Acute injuries of the extensor mechanism of the knee

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Summary  Injuries of the extensor mechanism are still a challenge for orthopaedic surgeons. Early accurate diagnosis is important, as the method of treatment and the outcome depend on this. However, other factors include the time since injury, as those treated acutely have a more favourable outcome. Numerous techniques have been described for treating disruption of the quadriceps and patellar tendon. The best results have been obtained by anatomical reconstruction of fresh disruption. For patellar fractures, the best results are reported after anatomical reduction and internal fixation with a tension band, while the worst choice is total patellectomy. © 2005 Elsevier Ltd. All rights reserved.

Introduction

Active knee extension is necessary for both standing and walking. However, during these activities, high energy is generated at the knee and the patellofemoral joint, especially during running, jumping and climbing.

Anatomy

The extensor mechanism of the knee consists of the quadriceps muscle and tendon, patella and patellar tendon. The quadriceps muscle originates from the pelvic bones (m. rectus femoris from the anterior inferior iliac spine), the anterior surface of the femur and the intermuscular septa (m. vastus intermedius, vastus medialis and lateralis) inserting into the patella, with a 2 cm length of quadriceps tendon. The patellar tendon is shorter and connects the lower pole of the patella to the tibial tubercle. At maximum flexion, the patella lies deep in the trochlear sulcus (between the femoral condyles). The knee extensor mechanism also consists of the medial and lateral patellar retinaculi, which are reinforced by the fascia lata extension which thickens to form the iliotibial band.

Mechanism of the injury

Since the patella is a subcutaneous bone, without subcutaneous soft tissue, it is susceptible to injury by a direct blow. Other than this, injuries of the...
extensor mechanism are caused by an excessively forceful quadriceps tendon contraction. In young healthy individuals it is less likely for a disruption to occur, while it is more probable and common in the old, or in persons with predisposing factors such as renal failure, secondary hyperparathyroidism, diabetes mellitus, rheumatoid arthritis, gout and other metabolic diseases. It may be caused by large doses of corticosteroids or direct steroid injections. There have been reports of patellar tendon failure after anterior cruciate ligament (ACL) reconstruction with a patella tendon bone (PTB) graft, when the middle third of the patella has been taken and devascularisation of the remaining patellar tendon occurs. A patellar fracture can even occur during ACL reconstruction with a PTB graft. Patellar dislocations can result in patellar osteochondral fractures.

Fractures of the patella

Fractures of the patella occur most frequently in patients between 40 and 50 years of age and they comprise 1% of all fractures. The patella, except on its distal pole, articulates with the femoral trochlea, and during a direct fall on the knee or in dashboard injuries compression forces are generated. Usually, there is a transverse fracture, but longitudinal, as well as avulsion and stress fractures can occur producing a stellate pattern (Fig. 1). The fracture pattern indicates the kind of treatment required.

![Figure 1](image)

Figure 1 Scheme for classification of patellar fractures according to the fracture line pattern: (a) transverse, (b) vertical, (c) marginal, (d) comminuted, (e) osteochondral, and (f) sleeve.

The aim of treatment is to restore anatomically the articular congruity and extension efficacy, as well as to permit early knee motion and weight bearing. In the case of gross comminution, the patella must be sacrificed, and a partial or even total patellectomy is performed. In the latter situation, one must be aware of a significant loss of extension strength and anterior knee protection that results.

Clinical findings

According to Scuderi, fractures of the patella can easily be overlooked. Usually, there is swelling of the soft tissue, while a skin abrasion is present in up to 25% of cases and this can interfere with the timing of surgery and the line of incision. If the parapatellar retinacula (medial and lateral) are preserved, there is minimal displacement of patellar fragments and the patient can raise the extended leg (straight leg-raise), indicating the possibility of non-operative treatment. However, in most cases there is disruption of the extensor retinaculum and mild-to-large displacement of fragments exists with a palpable gap and the patient is unable to raise the leg. In the presence of a large hematoma, the integrity of the knee joint ligaments must be confirmed (ACL-PCL), since a PCL injury is present in 3% of cases. Also a hip examination is necessary, since concomitant fractures of the acetabulum with dislocation of the hip are possible, due to a blow on to the patella with the hip flexed with axial transmission of the forces to the hip joint.

X-ray findings

Standard conventional antero-posterior and lateral radiographs are mandatory in the evaluation of both patellar fractures and disruptions of the quadriceps or patellar tendon. When there is doubt about the existence of patella bipartita or a tendon disruption, a radiograph of the opposite knee joint is helpful. The accessory ossicle of the bipartite patella is always on the superolateral corner of both patellae. If there is a symmetrical high or low position of the patella, an assymetrical patellar position suggests a tendon injury lesion. CT and/or MRI imaging is useful in the evaluation of chondral and tendon injuries.
Classification

Fractures with a displacement less than 2–3 mm step-off are considered non-displaced. The pattern of the fracture on plain and lateral views, enables a classification, i.e. transverse, vertical, superior or inferior pole and comminution. Besides the AO classification, Insall and Duparc classified patellar fractures into three groups: Type I—single transverse fracture, type II—comminution of the inferior pole and type III—global comminution or stellate fractures. Types I and III account for 70% of all patellar fractures.

Treatment

Non-displaced fractures with an intact, undamaged extensor retinaculum, can be treated non-operatively, with a plaster cast above the knee or a knee brace for a period of 4–6 weeks. Isometric quadriceps contraction exercises are instituted immediately, followed by straight leg raising. Weight bearing is allowed. After 6 weeks in a brace, the knee immobiliser can be unlocked to allow an increasing range-of-motion.10

In displaced patellar fractures surgical treatment is indicated.9,15–18 The necessary surgical technique is determined both by the X-ray picture and the intraoperative finding, i.e. sometimes only during surgery can the degree of comminution or number of osteochondral fragments be determined. This can change the initial plan for the internal fixation of the patellar fracture. There are numerous fixation methods: tension banding,15,19,20 tension band with cerclage,21 fixation of patellar fracture with absorbable sutures in children22 or non-absorbable sutures in adults,23,24 simple compression by metal wire or hooping, screw fixation, percutaneous cannulated screw fixation assisted by arthroscopy,25,26 external fixation and partial or total patellectomy.7,27

Transverse patellar fractures are fixed internally with a modified tension band, developed by the AO group (Figs. 2a–d). Thus, the modified tension band method of fixation relies on an anteriorly placed tension band (18-gauge wire) that is anchored by two Kirschner (K) wires placed longitudinally and in parallel to align the patellar fracture. The K wires are best introduced into the bone in the retrograde manner through the proximal fragment and after repositioning they should be driven progradely into the distal fragment of the patella. During reposition and internal fixation the knee is placed in 10 degrees of flexion. Once the tension band is placed around and in the front of patella, further knee flexion produces further impaction of the fragments and, according to Wolf’s law, this induces osteogenesis. Prior to closure of the retinacula, it is wise to palpate the articular surface of the patella in order to check whether accurate reduction has been obtained. Also, the knee should be flexed during the operation and the fracture site checked for stability. Both retinaculae are reconstructed and the knee immobilised postoperatively in 20–25 degrees of flexion for a short period. Partial weight bearing is allowed after 4 weeks.11

Ecker modified Magnusson’s technique by adding an anterior tension band.14,15 Lotke and Ecker’s tension band for transverse patellar fracture fixation is recommended by Aglietti and Buzzi.1 Cerclage alone is the only choice when comminution of the patella exists and when patellectomy should be avoided (Figs. 3a–c).

In the presence of large fragments, fixation can be done with a cannulated screw. Fixation with screws is also performed when the number of fragments should be reduced, prior to the placement of the tension band. Small fragments, which should not be excised, can be fixed with small K wires, which are cut at the surface level. In cases with patellar comminution, fragments can be put together concentrically by hooping with metal wire. External fixation may be indicated in open patellar fractures.7

Partial or total patellectomy is performed when there is no possibility for reconstruction of the patella. Partial patellectomy is preferable to total excision, with preservation of any kind of bone-to-bone contact. In the case of comminution of the proximal or distal pole, the quadriceps or patellar tendon is reattached to the remaining patella bone tissue by per osseous sutures.7,27 The expected outcome of partial patellectomy is increased pressure on the decreased articular surface area. To prevent this, anteriorisation of the patella is preferable, which includes an additionally placed suture secured by a wire (Figs. 4a–d). Also, augmentation and reinforcement with a semitendinosus graft could be performed.7 Favourable to excellent results have been reported in 78–86% of the patients with partial patellectomy.11

Primary total patellectomy is now rarely done, because total patellectomy is a mutilating operation and should be avoided whenever possible. In cases where there is severe patello-femoral arthrosis with pain after internal fixation of a patellar fracture, it is never too late to do the patellectomy. The final result is poor.11,28–31 The aim of total patellectomy is to restore the extensor mechanism without tension. If there is tension on the previous site of the patella, the defect can be closed by a
flap from the rectus femoris muscle fascia or, alternatively, the quadriceps tendon can be turned down. Postoperatively, the limb is immobilised in a cylindrical cast for 6 weeks and a prolonged period (up to 2 years) of rehabilitation is mandatory.\(^\text{11}\)

After the patellectomy the pain and discomfort may persist.\(^\text{31}\)

External fixation is recommended for open fractures.\(^\text{7}\)

**Complications**

Complications after patellar fractures include: stiffness of the knee, patella infera, non-unions, malunions, patello-femoral arthrosis.\(^\text{7, 11}\) According to Aglietti and Buzzi, after the operative treatment of patellar fractures infection occurs in 5\% of cases, aseptic pseudarthrosis also in 5\%, loss of reduction and deep venous thrombosis in 2.5\%, but after total patellectomy the complication rate increases and infection or deep venous thrombosis are recorded in 11\% of cases.\(^\text{1}\)

Open fractures of the patella are usually the result of a high-energy trauma and they are associated with gross comminution. After thorough debridement and irrigation, the treatment should include internal fixation or partial patellectomy. Scuderi recommended internal fixation to preserve as much of the patella as possible.\(^\text{10}\)

Other distinct types of patellar fracture are avulsion and stress fractures of the patella,
especially in children. This can often be inadvertently overlooked.

Avulsion patellar fractures are divided into: superior, inferior, medial or lateral avulsion patellar fractures. The superolateral fracture must be distinguished from the patella bipartita, and the inferior one from Sinding–Larsen–Johansson disease, which is common in jumpers. The superolateral fracture must be distinguished from the patella bipartita, and the inferior one from Sinding–Larsen–Johansson disease, which is common in jumpers.10 Medial and lateral avulsion patellar fractures are osteochondral, and they occur during dislocation of the patella. In the superior pole avulsion fracture, the chondral fragment should be left in place or fixed and not extirpated.10

On the other hand, stress fractures occur mostly in jumpers and running athletes7,32 and they are usually transverse, but vertical ones have also been reported. During knee flexion and quadriceps contraction high forces are generated, which, accompanied by cyclic loading and diminishing of bone strength, results in a stress fracture. Undisplaced stress fractures of the patella can be treated by 4–6 weeks immobilisation, but displaced fractures should be fixed.32

One must keep in mind that stress fractures heal more slowly than acute traumatic ones, and that they can be associated with patellar avascular necrosis.
Disruption of the quadriceps tendon

Besides patellar fractures, another cause of extensor mechanism dysfunction due to trauma is disruption of the quadriceps or patellar tendon. These are less common than fractures of the patella. In addition to disruption of the tendon adjacent to the patella, disruption can also occur at the musculo-tendinous junction or inside the quadriceps muscle belly itself.

Avulsion of m.rectus femoris from the anterior inferior iliac spine is seen on pelvic radiograms. This is not a common injury and it can be treated by rest and analgesics. Surgery is indicated only for competitive sportsmen.

Distally, injuries of the quadriceps muscle belly can occur in the midsubstance. These are commonly misdiagnosed as quadriceps muscle contusions. Actually, the rupture usually occurs in m.rectus femoris and m.vastus medialis. Since direct suture of a muscle is quite impossible, during the first 5 days the defect is filled by a sutured iliotibial band or Dacron prosthesis.

Rupture of the quadriceps tendon is infrequent and occurs mainly in persons over 40 years old, while patellar tendon disruptions occur in patients under the age of 40 years. Ruptures of the quadriceps tendon proximal to the insertion at the proximal patellar pole are palpable, and extension of the knee is impossible. CT, MRI and ultrasound

Figure 4 X-ray picture of comminution of the distal pole of the patella (a,b), treated by partial patellectomy (c,d).
are indicated, especially in chronic cases, in order to show any degeneration in the tendon.\textsuperscript{2,13} Surgery is indicated in most cases of acute and chronic quadriceps tendon ruptures. The history of surgical treatment of extensor mechanism disruptions dates from the time of Gallie. In 1927, Gallie and Le Mesurier\textsuperscript{10} surgically repaired the quadriceps tendon with a fascia lata graft. Numerous techniques have been described for quadriceps tendon ruptures\textsuperscript{33,34} ranging from simple sutures with silk, to wire reinforced repairs, autografts, xenografts, allografts and the use of synthetic materials. Even a kangaroo tendon was used for repairs.\textsuperscript{10,35} McLaughlin proposed two-stage procedures for old ruptures.

In acute ruptures, repair can be obtained by an end-to-end heavy suture,\textsuperscript{2} augmented by sutures passed through drill holes in the patella. A protecting wire which passes through the quadriceps tendon proximally and the tibial tubercle distally according to Muller et al. reinforces the construct\textsuperscript{13} (Figs. 5a–c). The sutures must be strong enough to permit knee flexion to 90°–120° (checked during the operation), but postoperatively a plaster cast or brace is applied above the knee, with tolerated weight bearing.

In chronic disruption of the quadriceps tendon, there is retraction of the tendon tissue by a few centimeters.\textsuperscript{36} The quadriceps tendon can be lengthened by the Codovilla technique which is a V–Y advancement flap\textsuperscript{2} (Fig. 6a). If mobilisation of the proximal tissue is insufficient, then the Scuderi technique\textsuperscript{33} or a tendon graft is employed (Fig. 7). The Scuderi technique can be used to reinforce the suture site both in the tendon allograft and Codovilla flap. Alternatively, reinforcement can be obtained with a protective wire. Postoperatively, the knee is also immobilised in a brace or plaster cast for at least 8 weeks.

**Figure 5** Scheme for operative treatment of acute quadriceps tendon rupture (a,b) and a case with wire reinforcement (c).

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**Patellar tendon ruptures**

Patellar tendon ruptures are at the most distal localisation of the extensor mechanism and occur, as mentioned above, in people younger than 40 years. Patellar tendon rupture is a last stage of tendinopathy, because healthy tendons rarely rupture.\textsuperscript{37} Predisposing factors such as rheumatoid arthritis, diabetes mellitus, chronic renal failure and/or systemic lupus erythematosus, as well as steroid medication are often recorded. The disruption usually occurs at the junction with the lower pole of the patella, and less commonly in the tendon midsubstance. Diagnosis is based on proper clinical examination and in particular the patient is unable to raise the extended leg. The patella may be retracted proximally, but when the retinacula are intact, the patella can be undisplaced. Clinical palpation, ultrasound and MRI examinations are sometimes necessary for the correct diagnosis of patellar tendon rupture in order to exclude bone fragments and intra-articular pathology.\textsuperscript{37} The most useful classification of patellar tendon rupture is that of Siwek, because it recognises immediate versus the delayed diagnosis of rupture.\textsuperscript{33} In most cases, surgical treatment is indicated, particularly when proximal migration of the patella is evident on lateral radiographs.\textsuperscript{38}
Acute patellar tendon ruptures can be treated by end-to-end sutures. Early surgery gives the best results. The recommended technique is a modification of McLaughlin’s procedure. If the tendon tissue is inadequate, then the pull-out technique (through drill holes) through the inferior pole of the patella or tibial tubercle is performed. The suture site can be protected by a wire or PDS, in a similar manner to the quadriceps tendon reconstruction.

For chronic cases (delayed diagnosis) with proximal migration of the patella, both distal mobilisation of the patella (by Steinam pin placed through the patella, or by V–Y lengthening of the quadriceps tendon) and augmentation or tendon substitution are carried out. The results of the delayed repair are inferior to those of acute repair. With a long delay between injury and surgery, the occurrence of quadriceps contracture and proximal patellar migration with fibrosis between the patella and underlying tissue is most likely.

The patellar tendon can be substituted with semitendinosus and gracilis grafts, according to Ecker (Fig. 8), or by a semitendinosus graft only, according to Kelikian and coworkers (Fig. 9). In both techniques the graft is pulled through the hole in the distal pole of the patella and through the

Figure 6 Scheme for operative treatment of chronic quadriceps tendon rupture where distalisation is obtained by a V–Y flap (a,b).

Figure 7 Scheme for operative treatment of chronic quadriceps tendon rupture where the suture site is augmented by a tendon allograft.

Figure 8 Scheme for operative treatment of patellar tendon rupture: patellar tendon substitution by semitendinosus and gracilis tendon graft—Ecker technique.

Figure 9 Scheme for operative treatment of patellar tendon rupture: patellar tendon substitution by semitendinosus graft—Kelikian technique.
tibial tubercle. As well as traction with a Steinman pin, distal mobilisation of the patella in an old, neglected patellar tendon rupture can be obtained using an external ring fixator. In such cases the patella can be mobilised distally by a Z plasty procedure, as recommended by Scuderi. Internal protection of the suture site can be also obtained with LAD, Dacron or PDS-resorbable material.

The timing of patellar tendon repair is the only factor that correlates with the final outcome. Namely, early surgery is the best choice, while rehabilitation in delayed repair is longer and more conservative. Complications include shortening, flexion limitations, decreased quadriceps strength, as well as secondary ruptures and wound infection.

Finally, the extensor mechanism can be disrupted at the distal tubercle level, an avulsion fracture of the tibial tuberosity. This type of injury may be associated with pre-existing Osgood Schlatter disease. Avulsion of the tibial tubercle is most commonly seen in adolescents (ages 12–17) and in 50% of cases the patients are jumpers. The avulsion can be palpated under the skin and a peak can be seen on the lateral radiograms. Operative treatment is suggested for types 2 and 3 of displaced tibial tubercle fractures according to their classification (Ogden type 1, 2, 3).

References


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