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REVIEW ARTICLE

# Surgical management of patellofemoral instability part 2: post-operative imaging

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## Abstract

The patellofemoral joint is a complex joint requiring contributions from both bone and soft tissue for its stability. Pathology of the patellofemoral joint manifests as instability or anterior knee pain. Careful clinical and imaging assessment is important for managing these patients with cross-sectional imaging being a vital component in pre-surgical planning. Operative treatment can involve soft tissue procedures, bony procedures or both. The purpose of part 2 of this two-part article is to review the post-operative imaging findings of the knee extensor mechanism. In doing so, we will provide an overview of some of the bony and soft tissue procedures performed with details of their indications and possible complications. An appreciation of the post-operative surgical appearances will ensure a more comprehensive report and can prevent misinterpretation by the radiologist.

**Keywords** Knee · Extensor mechanism · Patellofemoral · Post-operative assessment · Surgery · Instability

## Introduction

There are numerous anatomical and neuromuscular factors that can affect the patellofemoral joint, which in turn can lead to knee pain, patellar instability, and ultimately dysfunction. The decision to operate is often made following through clinical and radiological assessment. Numerous bony and soft tissue operative techniques exist in the management of patellofemoral syndrome, which can be performed in isolation or in conjunction with other procedures [1–3].

We will demonstrate the normal and abnormal post-surgical findings on imaging, and in doing so, we will review the different surgical procedures that a radiologist may encounter.

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## Lateral release and medial reefing

Release of the lateral patellar retinaculum, which is commonly performed arthroscopically, is a purely soft tissue procedure with no appreciable findings on radiography. It can be performed in isolation, or in combination with proximal or distal realignment surgery. However, the role of lateral release for patellar instability is controversial, as cadaveric studies have shown that the forces required to displace the patella laterally are significantly reduced following lateral release. Long-term outcomes following lateral release are less favorable in cases of patellar instability versus patellofemoral pain. There is evidence to support the use of lateral release in cases of excessive lateral pressure syndrome (ELPS), a cause of anterior knee pain due to tightness and hypertrophy of the lateral retinaculum.

Medial reefing (medial capsular plication) describes a procedure of tightening the medial capsulo-ligamentous structures with suture material. Its role in cases of patellar instability has shown promising results, with or without a lateral release. However, in cases of patellar dislocation with proven medial patellofemoral ligament (MPFL) rupture, medial reefing alone does not address the instability issues. The medial retinaculum contributes just 13% to the medial restraining force of the patella, compared to over 50% for the MPFL .

## Imaging findings

Imaging findings are best appreciated on MRI where there may be excess scar tissue formation at the site of surgery, or fluid herniating through the defect in the lateral retinaculum (Fig. 1). Imaging findings can vary depending on whether the procedure was performed open or arthroscopically. An open procedure has been described as producing a "heaped-up" thickened appearance of the distal vastus medialis obliquus along the anterior surface of the superomedial patella with foci of susceptibility artifact [4]. MRI appearances following an arthroscopic approach can be more subtle.

## Complications

Complications of lateral release include medial patellar instability, while over-tightening during medial reefing can lead to abnormal loading of the medial patellofemoral joint (PFJ) and subsequent pain.

## MPFL reconstruction

MPFL reconstruction is used to treat lateral patellar instability due to damage and excess laxity of the medial retinacular structures and MPFL, with a variety of techniques described [5, 6]. It is currently the commonest surgical technique performed for management of PFJ instability. It is indicated in patients with at least two documented PFJ dislocations and excessive lateral patellar mobility but is not performed for patellofemoral pain. PFJ osteoarthritis is a relative contraindication to MPFL reconstruction, as increasing the patellar constraint can lead to greater joint reaction forces and therefore accelerated osteoarthritis and worsening pain. The role of MPFL reconstruction in a subset of 'high risk' first time dislocators is currently being investigated.

Biomechanical studies have suggested that MPFL reconstruction can restore patellar translation and mean medial contact pressures in the presence of a normally located tibial tuberosity, but not when the tibial tuberosity is lateralized by 10-15 mm [7]. Similarly, a study using computational simulation has suggested that lateral patellar maltracking may not be completely corrected following MPFL reconstruction in the presence of trochlear dysplasia (TD) and a lateralized tibial tuberosity. Therefore, patients with these structural abnormalities may be at greater risk of recurrent postoperative instability [8]. However, in the presence of TD isolated MPLF reconstruction has been reported to produce very good results [9], while other studies suggest that in the presence of an increased tibial tubercle-trochlear groove (TT-TG) distance and TD, combined MPFL reconstruction and tibial tuberosity transfer and/or trochleoplasty will produce better outcomes [10–12]. Reconstruction of the medial patellotibial (MPTL) ligament in isolation or combined with MPFL reconstruction has also been described to show good clinical outcomes [13].

## Imaging findings

Post-operative imaging findings will be dictated by the surgical technique, which varies both in relation to graft selection and fixation device. Graft choice includes autograft, allograft, and synthetic options. An overall recurrent instability rate following MPFL reconstruction of 1.8% has been reported in a large meta-analysis [14]. The utilization of gracilis or a double bundle semitendinosus tendon graft is common and has been reported to have good long-term clinical outcome [15]. However, more recently, a technique using a quadriceps tendon autograft has been described with an intact graft pedicle on the patellar side. This means that drilling patellar bone tunnels and screw fixation is no longer necessary, thus reducing the risk of patellar fracture [16]. Patellar fixation options include interference screws and suture anchors. There is no significant difference in the reported rate of redislocation, but suture fixation is associated with improved patient outcome scores [17]. The use of suture anchors also reduces the risk of patellar fracture, and in combination with a biosynthetic graft has been reported to produce reliable reconstruction [18].

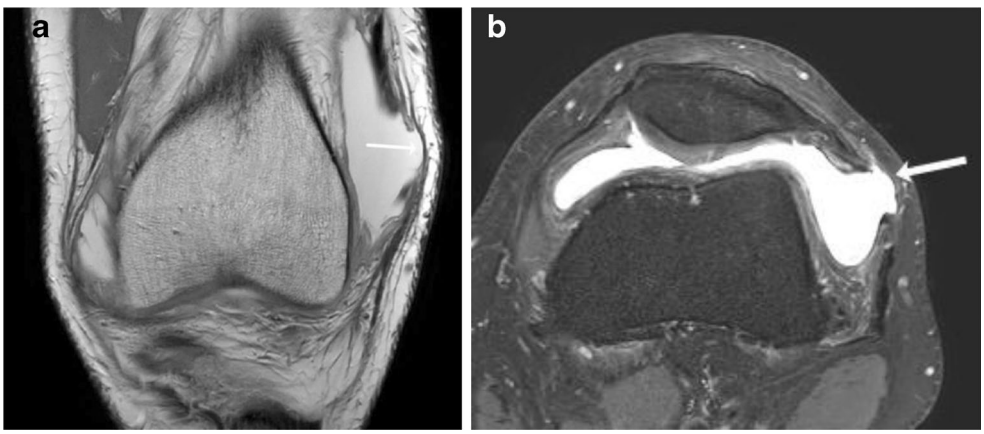


**Fig. 1** A 33-year-old male who underwent a lateral retinaculum release. **a** Coronal PDW FSE and **b** axial fat-suppressed PDW FSE MR images demonstrate fluid herniating through a defect in the lateral retinaculum (*arrows*)

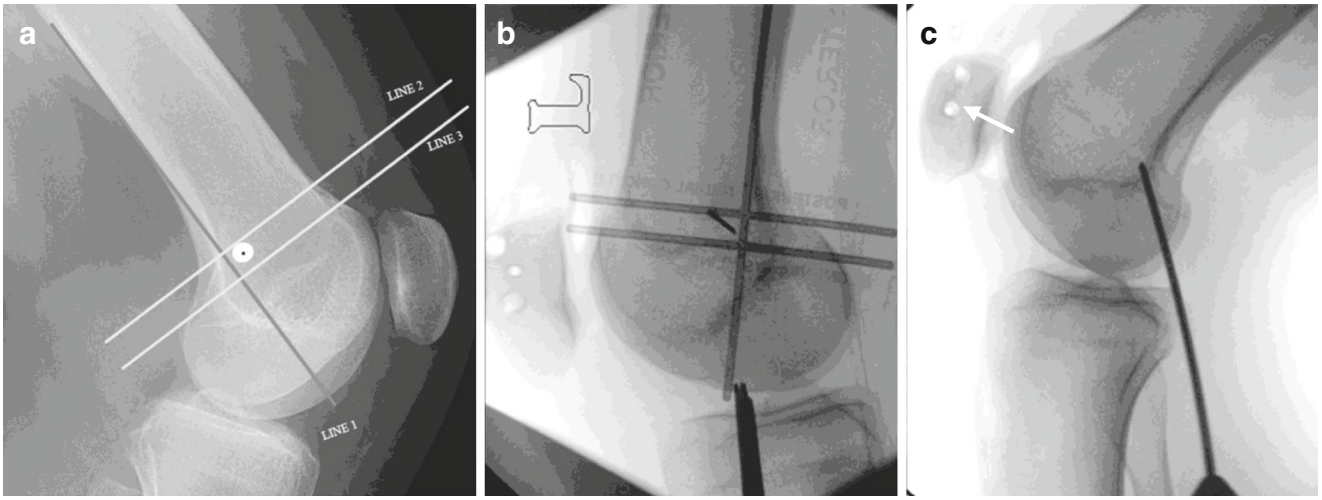


**Fig. 2** **a** Lateral radiograph demonstrating optimal femoral tunnel placement for MPFL reconstruction (Schottle's point). In the anterior-posterior position, it is located approximately 1 mm anterior to the posterior cortical extension line (*line 1*). In the proximal-distal position, it is located 2.5 mm distal to the posterior articular border of the medial femoral condyle (*line 2*) and proximal to the level of the posterior most point of Blumensaat's line (*line 3*). **b**, **c** The femoral tunnel placement can be prepared using a template intra-operatively. Note the presence of two patella screw tracks positioned within the superior half of the patella (*arrow*)

The tendon graft is secured to the femur with the use of an interference screw with the other end of the graft passing through the patella, either as a single or double bundle reconstruction via pre-prepared drill holes. A double bundle technique produces a more anatomical reconstruction of the ligament since it is fan-shaped and broader at its patellar insertion [19]. Accurate anatomical placement of the femoral tunnel is critical and its location can be pinpointed on a true lateral radiograph of the knee, known as "Schottle's point" (Fig. 2) [20]. On MRI, the femoral tunnel placement is just distal to the attachment of adductor magnus. The patellar insertion of the MPFL is not as critical as the femoral attachment and is located along the proximal half-to-third of the medial patellar border. Transverse tunnels have fallen out of favor due to stress riser and increased fracture risk. Formation of two parallel oblique tunnels extending from the medial border of the patella to the anterior cortex is the preferred technique. The ends of the grafts can be sutured back onto themselves [21]. Post-operatively, the graft should remain taught and demonstrate low T1 and T2 signal intensity (Fig. 3) [22]. MPFL reconstruction is also associated with a consistent reduction of patellar height in patients with pre-operative patella alta, which may reduce the requirement for distalization of the tibial tuberosity [23].

## Complications

Biomechanical studies have suggested that graft over-tensioning and non-anatomic attachment on the femur result in over-

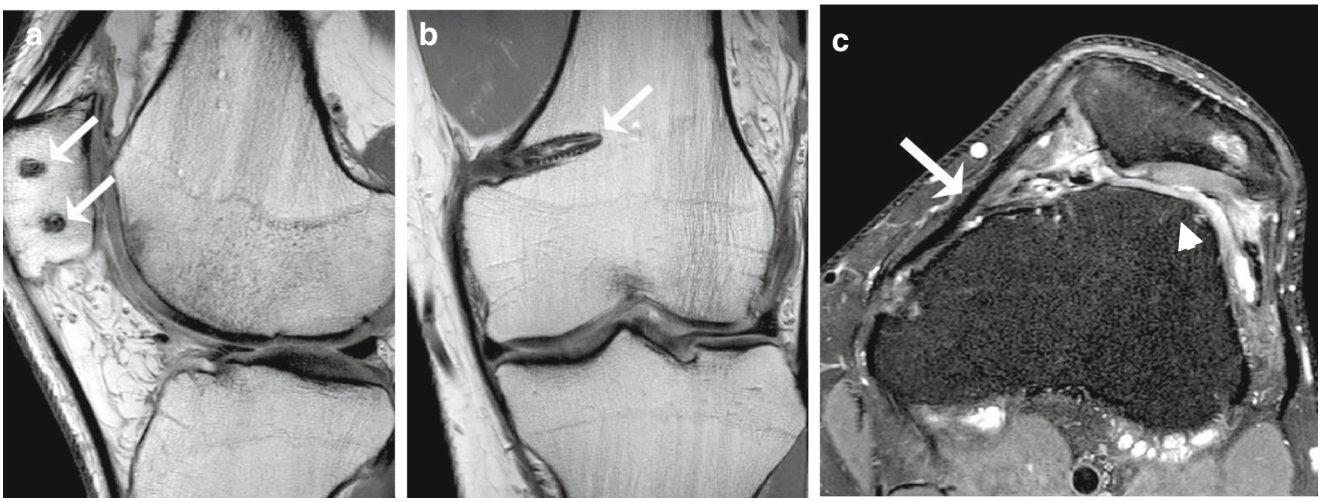


**Fig. 3** MPFL reconstruction. **a** Sagittal PDW FSE MR image showing the patellar screws. **b** Coronal PDW FSE MR image showing the femoral screw. **c** Axial fat-suppressed PDW FSE MR image showing the low SI neo-ligament (*arrow*). Note the presence of TD with convexity of the lateral trochlear facet (*arrowhead*). There is PFJ chondropathy, which should be mentioned in the report and compared with the preoperative images

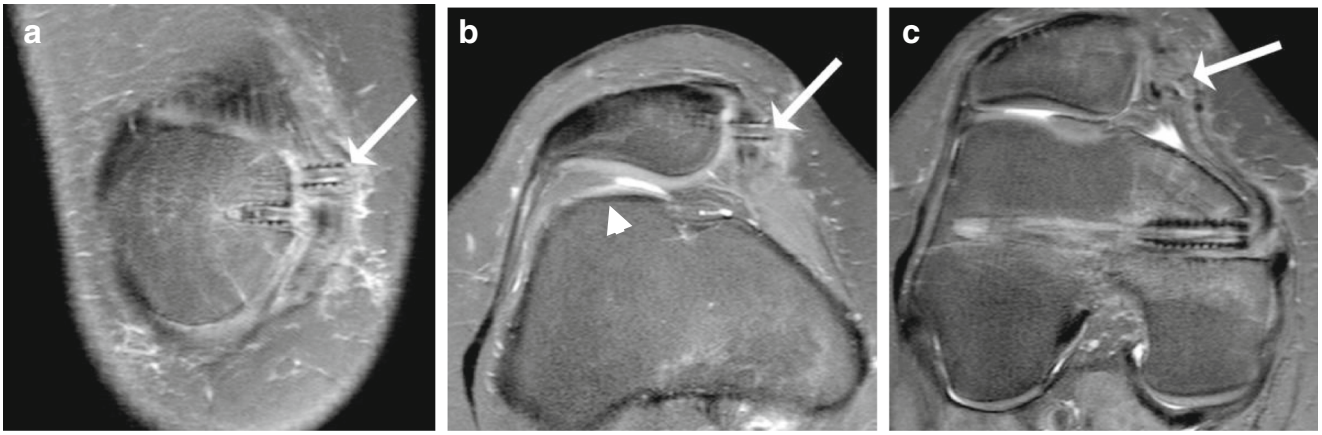


**Fig. 4** MPFL reconstruction in a 21-year-old female. **a** Coronal and **b** axial fat-suppressed PDW FSE MR images showing retraction of the proximal patellar screw (*arrows*). Note the presence of TD with convexity of the lateral trochlear facet (*arrowhead*). **c** Axial fat-suppressed PDW FSE MR image showing an anteriorly positioned femoral screw and rupture of the graft at its patellar insertion (*arrow*)

constraint of the patella and elevated medial contact pressures [8]. Therefore, over-tightening of the graft can lead to overload of the medial patellar facet and subsequent osteoarthritis. Non-anatomical position of the graft can result in recurrent lateral laxity, which may lead to recurrent lateral patellar dislocation and subsequent graft rupture, either at the patellar (Fig. 4) or femoral side [22]. Mal-positioning of the patellar and femoral tunnels may lead to disabling symptoms, often necessitating revision surgery. A recent study identified mal-positioning of the femoral tunnel (> 10 mm from Schottle's point) to be a common occurrence, which was not necessarily associated with unsatisfactory subjective or objective clinical outcomes [24]. Patellar fracture is a rare but recognized complication through the patellar tunnel (Fig. 5).

## Distal realignment procedures

Distal realignment procedures are considered effective in correcting patellar maltracking and offloading the PFJ in patients with an increased TT-TG offset. The two main surgical techniques performed are the Elmslie–Trillat procedure and the Fulkerson osteotomy.

The Elmslie–Trillat procedure aims to restore patellofemoral alignment via a combined soft tissue and bony approach. This involves a medial tibial tubercle transfer hinged on a distal periosteal attachment, together with lateral release and medial reefing (Fig. 6) [25]. The Fulkerson osteotomy is a modification of the Elmslie-Trillat procedure, involving anterior as well as medial translation of the tibial tubercle. The combination of a modified Fulkerson osteotomy (in which there is also internal rotation of the osteotomy) and MPLF reconstruction in habitual dislocators with underlying TD is reported to result in a significant improvement in functional outcome scores, and a significant reduction in TT-TG and patellar tilt angle [26].

The Marquet procedure, a somewhat historical technique, involves anterior translation (elevation) of the tibial tubercle by 2–2.5 cm (Fig. 7). This procedure is performed in patients with symptomatic PFJ osteoarthritis. A cortical iliac bone graft is often interposed between the tibial tubercle (TT) and donor site. Disadvantages include a high incidence of skin necrosis, and that this procedure does not address the Q angle [27]. Another somewhat historical procedure is the Hauser procedure, which medialized the TT. In doing so, it shifted the tubercle posteriorly and although

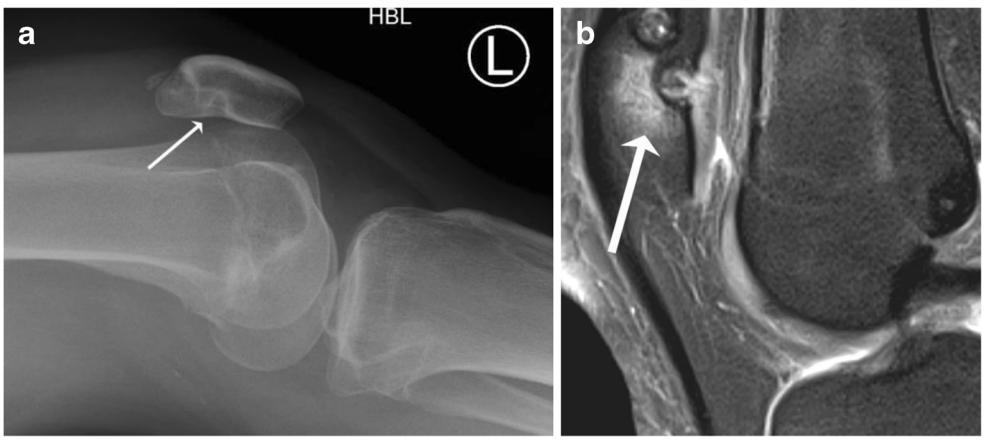


**Fig. 5** A 27-year-old female presenting with anterior knee pain following previous MPFL reconstruction. **a** Lateral radiograph demonstrating a deep patella tunnel placement with cortical breach (*arrow*). **b** Sagittal fat-suppressed PDW FSE MR image showing bone marrow edema within the patella related to the more distal tunnel (*arrow*) and associated chondromalacia

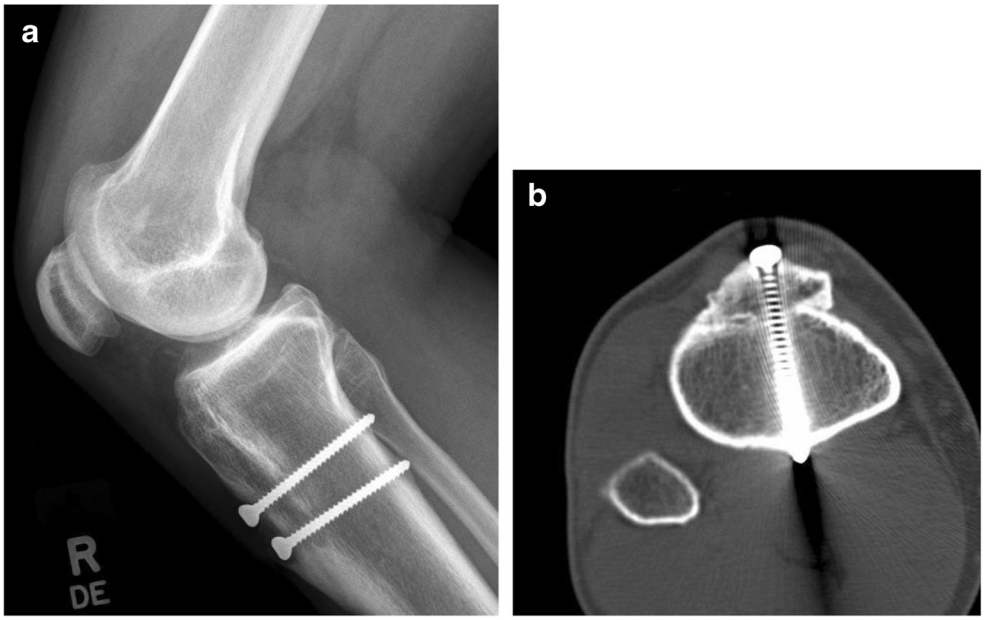


**Fig. 6** A 22-year-old female with recurrent lateral patella instability of the right knee. **a** Lateral radiograph demonstrates two sagittally orientated screws following a medial tibial tubercle transfer. **b** Axial CT image demonstrating bony fusion across the osteotomy site

effective in preventing lateral patellar dislocations, it predisposed to early PFJ osteoarthritis.

## Imaging findings

Radiographs will show prominence of the TT with often two parallel screws running in an anterior posterior direction (Figs. 6, 7). Assessment of bony union between the TT and the anterior tibia should be made, and if non-union is suspected CT may be performed to better assess for this. TT alignment may be performed in combination with soft tissue procedures such as an MPFL reconstruction.

## Complications

Complications include over-correction with excess medialization or even excessive distal transposition of the TT, which can lead to pain in the PFJ (Fig. 8). Other complications include non-union or fragmentation of the TT osteotomy.

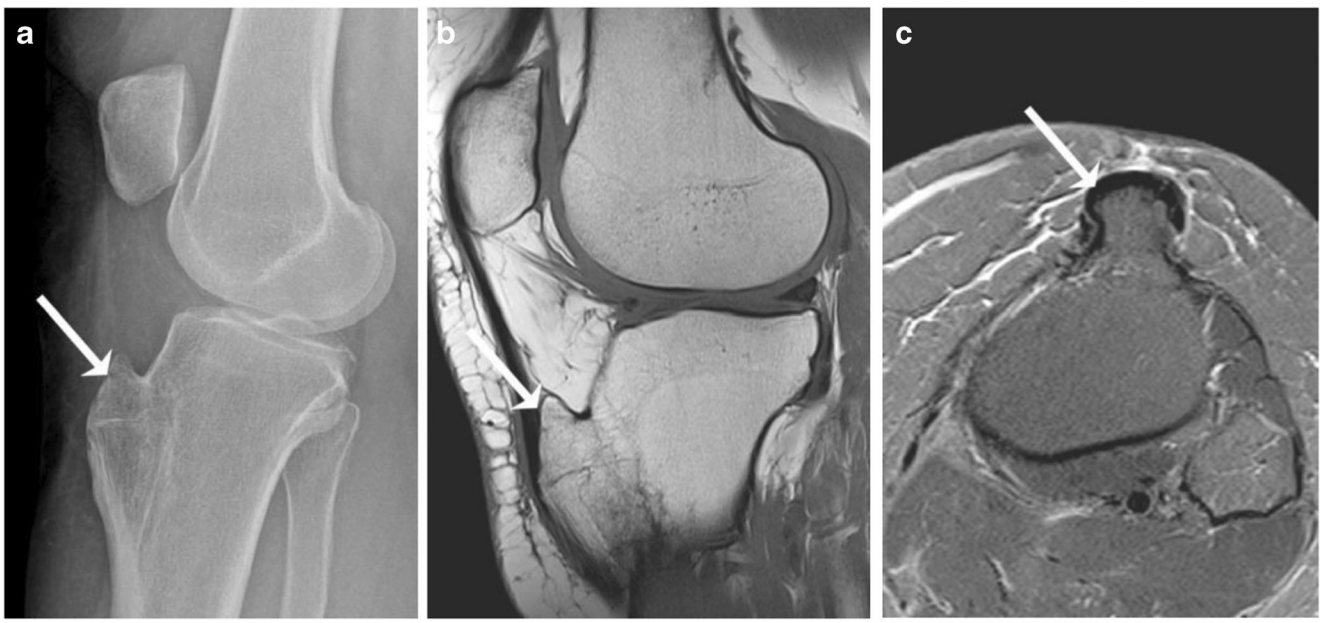


**Fig. 7** A 56-year-old female who underwent a Marquet procedure. **a** Lateral of the left knee demonstrating an elevated TT (*white arrow*). **b** Sagittal PDW FSE and **c** axial fat-suppressed PDW FSE MR images showing the patella tendon inserting into the raised TT (*arrows*)

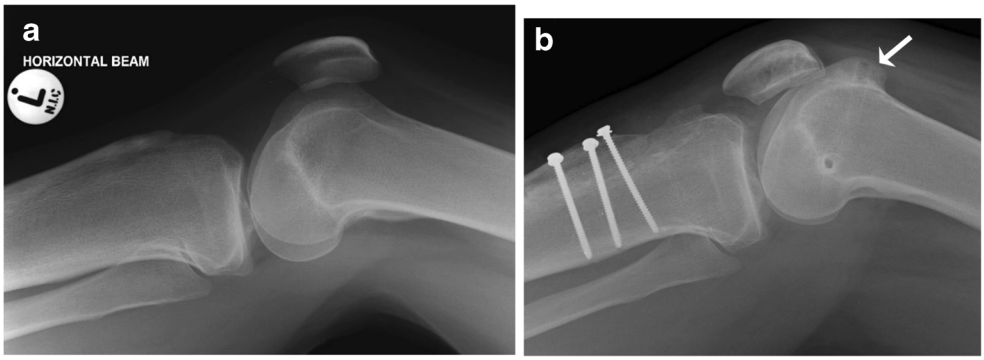


**Fig. 8** **a** Lateral radiograph in a 17-year-old female with a history of recurrent dislocations. **b** Lateral radiograph 5 years later following trochleoplasty (*arrow*), MPFL reconstruction and Fulkerson osteotomy with distal transposition of the TT resulting in severe patella baja

## Trochleoplasty

Open trochleoplasty is indicated in patients with symptomatic patellofemoral instability in the presence of severe TD [1, 28–31]. The aim is to reconstruct/recentralize the trochlear groove, thereby stabilizing the patella during the initial 30° of flexion. This is achieved by a number of options including lateral facet elevation, sulcus deepening trochleoplasty, or recession wedge trochleoplasty [29], the latter technique aimed at removing a prominent supratrochlear spur. Trochleoplasty is considered a demanding procedure and lacks familiarity amongst many knee surgeons [2]. Sulcus deepening trochleoplasty is commonly combined with other procedures such as MPFL reconstruction and tibial tuberosity transfer

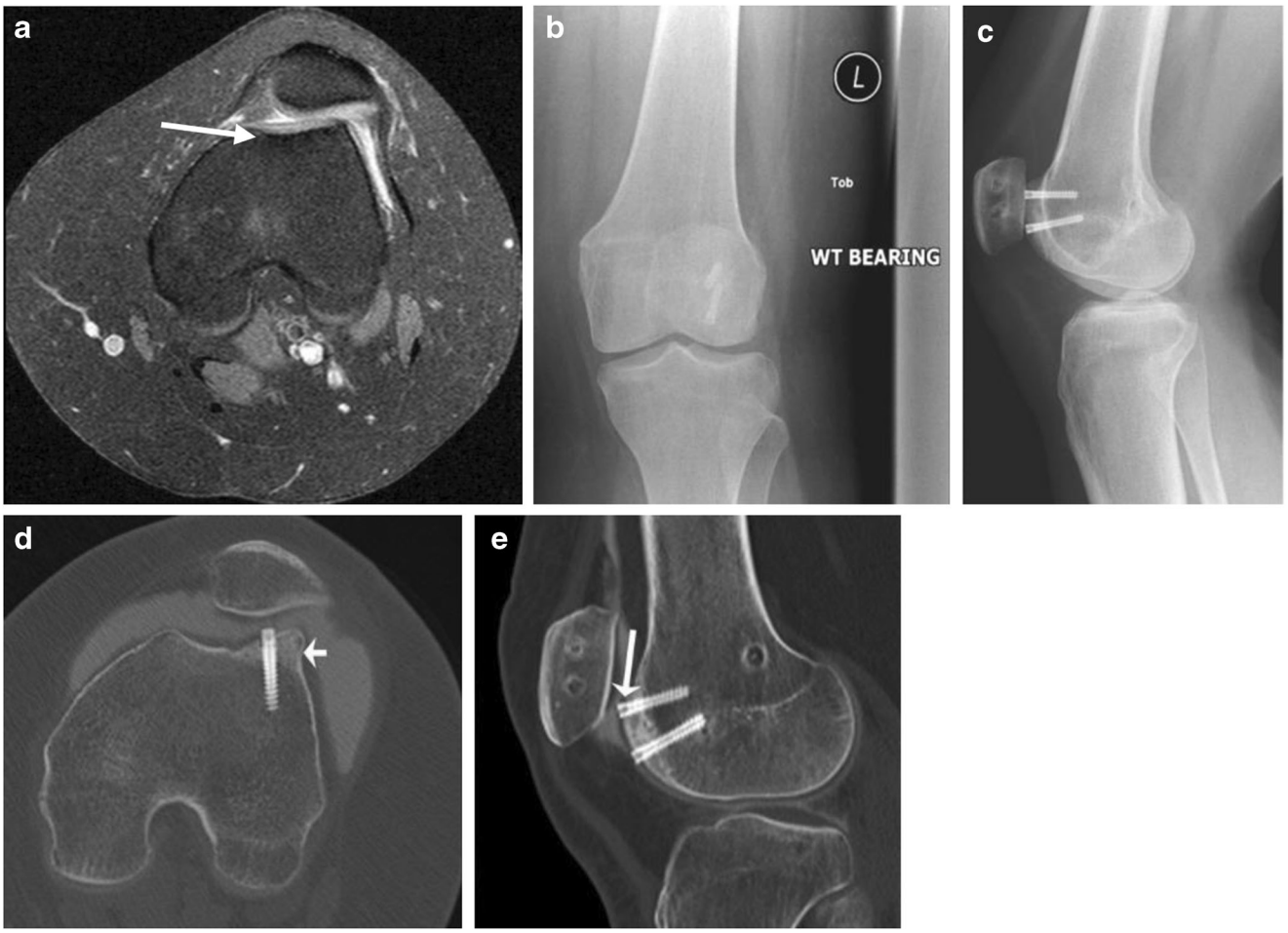


**Fig. 9** A 25-year-old female with TD and patellar instability. **a** axial fat-suppressed PDW FSE MR images showing shallow trochlear groove – low-grade TD (*arrow*) **b** AP, and **c** lateral radiographs demonstrating two headless compression screws used for the trochleoplasty. **d** Axial CT image demonstrating deepening of the trochlear groove (*short arrow*). The patella is still lateralized. **e** Sagittal CT arthrogram image show two headless compression screws following trochleoplasty performed with a tri-cortical iliac crest bone graft augmentation. The more proximal screw is sitting slightly proud of the articular surface leading to anterior knee pain (*arrow*). This was subsequently removed. Femoral and patellar drill holes from MPFL reconstruction are also present

[32–34]. However, the use of trochleoplasty alone in adolescents with recurrent patellar dislocation with Dejour types B to D TD and an open physis has been reported to have a good outcome [35], but trochleoplasty is contraindicated in the presence of an open physis [29, 36].

## Imaging findings

The post-operative appearances will depend upon the technique used and any additional procedures. The two commonest types of sulcus deepening trochleoplasty are those described by Beretier, which results in a U-shaped defect, and by Dejour, which produces a V-shaped defect [37, 38]. Radiological assessment of the bony correction can be performed with plain radiography, CT, and MRI. Reduction of the trochlear bump and deepening of the trochlear groove are useful post-operative surrogates together with PFJ congruence (Fig. 9). Screws are often used to fix the osteotomized trochlear in place. The screws are generally headless compression screws that are recessed beneath the subchondral bone.

Patellofemoral morphology, lateral facet cartilage signal intensity, and TT-TG have been compared prior to and following trochleoplasty [39]. Lateral facet patellar cartilage was hyperintense in 20 out of 22 cases before trochleoplasty and in only four cases after trochleoplasty. The authors suggested that this represented an improvement of patellofemoral articulation. A reduction in the mean TT-TG from 14 to 10 mm was also noted.

## Complications

Due to its high surgical demands, on-going patellofemoral incongruence remains a possibility. Concerns after trochleoplasty include viability of the articular cartilage and subchondral bone necrosis. Arthrofibrosis is also reported [36]. A recent meta-analysis of various trochleoplasty procedures identified the Bereiter and Dejour techniques as the commonest reported, with complications including recurrent dislocation (2–4%), recurrent instability (6–9%), patellofemoral osteoarthritis (7–12%), and requirement for further surgery (8–20%) [37]. Although the Bereiter trochleoplasty is associated with fewer complications, the Dejour technique results in better outcome measures [38]. Complications from screw placement can arise, and if they are sitting proud within the joint (Fig. 9) may lead to focal chondral wear.

## The Roux–Goldthwait procedure

The Roux–Goldthwait procedure is another form of distal realignment surgery and is somewhat historic [40]. The patella tendon is split vertically, the lateral half detached from the TT and pulled deep to the medial half and reattached to the anterior tibia. This pulls the patella medially and helps prevent excess lateral patellar displacement during flexion.

## Imaging findings

This is best appreciated on MRI with crossing over of a vertically split patella tendon (Fig. 10). Despite this procedure

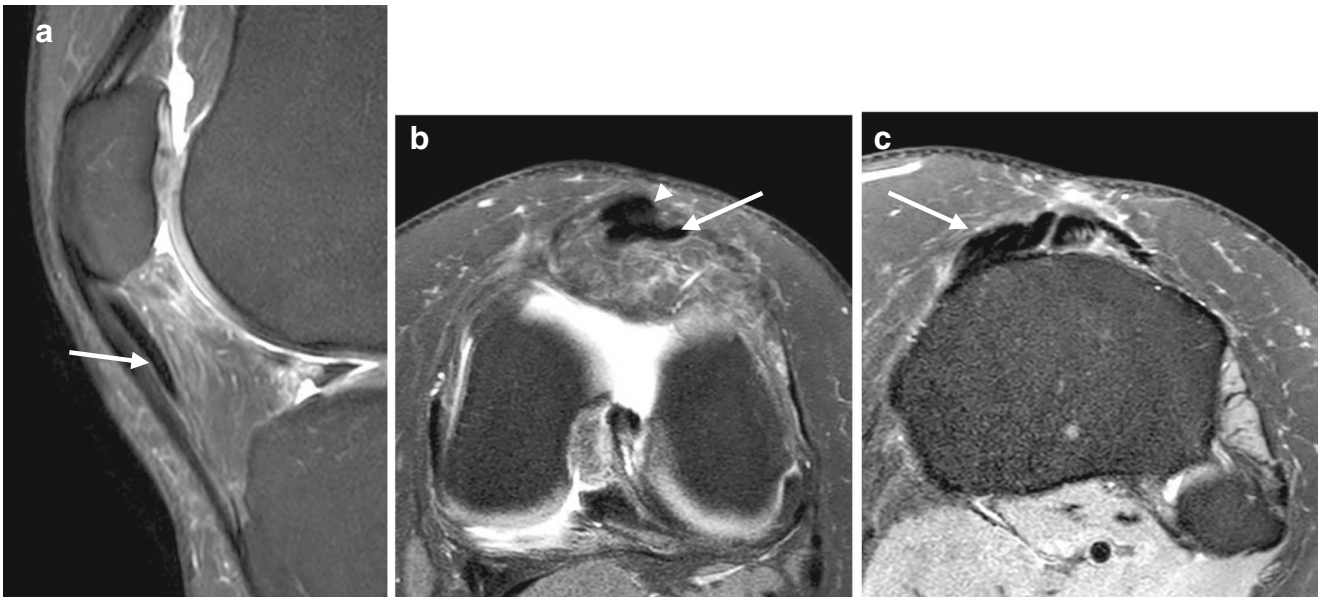


**Fig. 10** Roux–Goldthwait procedure. **a** Sagittal fat-suppressed PDW FSE MR image showing the longitudinally split patellar tendon (*arrow*). **b**, **c** Axial fat-suppressed PDW FSE MR images showing with the lateral component of the tendon (*arrow*, **b**) running posterior to the medial component (*arrowhead*, **b**) and re-attached to the medial aspect of the tibial tuberosity (*arrow*, **c**)

being historic, radiologists may occasionally encounter imaging studies for patients having undergone this operation.

## Complications

Sillanpaa et al. reported an increased incidence of osteoarthritis and recurrent dislocation when compared with a group that underwent medial ligament reconstruction [41].

## Conclusions

The number of surgical procedures performed on this cohort of patients is large. An awareness of the commonly performed procedures will enable the radiologist to assess for possible complications.

When reporting these post-operative imaging studies, it is vital to review pre-operative imaging and to assess whether or not the intended aim of the surgery has been achieved. For example, has the trochlear groove been restored following a trochleoplasty or has the excess patella lateralization been corrected following a distal realignment procedure. Numerous pre and post-operative measurements can be performed to assess the anatomy of the patellofemoral joint. Working closely with your orthopedic surgeon and finding out which measurement they use is a vital part in constructing a useful and relevant report.

### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflicts of interest.

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