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Review

# Adult native knee extensor mechanism ruptures

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ABSTRACT

Extensor mechanism rupture is a serious event requiring prompt diagnosis and treatment. Patella fractures are reportedly six times more frequent than soft tissue injuries such as quadriceps or patella tendon ruptures. Classically quadriceps and patella tendon ruptures are seen more in males, with those over 40 predominantly suffering from quadriceps tendon ruptures, often associated with an underlying condition, whereas patella tendon ruptures are mostly associated with sport injuries and are commonly seen in the under 40s. Almost all types of extensor mechanism ruptures benefit from early management which typically involves surgery.

Diagnosis can be deemed easy to make by demonstrating inability to actively extend the knee, this however can be easily overlooked and missed in a busy emergency department leading to a late diagnosis and necessitating more complex surgery. Earlier surgical intervention and rehabilitation tend to produce improved outcomes.



**Contents**



## Introduction

The patella is the largest sesamoid bone and is the enveloped fulcrum of the extensor apparatus with the quadriceps and patella tendons on either end. Quadriceps-generated forces converge through the patella tendon and patella retinaculae to the tibial tubercle. Discontinuation of the extensor mechanism from either patella fracture or tendon rupture, manifesting by an inability to achieve and maintain knee extension, is a highly disabling injury

Anatomically the quadriceps tendon consists of the tendinous coalescence of four muscles, all innervated by the femoral nerve. The rectus femoris, a double joint muscle, contributes only one fifth of the total generated force, with the remaining three single joint muscles (vastus lateralis, intermedius and medialis) being of greater importance to knee extension. The quadriceps muscle

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group attaches to the patella in three separate layers which consist of the rectus femoris superficially, vastus lateralis and medialis as the middle layer, with the deepest layer formed by vastus intermedius. The pre-patella fascia, formed by an expansion of the vasti and the fascia lata, is also involved in maintaining knee extension [1,2].

The patellar tendon (called a tendon not a ligament as the patella is a sesamoid bone) is the second strongest tendon after the Achilles tendon and is able to withstand forces up to 17.5 times body weight. It's made up from type I collagen (90% of dry weight) and receives its blood supply from a number of sources, with the fat pad responsible for the posterior portion, the retinacular and recurrent tibial artery anteriorly, leaving the proximal and distal insertion areas relatively avascular and more susceptible to rupture [3,4].

Disruption of the extensor mechanism can be divided into bony or soft tissue causes, due to either patella fracture or quadriceps and patella tendon ruptures caused by direct or indirect trauma.

## Patella fracture

### *Diagnosis*

Direct force onto the anterior part of the knee leads to patella compression resulting in significant cartilage damage followed by a fracture with a pattern that is often either stellate or multi-fragmentary. Indirect trauma, in the form of forceful eccentric or concentric quadriceps contraction, tends to lead to transverse superior or inferior pole avulsion patterns of fracture [5–7].

Classification systems ideally are designed to allow communication between physicians, guide treatment and predict outcomes. There is no universally accepted system to classify patella fractures, other than the AO/OTA classification system [8]. It comes as no surprise that commonly descriptive terminology such as transverse, stellate/comminuted, marginal, longitudinal, pole avulsion and osteochondral fracture seem to be preferred.

The diagnosis is often straight forward as the patient presents with a swollen, painful knee, incapable of active extension. On occasion signs can be more subtle and further investigations are required to identify the diagnosis.

Plain radiography is usually sufficient, with orthogonal anterior-posterior (AP) and lateral knee views supplemented with skyline views enabling identification of sagittal plane fractures (Fig. 1).


**Fig. 1.** Plain lateral radiograph of a patella fracture.

### *Management*

Once the diagnosis and pattern of the patella fracture are established, treatment options fall between operative and non-operative.

Excluding significant medical comorbidities as the sole indication, generally it seems that non-operative management can have satisfactory outcomes in fractures patterns with no or very little displacement [5,9]. This usually entails an above knee cast, from the malleoli to the greater trochanter, for 6 weeks. Earlier resumption of knee motion is advocated by some authors [9].

Operative intervention is indicated in all cases demonstrating an inability to straight leg raise and could be considered in patients who can straight leg raise but have an inter-fragmentary gap or articular step of >2–3 mm noted on plain films. Although no clinical studies seem to have demonstrated that the 2–3 mm gap is the clinically significant cut-off, there seems to be a consensus in published literature, mainly in the form of literature reviews and expert opinions [10–12].

Open reduction and internal fixation is classically performed by the tension band wiring technique [13], although other authors have reported similar results with polyester sutures [14] or by passing the wires through cannulated screws and therefore reportedly avoiding k-wire related complications [15]. Good to excellent outcomes are observed in up to 80% of patients who underwent patella fixation with tension band wire [21,28]. Other authors have reported promising results with minimally invasive techniques [16,17] which perhaps on account of their technical difficulty have not become widespread in use.

Total patellectomy should be performed only in exceptional circumstances, such as when reconstruction is impossible, due to poor long term outcomes [18]. Specifically, although total patellectomy may address the problem of pain following a highly comminuted fracture, it significantly reduces the mechanical advantage to the extensor mechanism and results in a reduction to quadriceps strength by up to 49%, making ascending stairs and negotiating deep seats difficult [19,20]. It may also result in ligament instability and atrophy of the quadriceps complex [20]. Partial patellectomy is preferable especially if large fragments with good articular surface are retained [5,21,22] demonstrating near normal outcomes. Even the retention of a small bony fragment has proven beneficial in maintaining the extensor mechanism lever arm [23]. Inferior pole patellectomy in highly comminuted or non-reconstructable fracture patterns, has been reported to lead to 78% good and very good results, demonstrating 85% quadriceps strength as compared to the contralateral side at a mean 8.4 year follow-up [24].

In an attempt to preserve the distal pole, a basket plate enabling osteosynthesis was first introduced in 1988 in Croatia [25]. Although variations of the original plate have since been introduced, the basic design is that of a shaped plate to fit the geometry of the patella, which has a number of hooks and cancellous bone screw holes [25]. Results from the use of this implant were reported in 1996 [26] in a series of two patients and subsequently again in 2004 [27], demonstrating superior outcomes by preserving the inferior pole and preventing patella baja. The largest series was published in 2015 with 142 patients included and the authors reported mostly excellent and good functional outcomes as per the modified Cincinnati knee rating system [25].

### *Complications*

Closed fractures have a reduced risk of deep infection and non-union reported as 0–5% and less than 1% respectively, with open fracture rates much higher at 11% and 7%, respectively [6,28,29].

Intolerance of hardware, such as k-wires, due to close proximity to the skin is the most frequent complaint, with implant removal reported from 0 to 60% and this inconsistency in published literature is put down to the variety of fixation techniques [30]. Symptomatic hardware rates appear to be similar in closed and open patellar fractures, as reported in a matched cohort study by Anand et al[31]. Kumar et al. demonstrated in a retrospective case series that prominent metalwork removal can vary with age, with 22% of their patients over the age of 60 needing this, whereas 40% of patients under the age of 60 needed metalwork removal[32]. This result was not reported as statistically significant by the authors attributed it to the differing demand levels of younger and older patients.

Knee stiffness is another complication recognized after patella fractures, with the length of immobilization not shown to be a significant factor [6,33]. Operative intervention and earlier mobilization has not shown to reduce the risk, with short lever arm manipulation under anaesthesia or arthroscopic arthrolysis recommended by Bell in an expert review article, if no improvement is observed after 6 months [30]. A similar suggestion was made by Kakazu and Archdeacon in their review, again based on expert opinion [11]. Sassoon et al. published the results of their retrospective case series, advocating manipulation under anaesthetic after at least 90 days following surgical fixation, although their cohort of 22 patients included only three patients with isolated patellar fractures [34].

Patellofemoral joint osteoarthritis has been observed following patella fractures, with Nummi reporting patello-femoral arthrosis in half of his study's patients at 2 years after injury [35]. Whether this is down to the quality of reduction or the traumatic primary injury, it still remains unclear [5,36,37].

Good results were reported following patello-femoral arthroplasty in a retrospective series by Argenson et al., using subjective outcome measures in patients with patellofemoral osteoarthritis of various causes, including 20 patients following patellar fracture [38]. Of interest was the fact that in the same study, post-fracture patients seemed to fare slightly worse after patellofemoral arthroplasty, when compared to patients with primary osteoarthritis or patients with osteoarthritis secondary to dysplasia. Other authors suggest distal patella realignment and off-loading procedures, such as Fulkerson or Maquet [39].

Where a patella fracture has been missed and is not tolerated due to pain or quadriceps insufficiency, this can be addressed in a stepwise manner and depending on the resulting late complication, such as non-union, delayed union and malunion. Although non-union or delayed union seem to be more common in transverse configuration fractures, they are infrequent events, with a combined incidence of up to 12.5%, their treatment is often technically challenging [40].

A major determinant of the treatment choice should be the functional demands and pre-injury status of the patient. Klassen reported on a series of 20 patients who presented with a patellar fracture non-union and were treated either non-operatively or operatively. He reported that patients that are minimally symptomatic with patellar non-union or delayed union may be treated non-operatively, accepting that the fracture will not unite. On the other hand, he demonstrated that operative management usually leads to fracture union and improved knee function [41].

Specific surgical options largely depend on fracture pattern and chronicity and include simple freshening-up of the fracture site followed by tension band wiring [42], contralateral tendon-bone-tendon-bone harvesting and reconstruction [43], partial patellectomy and total patellectomy as per the De La Caffiniere & Theis technique [44]. Uvaraj et al. suggested the application of an initial cerclage wire for initial gross approximation of the fracture ends, followed by anterior tension band wiring and removal of the initial cerclage wire. In their series of 22 patients, they did not need to perform a quadricepsplasty in order to reduce the fragments [45].

Other options include a modified V-Y quadricepsplasty followed by fracture fixation or patellectomy, as described by Garg et al. in their retrospective series of 35 patients [46]. Their modification was introduced in order to manage the quadriceps contracture and is in the form of pre-operative traction of the proximal fragment with a skeletal pin-traction system for a few days, followed by the V-Y quadricepsplasty and fixation of the fracture.

Mal-united patella fractures with an articular step-off of 1 mm or higher presented with osteoarthritis more commonly than patients without an articular step, highlighting the importance of anatomical reduction when dealing with these fractures [47].

In a recent Cochrane review it was noted that percutaneous osteosynthesis may give better results than conventional open surgery, with biodegradable implants faring no better than metallic ones for displaced fractures and that patellectomy combined with vastus medialis advancement may be better than simple patellectomy. However the authors noted that available trials had small numbers of patients, emphasising the need for randomised controlled trials and that specific treatment options should be chosen on an individual patient basis [48].

## Soft tissue ruptures

### *Quadriceps tendon ruptures*

Quadriceps tendon ruptures are 8 times more common in males than females, mostly seen in those over 40 years old, peaking at the sixth and seventh decade. They have been noted to be twice as common in the non-dominant limb [49], with bilateral ruptures reported at around 12% of all ruptures [50] and black men exhibiting a 10 fold risk of quadriceps tendon rupture [51].

Quadriceps tendon rupture is usually associated with indirect trauma in a relatively hypovascular zone, 1–2 cm proximal to the superior pole of the patella, with patients under the age of 40 having mid-substance tears and those >40 years of age rupturing at the tendon-bone junction [52]. Such ruptures have also being associated with underlying systemic disease such as renal failure, rheumatoid arthritis, diabetes mellitus, hyperthyroidism, connective tissue disorders [53–56], as well as long term fluoroquinolone [57] and corticosteroid use which leads to fatty infiltration and weakening of the tendon [50].

The diagnosis is again based on failure of active knee extension, with an associated history of pain, occasionally an audible sensation of crepitus, along with signs of palpable gapping and/or a suprapatellar mass due to tendon retraction. Plain radiographs may depict suprapatellar calcification, avulsion of a patella bony fragment, patellar spurs, dystrophic calcification within the tendon and patella baja [1,58,59] (Fig. 2). Even with such typical signs and symptoms, up to 50% of cases have reportedly been missed in the emergency department [60]. If the diagnosis is in doubt or the extent of the tear is in question, an MRI scan may distinguish between complete or incomplete tears as well as give further information regarding the intra-articular state of the knee, as it provides a more visual depiction compared to ultrasound scanning [61].

Management is dependent on the extent as well as the location of tear. In partial ruptures, non-operative management with a cylinder cast for a minimum of 6 weeks, followed by a hinged brace allowing active extension in situ until pain resolves, has been suggested as adequate [62]. Acute complete tears benefit from transosseous repairs, as anchor suture fixation seems to be inadequate [63], and mid-substance tears require end-to-end repair and augmentation, which can be achieved by a reverse

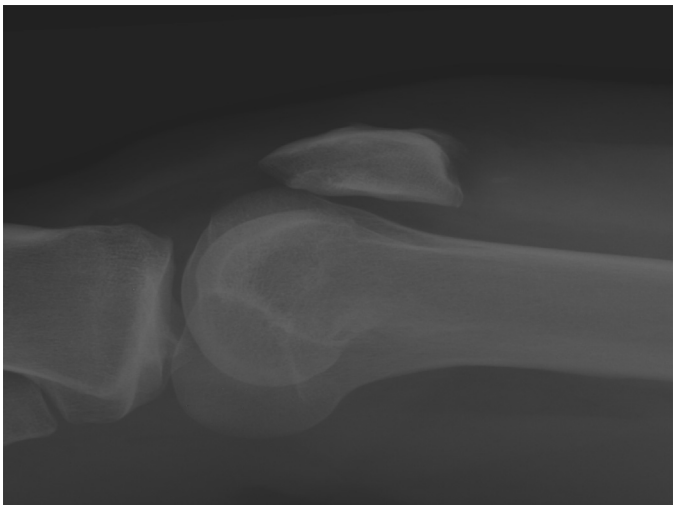

**Fig. 2.** Lateral knee radiograph demonstrating quadriceps tendon rupture with a proximal patella spur.


**Fig. 3.** Demonstrating patella tendon rupture with an associated patella alta.

tendon Scuderi technique flap [64]. The results of early repairs are encouraging, with patients achieving satisfaction rates approaching 90% and return to function in the order of 80–90% [50,65,66].

Chronic quadriceps rupture on the other hand may be significantly more challenging due to tendon scarring and retraction, leading to poorer surgical outcomes when compared to acute repairs [65]. There are reports of favourable outcomes if the tendon can be approximated following medial and lateral releases [67]. When this proves impossible, surgical options include tendon lengthening techniques such as V-Y plasty and the Codvilla technique [54,64], hamstring grafting techniques [67] and synthetic Leeds −Keio ligament implantation, with the added benefit of its collagen inducing properties [68].

Recently, a novel technique using hamstring tendons along with a prolene mesh and autologous platelet rich plasma augmentation was described for a previously twice-failed repair as a salvage procedure [69].

*Patella tendon ruptures*

Patella tendon ruptures are infrequent events, usually seen in active under 40s male patients following direct or indirect trauma. The latter is often in the form of a sudden quadriceps contracture with the knee flexed at around 60°. It is indeed more common to see the patella fracturing instead in such a scenario, suggesting that indirect patella tendon ruptures are perhaps the result of repetitive microtrauma [70–72]. Bilateral patella tendon ruptures are rare and have been reported in association with underlying pathologies [73]. Such pathologies according to a literature review by Rose and Frassica include systemic lupus erythematosus, renal failure, rheumatoid arthritis and primary hyperparathyroidism [74].

Rupture (Fig. 3) is usually followed by intense pain and inability to stand unaided and is associated with a haemarthrosis, a palpable gap and the inability to achieve or maintain knee extension against gravity, with patella alta [59] seen on plain films [71,75–77].

Associated injuries have been noted and include tibial plateau fractures, meniscal tears and intra-articular ligamentous ruptures. The use of MRI and ultrasound scanning has been advocated in order to identify these and assess the degree of tendon rupture, whether complete or incomplete [78,79].

Treatment is usually surgical, as neglected tears or non-operative management leads to patella tendon retraction and scarring, loss of normal knee biomechanics and diminished long term function [71,80].

The technique for repairing acute tears depends on the site of tear, with end-to-end absorbable suturing if mid-substance and through-transosseous tunnel suturing preferred for proximal or distal tears, with the use of heavy non-absorbable suture material [73,80]. The repair is often augmented with a frame-type configuration between the patella and tibial tuberosity, using either cerclage wire or a semitendinosus autograft. It is important to avoid patella baja by comparing the patella radiographically with the contralateral patella at 45° degrees of flexion [71,76]. In proximal tendon avulsions, the tendon is anchored to the bone using custom-made bone anchors or non-absorbable sutures through two parallel patellar bone tunnels. Distal avulsions are rare in adults, and these can be managed with notched staples or bone anchors.

With regards to neglected or chronic tears, especially after the 6 week mark, retrieving the retracted patella is technically challenging with some authors suggesting a transpatellar traction of up to two weeks prior to reconstruction [75,81], usually requiring augmentation in the form of autografts, allografts or synthetics [71,76]. Examples of these include fascia lata or semitendinosus autografts, absorbable materials such as PDS or synthetics such as Dacron [43,75,81,82]. Another option suggested by Dejour et al. is the use of an autologous contralateral graft of tendon-bone-tendon-bone with the advantage of solid bone anchorage [43,83]. Allograft solutions such as Achilles tendon or patella tendon can also be used if needed [84].

Post operative outcomes often include some residual loss of quadriceps strength [85], which does not seem to be affected either by the type of tear or the type of repair [75]. Although early repair is defined as taking place within 3 weeks or less from injury [65], a negative correlation with outcome has been observed if the time interval of trauma to surgery exceeds one week [75]. However, favourable outcomes have been reported in 10 out of 13 chronic repairs, when using contralateral tendon-bone-tendon-bone autograft as described by Dejour et al. [83].

*Rehabilitation of extensor mechanism injuries following repair*

As the quadriceps complex is such a powerful muscle group, rehabilitation following patella tendon reconstruction should be cautious. Some authors recommend strict immobilisation for one

month, followed by a further period of passive motion and eccentric exercises prior to allowing concentric exercises, aiming for full recovery by 4–6 months [1].

Biomechanical and anatomical studies have identified early mobilization as beneficial for tendon healing, maintenance of a healthier articular cartilage and maintaining joint motion, which in turn leads to reduced stiffness. This has prompted rehabilitation protocols that allow early passive flexion between 30° −90° of flexion from the first post-operative day [86,87]. Although these protocols have demonstrated a return to pre-injury sporting activity [73,80,88], controversy remains over the optimal weight-bearing status following surgery [66,88,89].

The risk of re-rupture is of particular concern with up to 40% being reported in patients with previous total knee arthroplasty [90]. Studies have reported re-rupture rates of 1:21 following long leg cast immobilization [91], whereas those with early rehabilitation have a re-rupture rate of 1:39 [85], with Rougraff et al. finding no difference between early range of motion and immobilization [65]. To our knowledge, no randomized controlled trial has assessed rehabilitation protocols or specific surgical techniques [62], leaving the decision to the surgeon's experience and on a case by case basis.

## Conclusion

Knee extensor mechanism rupture in adults mainly comprises patellar fractures, reported as six times more frequent than soft tissue tears of the quadriceps or patella tendons, with surgical intervention considered the gold-standard for the restoration of function when active extension is lost.

With regards to patellar fractures, tension band wiring and early range of motion rehabilitation tend to produce favourable outcomes, with every effort made to avoid patellectomy and preserve bone stock. Hardware removal, stiffness and patello-femoral joint secondary osteoarthritis have been described as potential complications of patella fractures and their treatment.

Quadriceps and patella tendon ruptures have improved outcomes when repaired early, with delayed repairs presenting technical challenges and often requiring augmentation techniques. Complications from these injuries include inability to return to pre-injury level of activity, loss of strength, risk of re-rupture and stiffness. Early rehabilitation protocols, especially when augmentation is utilized, tend to produce good results.

## Conflict of interest

No Author of this review article has any disclosure to make. There is no conflict of interest regarding this article.

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