'How to operatively stabilize the patella'

Siebren Tigchelaar [1]
Sebastiaan van de Groes[2]
David Dejour [3]
Marie Askenberger [4]
Petri Sillanpää [5]
Sander Koëter [1] ✉ E-mail: s.koeter@cwz.nl
1 Canisius Wilhelmina Ziekenhuis Nijmegen, The Netherlands
2 Radboud Universitair Medisch Centrum Nijmegen, The Netherlands
3 Lyon Ortho Clinic, France
4 Department of Pediatric Orthopedics Astrid Lindgren Children's Hospital, Karolinska University Hospital Solna, Sweden
5 Dextra Koskisairaala Hospital Tampere, Finland

Abstract

20.1. Introduction

The patellofemoral joint is an exceptional joint, unlike any other joint in the human body. The patella, albeit just a small part of the knee, has an important function as a fulcrum for the extensor mechanism of the knee. Patellofemoral problems account for a significant amount of consultations in both general and orthopedic practice. About 11–17% of all knee consultations in general practice concern patellofemoral complaints [1]. The incidence of primary patellar dislocations is 5.8 per 100,000 and increases to 29 per 100,000 in adolescents. Recurrent instability vigorously increases the number of patellar dislocations, as recurrent patellar instability occurs in 17% of persons after a first dislocation and in 49% after a second dislocation [2]. Unlike instability in other joints, patellofemoral instability is usually the direct consequence of congenital malformations of the patella and/or femoral trochlea. These malformations result from aberrations and disruptions in the evolutionary, embryological, and genetic development of the patellofemoral joint. The introduction of this chapter addresses the development of the patellofemoral joint in order to understand the etiology and causative factors of patellofemoral instability.

20.2. Congenital and Biomechanical Causes of Patella Instability

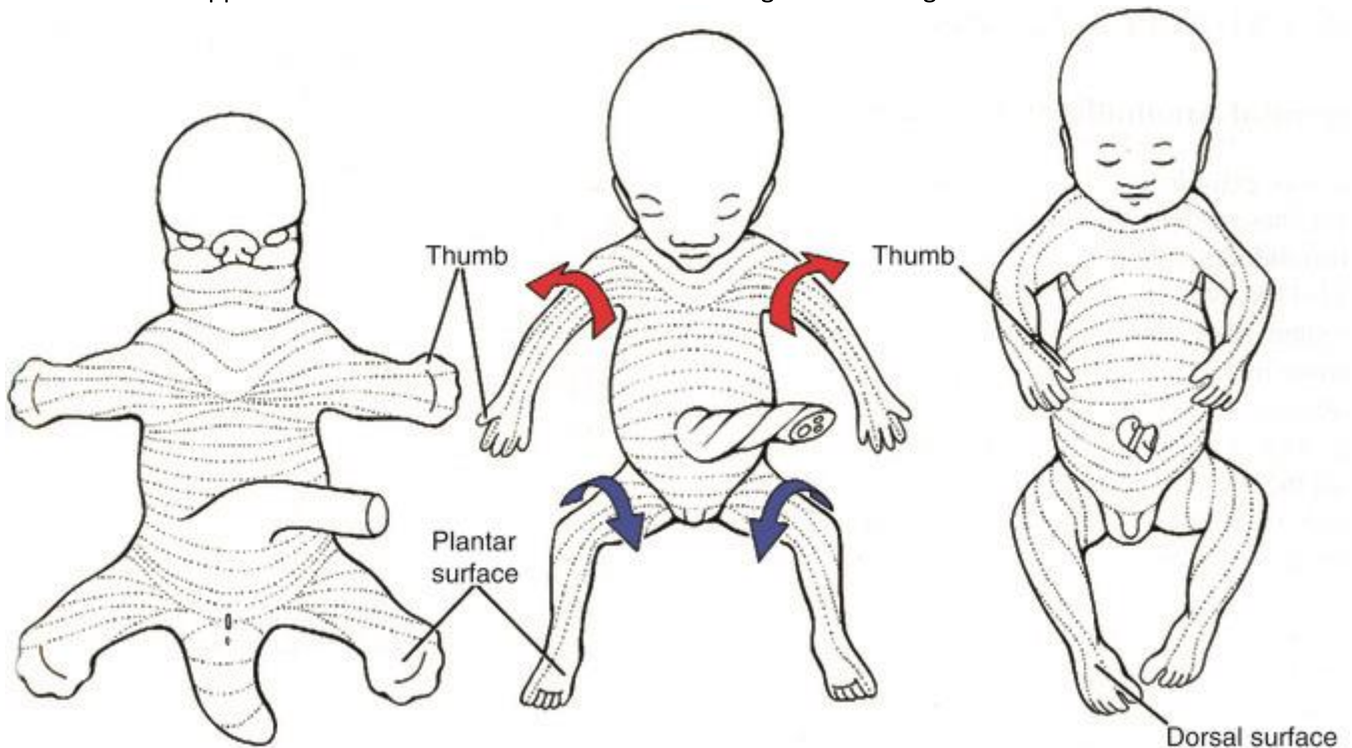
20.2.1. Congenital Aspects

Normal embryonic development of the anatomic structures of the patellofemoral joint is of crucial importance for proper patellar function and stability. The differentiation of the patella and the patellar tendon starts at day 37 with chondrification starting at day 45 of gestation. The patella increases in relative size up to the sixth month of fetal life, and after which it increases at the same rate as the other bones of the lower extremity. Initially, the medial and lateral patellar facets are equal in size, but at week 23 of gestation, the lateral facet has become the more predominant, which is the key characteristic of the adult patella. Ossification of the patella usually starts at ages 5–6 but is sometimes visible on radiographs at ages 2–3 [3].

During human embryonic development, limb patterning is accompanied by rotation of the limbs. Initially, the upper and lower limb buds extend laterally from the body wall with the thumb and great toe facing cranially and the flexor surfaces facing ventrally. Subsequently, the limbs shift into a more ventral position with both the thumb and great toe still facing cranially, but the flexor surfaces are now facing medially. The limbs rotate around their proximo-distal axis between the sixth and eighth week of embryonic development. The upper and lower limbs rotate in opposite directions, the upper limbs rotate dorsally, and lower limb rotation occurs in the ventral direction. At this end stage of limb

rotation, the flexor/palmar surfaces of the hands face ventrally, the flexor/plantar surfaces of the feet face dorsally, and the elbows and knees face outward (Fig. 20.1). Consequently, the patella, which primordial anlage is a dorsal structure, comes to lie ventrally during limb development [4]. It is argued that the patellar instability, which is always lateral, is frequently caused by a deficiency in this dorsoventral and rotational development.

Fig. 20.1
Rotation of the upper and lower limbs between the sixth and eighth week of gestation



In the embryo, the knee develops in a position of 90° flexion. This means that the patella initially conforms to the distal aspect of the femoral condyles, the part that will articulate with the tibial plateau in stance. The general adult form of the trochlear surface of the femur is achieved very early in fetal life, before movement has occurred. This means that it is not formed in contact with or in response to the patella but to the quadriceps musculature. As with most anatomic structures, form follows function and the final shape of both the patella and the femoral trochlea will be modified by use [5].

20.2.2. Biomechanical Aspects
The patella is the largest sesamoid bone in the human body, and its most important function is to facilitate extension of the knee by increasing the efficacy of the quadriceps muscle. This is achieved through the patella's function as a fulcrum, thus anteriorly displacing the line of pull and increasing the moment arm of the quadriceps muscle force in relation to the center of rotation of the knee. The patella enhances the force of extension by as much as 50% throughout the entire range of motion (ref: Fulkerson). The function of the patellofemoral joint is normally maintained by a complex interaction between soft tissues and bony structures. The structures responsible for its stability can

be divided into three groups: the *active* stabilizers represented by the quadriceps muscles, the *passive* stabilizers (particularly the retinacula, of which the medial and lateral patellofemoral ligaments are a part), and the *static* stabilizers represented by the articular surfaces. In normal knees, these structures act in harmony to maintain stability of the joint. In case of an imbalance between these stabilizers, patellofemoral dysfunction occurs.
Radiologic evaluation of patellofemoral dysfunction is traditionally performed using conventional radiographs and computed tomography (CT) scanning. Using these common radiologic modalities, excellent work by Dejour and his co-workers from the Lyon School has revealed four different factors that are significantly correlated with recurrent patellar instability and are currently considered to be the primary causes of patellar instability [6]. These four factors are:

Patella alta
In case of patella alta, or high-riding patella, the position of the patella is more proximal in relation to the trochlear groove. Due to this position of the patella, it engages in the trochlea only at greater flexion of the knee. Therefore, the patella has a greater trajectory in which there is no bony (static) restraint which prevents a lateral dislocation of the patella [7]. In this situation, the stability of the patellofemoral joint is completely dependent on the active (quadriceps muscles, in particular the m. vastus medialis obliquus) and passive (medial retinaculum) stabilizers of the patella.

An increased tibial tubercle-trochlear groove (TT-TG) distance
If the position of the patellar tendon insertion, the tibial tubercle, is located more lateral on the tibia, the distance between the trochlear groove and the tibial tubercle increases. This in turn increases the angle between the quadriceps muscles and the patellar tendon, the Q angle, creating a larger lateral force vector on the patella. A lateralized tibial tubercle therefore leads to an increased laterally oriented force on the patella. A higher lateral force on the patella may lead to either instability or initiate patellofemoral pain by raising the cartilaginous pressure from the patella on the lateral femoral condyle.
In 96% of patients with patellar instability, trochlear dysplasia is present. Trochlear dysplasia is a common denominator for all types of aberrant anatomy of the femoral trochlea. All types of trochlear dysplasia share either a flat or convex trochlear groove which decreases lateral restraint and/or a bump at the entrance of the trochlea which prevents the patella from easy entry into the trochlea. A flat femoral trochlea reduces the bony lateral restraint by 70% at 20–30° of flexion, which makes the trochlea the largest contributor to patellofemoral stability from 20–30° up to full flexion.
The MPFL is a thin ligamentous structure within the medial capsule of the knee with its origin on the proximal half of the patella and its insertion just proximal and posterior to the medial epicondyle of the femur. After a first-time patellar dislocation, the MPFL is ruptured in 90–100% of patients. The MPFL is the single most important restraint in full or near full extension of the knee. It is responsible for 50–60% of the lateral restraint of the patella at 0–20° of knee flexion.

20.3. Clinical Relevance and State-of-the-Art Treatment

Primary patellar dislocations should be treated conservatively by brief immobilization, followed by active mobilization. Recurrent dislocations can be treated surgically. In clinical practice, usually a combination of factors leads to patella instability. The optimal, state-of-the-art, operative treatment is tailor-made (a la carte) and has to be individualized in every patient. Adequate physical examination, a good knowledge of the patients' specific (sports) goals, and different radiologic modalities—such as conventional radiographs, computed tomography (CT) scan, and magnetic

resonance imaging (MRI)—are helpful in making the optimal surgical preoperative plan. In the following paragraphs is a short outline of the different treatment options and there indications.

20.3.1. MPFL Reconstruction: Novel Insights
After patella dislocation, the thin fibers of the MPFL are always affected. Although they have some healing potential, elongation and wearing of the structures almost always persist. Repair of this structure leads to poor residual restraint, and—in cases of recurrent dislocation—reconstructing of the MPFL has become a key procedure for stabilizing the patella. Different techniques to reconstruct the MPFL have been described: static techniques in which the graft is fixed rigidly to the bone or dynamic techniques with soft tissue fixation. Static MPFL reconstruction with the use of implants at both the patella and femoral side is most commonly used. However, dynamic reconstruction deforms more easily and presumably functions more like the native MPFL.

20.3.2. MPFL in the Young Patient
In young patients, with open physes, bony procedures are usually contraindicated because of the likelihood of postoperative growth disturbances. Soft tissue procedures may be indicated in patients with severe limitations caused by the patella instability. Various procedures have been described in literature, ranging from muscular transfer, patella tendon realignment, to capsular procedure. Examples of the latter are VMO transfer, Roux-Goldthwait procedures, and capsular reefing/lateral release. MPFL reconstruction has replaced much of the previously mentioned operations. The employed technique differs slightly from the techniques use in adults, but the basics are the same. In some cases the MPFL reconstructions can be combined with other soft tissue procedure.

20.3.3. Tibial Tubercle Transfer: Is It Still Indicated?
Historically, was the corner stone of patella surgery, but various articles showed poor long-term results of this treatment with high changes of developing osteoarthritis. The procedure developed a bad name, and its central role in the arsenal of the patella surgeon has now been overtaken by the MPFL reconstruction. The question arises: is there still a role for this procedure or is it outdated? The transfer of the tibial tubercle has an enormous biomechanical effect on the force acting upon the patella, and by alteration of the tibial tubercle-trochlear groove (TT-TG) distance and/or the patella height, the stability can be improved. Most experienced surgeons use a tibial tubercle transfer in selected cases, but the TT-TG threshold for correction varies between surgeons and institutions, from 15 to 20 mm. The measurement has a measurement error of around 2 mm [6]. x Care must be taken not to overcorrect the abnormality, because this can lead to unacceptability of high retropatellar pressures and the development of osteoarthritis. We use a self-centering technique to prevent overcorrection; please refer to Fig. 20.2 for a brief description of this technique. Using this technique we found good improvement in functional scores (VAS pain, Lysholm, and Kujala scores are improved significantly compared to their preoperative values and do not deteriorate at final follow-up), low postoperative instability, and a limited deterioration in osteoarthritis (similar to the natural course of osteoarthritis after patellar dislocation without surgical treatment). Based on these results, we conclude that this self-centering tibial tubercle osteotomy provides good long-term results without inducing progressive osteoarthritis [8]. Nowadays, it is usually combined with MPFL reconstruction, the cornerstone of patella-stabilizing surgery (Figs. 20.3 and 20.4).

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Fig. 20.2
Self-centering transfer technique. After a straight osteotomy, the knee is flexed and the tibial tuberosity medializes. Care must be taken to make a straight (and not a step cut) osteotomy because this will lead to stress rising in the tibia during weight bearing

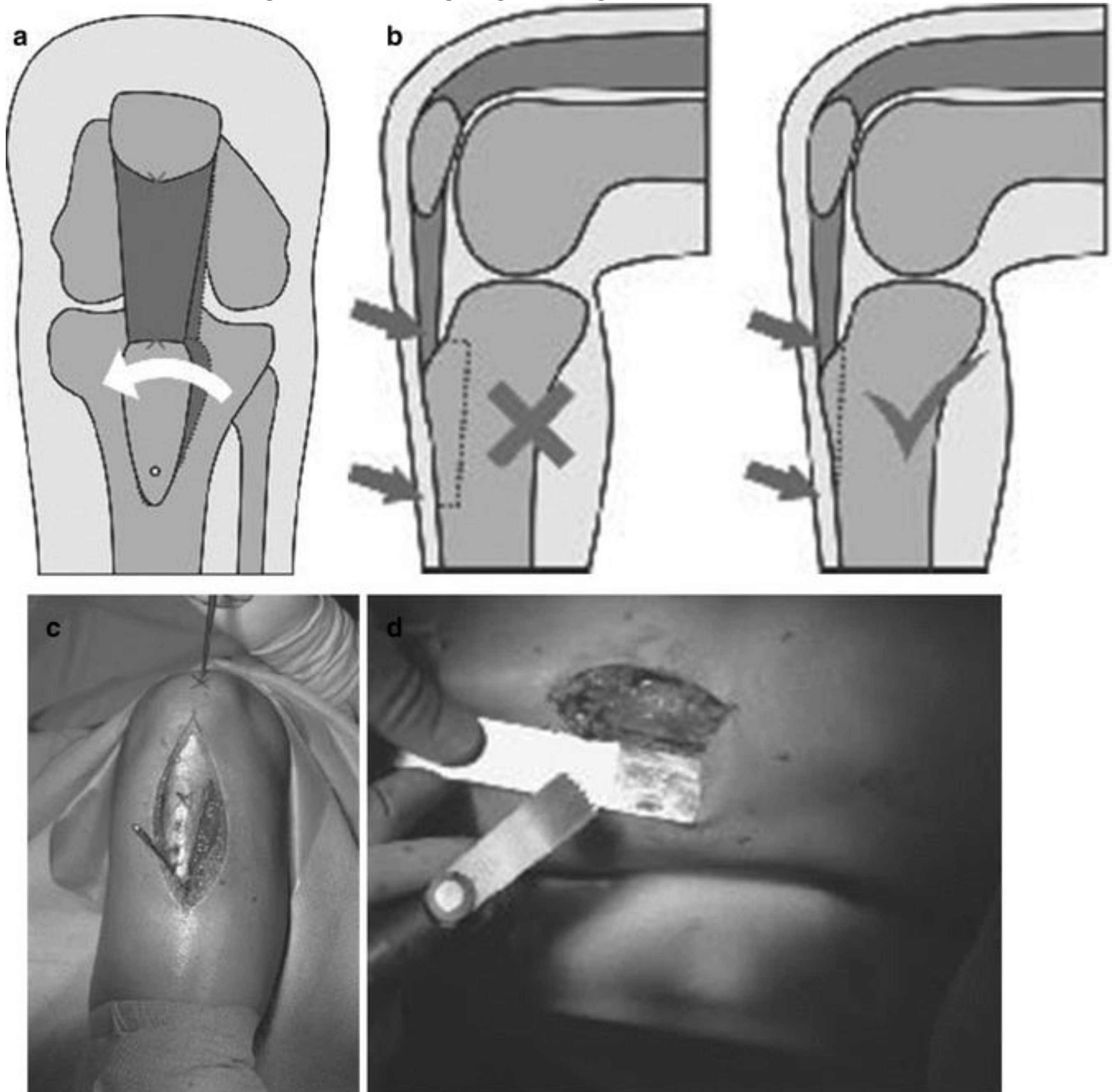


Fig. 20.3
Measurement technique for measuring the tibial tubercle-trochlear groove (TT-TG) distance on a CT or MRI. The deepest point of the sulcus is marked on Fig. A, the lines are transferred to the tibial tuberosity, and the medial point of the tuberosity is located, and the distance between C and E is the TT-TG

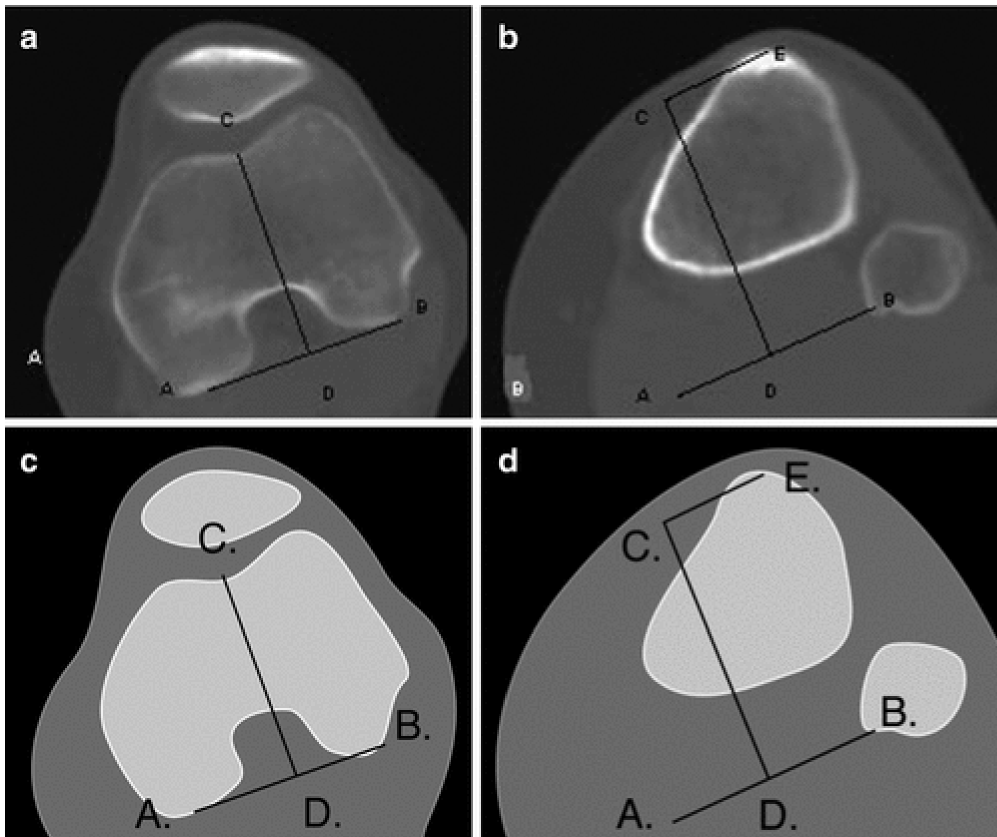
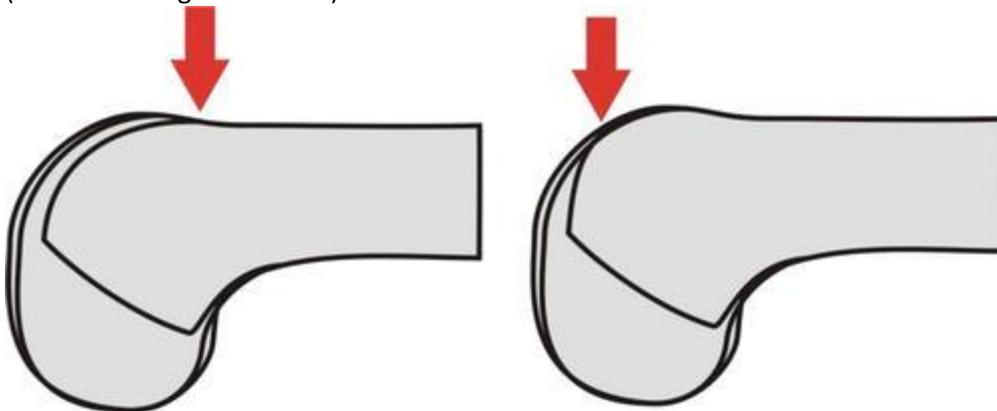


Fig. 20.4
The crossing sign can be seen best on a true lateral radiograph. The posterior condyles need to overlap; the crossing of the anterior part of the femoral trochlea with the line of the trochlea bottom is located at the arrow. The left figure is normal (no crossing of the lines), the right figure is dysplastic (with a crossing of the lines)



20.3.4. Trochleoplasty for Patellar Instability
Trochlear dysplasia is a universally accepted primary anatomic risk factor for patellar instability. Trochlea dysplasia can be diagnosed on axial radiographs by measuring the sulcus angle or—on true lateral radiographs—by identifying a specific sign for trochlear dysplasia, the "crossing sign." Trochlea dysplasia can be classified in four categories (Dejour A, B, C, or D), according to the severity of the dysplasia [7]. MRI gives more precise analysis of the trochlear shape, including the cartilaginous shape of the trochlea, which does not follow bony morphology in the patellofemoral joint. Therefore, advanced imaging by MRI is necessary when considering surgery for patellofemoral instability in patients with trochlea dysplasia [9].
There are no guidelines for when to correct the dysplastic trochlea by a trochleoplasty procedure. In high-degree trochlear dysplasia (Dejour B and D), with a highly abnormal shape of the trochlea, a prominent bump deformity, and complete lack of sulcus groove, other surgical methods may not provide adequate stabilization of the patella. In patients with mild trochlea dysplasia (Dejour A), the shallow trochlear groove does not significantly compromise patellar stability, and these patients can be treated with isolated MPFL reconstruction if there are no other major anatomical risk factors. Generally, trochleoplasty (as a primary or secondary procedure) is only indicated in patients with high-degree trochlea dysplasia. To gain optimal patella stabilization, trochleoplasty is usually combined with MPFL reconstruction and some form of lateral capsular structure lengthening.
*Trochleoplasty*aims at removing the trochlear bump and creating a normal or nearly normal sulcus groove. Different surgical techniques have been described in the literature, all of which deepen the trochlear groove by removing excessive bone after creating a cartilaginous flap. This cartilage flap can be created by various methods, either by splitting the cartilage (thick flap technique) in medial and lateral flaps or mobilizing the flap subchondrally from proximal without touching the cartilaginous surface (thin flap technique). After a trochlear groove has been created, the cartilage flap is fixed, and soft tissue balancing is performed at lateral structures, combined with medial soft tissue restraints (MPFL) reconstruction. Despite the fact that trochleoplasty is a relatively extensive surgery for the patellofemoral joint, complications such as cartilage viability issues are rare [10], and rehabilitation closely follows the standard postoperative MPFL reconstruction protocol to avoid arthrofibrosis (which has been described as a potential risk in earlier studies [11]). Recent outcomes for trochleoplasty report good results in terms of patellar stability, though long-term patient-reported outcomes in different surgical techniques are yet to be determined.

20.4. Future Directions
Since patella instability has a number of anatomic causes, the surgical plan has to be tailor-made (a la carte). The specific indications for surgery and the exact surgical plan can vary among surgeons and between countries, depending on regional traditions and expertise. Future research can be helpful in establishing which interventions provide the best results and the smallest change on complications and which preoperative workup is needed to define the underlying anatomical problem.
The first step can be a more dynamic approach to the problem. Nowadays, surgery is planned based on 2D images, but patellar instability is a dynamic problem. New imaging techniques are available for the real-time dynamic scanning of patients. This provides new insights in the patella tracking and the influence of, for instance, the position of the tibial tubercle on tracking throughout the whole range of motion. This data can be used to plan surgery in a patient-specific manner, leading to more advanced planning techniques. Advanced computer modeling techniques can be used to plan, for instance, the optimal position of the tibial tubercle to reduce cartilage stresses and optimize patellar tracking. New surgical techniques, like robotics and navigation, can provide the tools needed to execute the plan in theater.

20.5. Take-Home Message

Recurrent patella dislocations are caused by a (combination of) underlying anatomic disorders. The four most critical factors are patella alta, MPFL insufficiency, increased tibial tubercle-trochlear groove distance, and trochlea dysplasia. These anatomic abnormalities have to be identified before a good surgical plan to stabilize the patella can be made. The surgical plan is tailor-made (a la carte) and depends on the anatomic abnormalities and the patients' characteristics and needs.

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