and diminution of movement.

References