

CURRENT CONCEPTS REVIEW

Patellar Instability

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- ▶ Recurrent patellar instability can result from osseous abnormalities, such as patella alta, a distance of >20 mm between the tibial tubercle and the trochlear groove, and trochlear dysplasia, or it can result from soft-tissue abnormalities, such as a torn medial patellofemoral ligament or a weakened vastus medialis obliquus.
- ▶ Nonoperative treatment includes physical therapy, focusing on strengthening of the gluteal muscles and the vastus medialis obliquus, and patellar taping or bracing. Acute medial-sided repair may be indicated when there is an osteochondral fracture fragment or a retinacular injury.
- ▶ The recent literature does not support the use of an isolated lateral release for the treatment of patellar instability.
- ▶ A patient with recurrent instability, with or without trochlear dysplasia, who has a normal tibial tubercle-trochlear groove distance and a normal patellar height may be a candidate for a reconstruction of the medial patellofemoral ligament with autograft or allograft.
- ▶ Distal realignment procedures are used in patients who have an increased tibial tubercle-trochlear groove distance or patella alta. The degree of anteriorization, distalization, and/or medialization depends on associated arthrosis of the lateral patellar facet and the presence of patella alta. Associated medial or proximal patellar chondrosis is a contraindication to distal realignment because of the potential to overload tissues that have already undergone degeneration.

The incidence of primary patellar dislocation is 5.8 per 100,000, and this increases to twenty-nine per 100,000 in the ten to seventeen-year-old age group^{1,2}. The recurrence rate ranges from 15% to 44% after nonoperative treatment of an acute injury². If the patient experiences a subsequent patellar dislocation, there is a 50% chance of recurrent episodes¹. Although the recurrence rate is relatively low after a primary patellar dislocation, many patients continue to have pain and mechanical symptoms after the initial dislocation episode³. Atkin et al. found that 58% (forty-three) of seventy-four patients continued to have limitation in strenuous activity at six months after the injury⁴. It has been reported that up to 55% of patients fail to return to sports activity after a primary patellar dislocation⁴.

Instability of the patellofemoral joint is a multifactorial problem. Patellar stability relies on the limb alignment, the osseous architecture of the patella and the trochlea, the integrity of the soft-tissue constraints, and the interplay of the sur-

rounding muscles. Treatment of patellar instability requires an understanding of these relationships and how to evaluate them.

Anatomy

Joint Geometry

Patellofemoral joint stability is influenced by the geometry of the trochlear groove, including its depth and steepness. The trochlear groove has a sophisticated geometry with a complex shape that does not have a constant cross section along its length. The lateral facet of the trochlear groove is highest on the anterior aspect of the femur and decreases in height more distally and posteriorly, giving more osseous constraint to the patella in extension and early flexion. In contrast, the Q angle (the angle between the lines of action of the patella and the quadriceps tendon) is largest and the quadriceps and patellar tendon tension is lowest in extension. These two variables counteract the osseous constraint of the trochlea and contribute to greater patellar instability in extension and lower

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degrees of flexion. The quadriceps and patellar tendons provide a strong posterior force vector during knee flexion, contributing to increased patellar stability with knee flexion. As the knee flexes and extends, the contact area moves across the patella. The patella leaves its engagement with the groove as the knee reaches full extension. When the knee starts to bend, the initial contact is at the distal and lateral edge of the patellar articular surface, which does not extend to the inferior facet. As the patella moves distally with knee flexion, the contact area on the patella moves proximally. In deep knee flexion (120°), the medial facet, or so-called odd facet, contacts the lateral margin of the medial femoral condyle⁵.

Patella alta has been associated with recurrent dislocations^{6,7}. Patella alta results in less osseous stability because the degree of flexion at which the patella engages in the trochlea is higher than that in a normal knee. Under normal conditions, the patella usually engages by 20° of flexion. Furthermore, knees with patella alta have reduced patellar contact areas when compared with knees with normal patellar height, and these reduced patellar contact areas lead to greater patellofemoral stress during fast walking^{8,9}.

Limb Alignment

Femoral and tibial torsion can play an important role in patellar instability. A more widely recognized aspect of osseous alignment is the Q angle. The Q angle is largest in full extension because the tibia rotates externally in terminal knee extension (the so-called screw-home mechanism), moving the tibial tuberosity more laterally¹⁰. Because the Q angle is greatest in full extension, this is the position in which the patella is at greatest risk for dislocation. In this position, the patella disengages from the trochlea and the posteriorly directed force from the extensor mechanism that holds the patella in the groove is the lowest.

The Q angle is difficult to measure because of the mobility of the patella. Quadriceps tension pulls the patella in a proximal-lateral direction in full extension. If the patella is unstable, it subluxates laterally, resulting in a falsely low Q-angle measurement. Therefore, it is important to keep the patella located in the trochlear groove manually during the measurement. Limb rotation should also be controlled during measurement since external tibial torsion can increase the apparent Q angle.

Retinacula

The iliotibial band attaches to the Gerdy tubercle distally but also has attachments to the patellar and quadriceps tendons. It has been found that tension in the iliotibial band causes the patella to track in a more lateral position. There are three layers that make up the lateral side of the patellar attachments. The superficial layer is confluent with the iliotibial band. The intermediate layer is the lateral patellofemoral band, or the iliotibial patellar band. This band extends from the deep layer of the iliotibial band to the midlateral aspect of the patella. The deep layer is confluent with the knee capsule¹¹.

The medial patellofemoral ligament is the primary passive soft-tissue restraint to lateral patellar displacement. It provides

50% to 60% of lateral restraint from 0° to 30° of knee flexion¹². The medial patellofemoral ligament runs transversely from the proximal half of the medial patellar border to the femur near the medial epicondyle. The superficial fibers of the medial patellofemoral ligament pass over the saddle between the epicondyle and the adductor tubercle and insert 1.9 mm anterior and 3.8 mm distal to the adductor tubercle¹³. The medial patellofemoral ligament provides an important stabilizing force on the medial side of the knee. A study of cadavers showed that cutting the medial structures results in a 50% decrease in the force required to move the patella 10 mm laterally¹⁴.

Muscles

The vastus medialis obliquus and vastus lateralis obliquus originate from septa alongside the femur and approach the patella from directions that deviate from the anatomic axis of the femur. These muscles can pull the patella medially or laterally. The vastus medialis obliquus has a mean orientation that deviates $47^\circ \pm 5^\circ$ medially from the femoral axis, and the vastus lateralis obliquus has a mean orientation that deviates $35^\circ \pm 4^\circ$ laterally from the axis¹⁵. An imbalance of strength may lead to instability. The vastus medialis obliquus is the first part of the quadriceps to weaken and the last to strengthen when function is inhibited¹⁶.

It has been shown that, if the muscle force vectors are added together in the coronal plane, their resultant force is almost exactly parallel to the femoral anatomic axis. If the force-producing capacity of each muscle head is in proportion to its physiologic cross-sectional area, the vastus medialis obliquus could contribute 10% of the total quadriceps tension¹⁵.

If the vastus medialis obliquus is completely relaxed, lateral patellar stability is reduced at all angles of knee flexion from 0° to 90° . Goh et al. found lateral stability to be reduced by 30% when the vastus medialis obliquus was relaxed at 20° of knee flexion¹⁷ and that relaxation of the vastus medialis obliquus caused the patella to displace laterally 4 mm and also increased the load on the lateral facet¹⁷.

Radiographic Evaluation

Standard radiographs for assessment of patellar instability include posteroanterior weight-bearing views of both knees in 45° of flexion, lateral views, and Merchant views. For the Merchant view, the knee is flexed 45° over the end of the table and the x-ray beam is inclined 30° downward¹⁸. This view is used to assess for patellar tilt, patellar sublaxation, and trochlear dysplasia. Patellar sublaxation is assessed by measuring the congruence angle, which reflects the relationship of the patellar articular ridge to the intercondylar sulcus and averages approximately $6^\circ \pm 11^\circ$ in the medial direction¹⁸. The sulcus angle is formed by the highest points of the medial and lateral femoral condyles and the lowest point of the intercondylar sulcus and is approximately $138^\circ \pm 6^\circ$ ¹⁸. A sulcus angle of $>145^\circ$ is indicative of trochlear dysplasia¹⁹. The lateral patellofemoral angle, as described by Laurin et al., is used to assess patellar tilt and is best evaluated on an axial radiograph of the patella with the knee flexed 20° ²⁰. Further flexion can result in a falsely normal angle²⁰.

Patella alta can be assessed on lateral radiographs with use of the Blackburne-Peel ratio, which appears to rely less on the anatomy of the patella and the location of the tibial tubercle and more on consistent osseous landmarks; it has better interobserver reliability^{21,22} than the Insall-Salvati ratio. Trochlear dysplasia is represented on a perfect lateral radiograph by the so-called crossing sign, a line represented by the deepest part of the trochlear groove crossing the anterior aspect of the condyles (Fig. 1)¹⁹. Other radiographic evidence of trochlear dysplasia on the lateral radiograph is the presence of a supratrochlear spur and a double contour representing a hypoplastic medial condyle. In a comparison of radiographs of 143 knees operated on for the treatment of patellar instability and 190 control radiographs, Dejour and Le Coultre found that 96% of patients with a history of a true patellar dislocation had evidence of trochlear dysplasia²³. However, because of a lack of interobserver and intraobserver agreement²⁴, the original system used to classify trochlear dysplasia was subsequently revised²³ (Fig. 2).

Cross-sectional imaging with transverse computed tomography slices at different positions along the lower limb can provide a three-dimensional view of the patellofemoral joint and be used to assess the lateral offset of the tibial tuberosity from the deepest point in the trochlear groove (Fig. 3). A distance between the tibial tuberosity and the trochlear groove exceeding 20 mm is nearly always associated with patellar instability¹⁹.

Magnetic resonance imaging is also useful for evaluating the medial-sided structures supporting the patella and identifying associated chondral injuries. When magnetic resonance imaging findings were correlated with operative findings, magnetic resonance imaging was found to be 85% sensitive and 70% accurate in detecting disruption of the medial patellofemoral ligament²⁵. Typical injuries seen after a patellar dislocation include cartilage damage or bone bruising of the medial patellar facet and the lateral femoral condyle²⁶. Injury to the vastus medialis obliquus, which lies superficial to the medial patellofemoral ligament, frequently presents as edema, hemorrhage, and/or elevation of the muscle away from the medial femoral condyle^{25,27}. Approximately 50% to 80% of injured medial patellofemoral ligaments are disrupted at their femoral origin^{25,27,28}.

Nonoperative Treatment

To our knowledge, no studies have demonstrated the efficacy of physical therapy or bracing in the treatment of acute patellar dislocations. However, the aim of treatment after a patellar dislocation is to decrease swelling, promote vastus medialis obliquus and gluteal activity, and increase the range of motion of the knee. Swelling has a detrimental effect on quadriceps activity so the faster the swelling is reduced, the better the outcome for the patient. Few studies have addressed the nonoperative treatment of primary patellar dislocation²⁹⁻³⁴. Treatment regimens range from immediate mobilization without a brace to cast immobilization in extension for six weeks. Immobilization in extension may help the medial structures to heal, but stiffness may be a problem with this treatment. In a

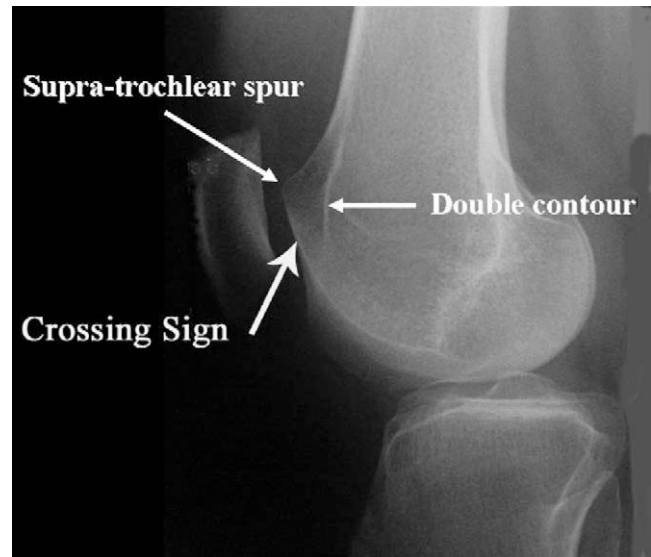


Fig. 1

Radiograph demonstrating findings of trochlear dysplasia, including the crossing sign, supratrochlear spur, and double contour (a hypoplastic medial facet). (Reprinted, with permission, from: Dejour D, Le Coultre B. Osteotomies in patello-femoral instabilities. *Sports Med Arthrosc*. 2007;15:40.)

study by Maenpaa and Lehto, 100 patients who had experienced a primary patellar dislocation were treated with one of three methods: cast immobilization, a posterior splint, or a patellar bandage or brace²⁹. The cast and splint were worn for six weeks. Patients were followed for an average of thirteen years after the initial injury. There was a threefold higher risk of redislocation in patients treated with the patellar bandage or brace. The cast immobilization resulted in a higher rate of stiffness.

Patients with chronic patellar instability may benefit from physical therapy, which can help them to regain strength, motion, and proprioception. Patellar taping may help to control excessive patellar motion during therapy. Taping has also been shown to increase quadriceps muscle torque and to activate the vastus medialis obliquus earlier than the vastus lateralis during stair ascent and descent^{35,36}.

Frequently, patients with chronic patellar instability have weak gluteal muscles. This weakness results in adduction and internal rotation of the femur during weight-bearing activities, which may accentuate the patellar instability. Strengthening the gluteal muscles or taping the hip to promote external rotation of the femur may help to address this problem.

There is increasing evidence that weight-bearing or closed-chain training is more efficacious than open-chain exercises. Stensdotter et al. found that closed-chain knee extension promoted simultaneous onset of electromyographic activity in the four different muscle portions of the quadriceps in asymptomatic subjects³⁷. The rectus femoris had the earliest response while the vastus medialis obliquus had the latest response with lower amplitude in open-chain extension.

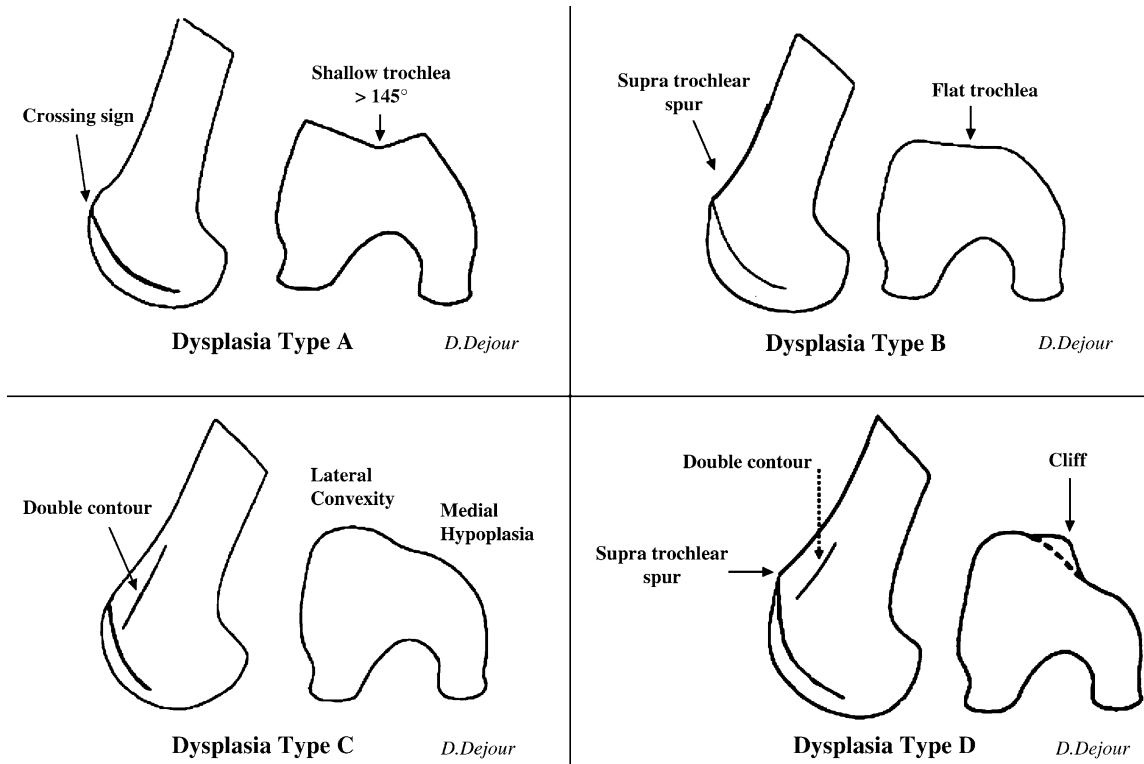


Fig. 2

Classification of trochlear dysplasia. Type A: crossing sign, with trochlear morphology preserved (fairly shallow trochlea [$>145^\circ$]). Type B: crossing sign, supratrochlear spur, and flat or convex trochlea. Type C: crossing sign, with double contour. Type D: crossing sign, supratrochlear spur, double contour, asymmetry of trochlear facets, and vertical link between medial and lateral facets (cliff pattern). (Reprinted, with permission, from: Dejour D, Le Coultre B. Osteotomies in patello-femoral instabilities. *Sports Med Arthrosc.* 2007;15:40.)

Escamilla et al. also found that open-chain exercises promoted more rectus femoris activity and that closed-chain exercises produced more vastus activity³⁸. Closed kinetic training allows training of the vastus muscles simultaneously with gluteal and trunk-muscle strengthening to control limb position.

Operative Treatment

More than 100 different operations have been described for the treatment of patellar instability, and these procedures typically involve a combination of lateral release, medial imbrication, distal realignment, and anteromedialization of the tibial tubercle³⁹. The so-called gold-standard treatment for patellar instability has yet to be defined. The literature reflects this in that no two studies have used the same operative procedure, inclusion and exclusion criteria, or outcome measures. Furthermore, there is a lack of prospective randomized trials.

Lateral Release

An isolated lateral release is the only procedure that has been shown to be ineffective for the treatment of patellar instability. While a lateral release can be useful in the treatment of lateral patellar compression syndrome, it does not yield acceptable results in patients with patellar instability⁴⁰. In fact, all twenty-eight patients in one series who underwent lateral release for

patellar dislocation continued to experience dislocations⁴⁰. Lattermann et al. reviewed the results from fourteen studies on lateral release for the treatment of patellar instability⁴¹. Although there was an average 80% patient-satisfaction rating in the short term, this rating had dropped to 63.5% after more than four years of follow-up⁴¹. The poor results after lateral release can be attributed to the inability of the procedure to align the patella more medially⁴². Furthermore, lateral release can be complicated by medial patellar instability if the release extends into, and detaches, the vastus lateralis obliquus⁴¹.

If the tibial tubercle-to-trochlear groove distance is <20 mm and there are minimal medial patellofemoral degenerative changes, lateral release may be performed in combination with a medial-sided procedure such as a medial plication or a reconstruction of the medial patellofemoral ligament⁴³. If there is osseous malalignment, these soft-tissue procedures can be combined with osseous procedures⁴⁴.

Medial Repair

We are aware of only two prospective randomized trials comparing medial repair with nonoperative treatment of acute patellar dislocation. In studies of 127 patients with a first-time patellar dislocation followed for two³⁰ and seven³¹ years, Nikku et al. found no significant difference between the results of

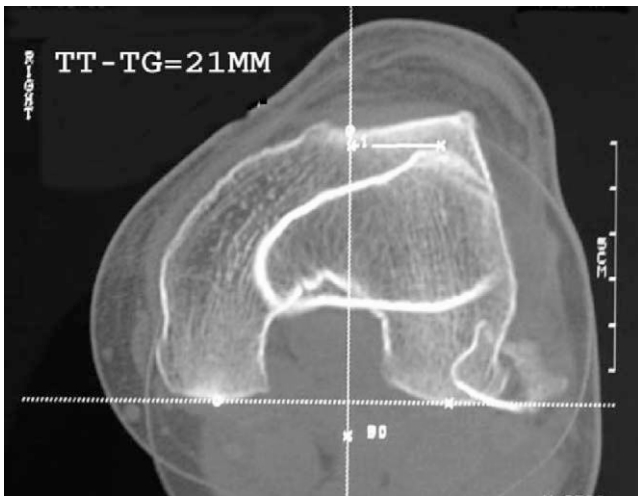


Fig. 3

The tibial tubercle-to-trochlear groove (TT-TG) distance is measured by superimposing axial computed tomography images of the tibial tubercle and the trochlear groove with the knee in extension. The normal distance ranges from 10 to 15 mm. (Reprinted, with permission, from: Dejour D, Le Coultre B. Osteotomies in patello-femoral instabilities. *Sports Med Arthrosc.* 2007;15:41.)

operative and nonoperative treatment with respect to scores determined with the systems of Kujala et al.⁴⁵ ($p = 0.6$), Flandry et al.⁴⁶ ($p = 0.1$), and Tegner and Lysholm⁴⁷ ($p = 0.7$); they also found no difference in the rate of recurrence of subluxations or dislocations. Palmu et al. found that the rates of redislocation (approximately 70%) were similar in patients who had been treated with repair of the medial structures and those who had had nonoperative treatment³⁴. At fourteen years, the two groups had similar good-to-excellent subjective outcome scores³⁴. Both groups of authors concluded that there was no advantage to primary repair of the medial structures after a first-time dislocation. On the other hand, several authors have reported good or excellent functional outcome scores and few redislocations after arthroscopic medial plication for treatment of recurrent patellar instability^{48,49}.

Acute medial-sided repair does have its proponents in clinical practice. In a recent survey of the National Football League Physician's Society (NFLPS), 6% (two) of thirty-one surgeons indicated that they would perform an early repair to treat an acute patellar dislocation without a loose body in a high-school, college, or professional athlete⁵⁰. Early operative repair to treat an acute patellar dislocation without a loose body was not recommended for athletes at any level by 58% of the surgeons. Ahmad et al. repaired the medial patellofemoral ligament in addition to the vastus medialis obliquus, if it was torn, because of the importance of the vastus medialis obliquus as a dynamic medial stabilizer⁵¹, and there were no recurrent dislocations in their series.

Advocates for medial imbrication, as opposed to reconstruction of the medial patellofemoral ligament, cite the potential for overload of the patella with a graft reconstruction⁴³. The native medial patellofemoral ligament has a load to failure

of 208 N⁵², and a hamstring graft used to reconstruct the medial patellofemoral ligament can generate up to 1600 N⁴³. However, because medial imbrication is a nonanatomic procedure, it can result in excessive medialization of the patella or abnormal tracking. In a biomechanical study, Ostermeier et al. found that the combination of a lateral release and a medial imbrication tensioned with the knee at 45° resulted in significantly medialized ($p < 0.01$) and internally tilted ($p < 0.01$) patellar movement when compared with the intact knee condition⁵³. Furthermore, medial imbrication fails to address problems with the medial patellofemoral ligament at the femoral attachment⁵⁴.

Reconstruction of the Medial Patellofemoral Ligament

Reconstruction of the medial patellofemoral ligament has the advantage of addressing damage at the adductor tubercle⁵⁴. Comparing studies is difficult, as a review of the English-language literature identified only eight papers describing a variety of medial patellofemoral ligament reconstruction procedures and outcome scales⁵⁵. There was no consensus with regard to the choice of graft, graft positioning, graft tension, or static versus dynamic reconstruction.

Adductor magnus autografts, semitendinosus autografts and allografts, and tibialis anterior allografts have all been proposed as possible graft choices^{53,56-61}. Steiner et al. recommended the use of bone-quadriceps tendon autograft or bone-patellar tendon allograft for severely dysplastic knees in which more strength was thought to be warranted⁶⁰. Farr and Schepsis advocated the use of a doubled semitendinosus allograft, not for its strength but rather to reproduce the broad attachment site on the patella⁵⁷.

Use of a doubled hamstring tendon graft could be problematic if it is malpositioned, since it is stronger and stiffer than the native medial patellofemoral ligament⁶². Elias and Cosgarea performed a biomechanical study and found a significant increase in force on the medial patellar facet with either 5 mm of proximal malpositioning ($p < 0.01$) or a graft that was 3 mm shorter than the native medial patellofemoral ligament ($p < 0.01$)⁶¹. Furthermore, a combination of the two errors led to a medial tilt moment from full extension through 90° of flexion. Increased pressures could theoretically lead to degeneration of the cartilage and arthrosis, while undertightening could lead to recurrent instability⁶⁰. Thus, Elias and Cosgarea recommended placing the femoral attachment of the graft 1 cm distal to the adductor tubercle to avoid overloading the medial patellofemoral cartilage. A biomechanical study by Beck et al. demonstrated that, when >2 N of tension was used to secure the reconstruction of the medial patellofemoral ligament, there was a significant increase in medial patellofemoral contact pressures ($p < 0.05$)⁶². There is also a risk of applying a net posteromedial force on the patella as the reconstruction results in a posterior force as well⁶².

The appropriate knee flexion angle at which to tension the graft is also controversial. While some believe the medial patellofemoral ligament to be isometric^{60,63}, others have shown that it is not^{52,54}. Tensioning the graft at between 60° and 90° of

flexion^{54,59,60}, instead of at the lower flexion angles (30° to 45°) that have been recommended by other authors^{53,57}, has been advocated to avoid overtightening of the graft and to ensure that the patella has engaged the trochlea. LeGrand et al. recommended applying tension at 45° to 60° of flexion and also checking that there is symmetric medial and lateral translation of the patella at 20° of flexion⁶⁴. Farr and Schepsis described an “anatomometric” placement of the graft: tensioning the graft with the knee in 30° of flexion so that it becomes more lax with further flexion and tighter in terminal extension⁵⁷.

A dynamic reconstruction of the medial patellofemoral ligament has been proposed as an alternative that is better than a static reconstruction. Ostermeier et al. performed a dynamic reconstruction by transferring the distal end of the semitendinosus behind the proximal aspect of the medial collateral ligament to the medial margin of the patella⁵³. The authors found that a static reconstruction medialized the patella significantly more than the dynamic reconstruction did ($p < 0.01$). Thus, a dynamic reconstruction could theoretically protect against overtensioning of the graft. Deie et al.⁵⁶ found that dynamic reconstruction provided a significant improvement ($p < 0.0001$) in scores derived with the system of Kujala et al.⁴⁵, with no recurrent dislocations in forty-six knees in forty-three patients followed for a mean of 9.5 years (range, five to twelve years).

However, Panagopoulos et al. believed that the medial collateral ligament is not an adequate pulley for the graft because its fibers are parallel to the direction of movement of the patella⁵⁴. In their experience, use of the medial collateral ligament as a pulley led to splitting of the ligament during motion of the knee and loosening of the graft. They proposed using, instead, the medial intermuscular septum as a pulley for a semitendinosus autograft that has been detached at the myotendinous junction and pulling the graft through a bone tunnel in the patella⁵⁴. In their series of twenty-five patients, there were improvements in the Tegner and Lysholm⁴⁷ and International Knee Documentation Committee (IKDC)⁶⁵ scores and no cases of redislocation at a mean of thirteen months postinjury.

The type of fixation of the medial patellofemoral ligament has also varied. Mountney et al. performed a biomechanical study comparing several different techniques, including suture repair, suture anchor repair, and allograft reconstruction with either blind-tunnel (ending in the medial femoral condyle) or through-tunnel (fixation in the lateral femoral condyle) fixation⁶⁶. The strength of the reconstruction with the through-tunnel fixation (195 ± 66 N) was essentially the same as that of the intact medial patellofemoral ligament (208 ± 90 N) ($p > 0.05$).

Fracture of the patella after fixation of the graft through a bone tunnel has been described^{54,58}. In a study of twenty-four knees treated with reconstruction of the medial patellofemoral ligament, Mikashima et al. reported two patellar fractures, both of which occurred through bone tunnels in the patella⁵⁸. The authors recommended suturing the graft to the patellar periosteum in all patients except those with a thin periosteum. However, we are not aware of any biomechanical studies comparing tunnel with suture-anchor fixation.

Reconstruction of the medial patellofemoral ligament has had good results in terms of preventing future subluxations or dislocations^{54,58,59}. However, not all patients with recurrent patellar instability may benefit from this reconstruction. Nomura and Inoue evaluated twelve knees in twelve patients at an average of 4.2 years (range, 3.1 to 5.6 years) after reconstruction of the medial patellofemoral ligament⁵⁹. Using the Insall scale, they found only fair results in patients with preexisting chondromalacia patella. Thus, they recommended reconstruction of the medial patellofemoral ligament for patients without advanced changes in the patellar cartilage.

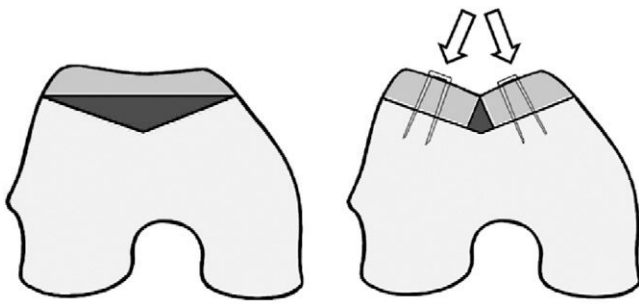
Biomechanically, reconstruction of the medial patellofemoral ligament provides more stability than a medial tibial tubercle transfer does. Ostermeier et al. evaluated patellar kinematics in cadaver knees after either a medial transfer of the tibial tubercle or a reconstruction of the medial patellofemoral ligament with a semitendinosus autograft⁶⁷. Patellar movement and strain in the medial patellofemoral ligament were measured with and without a 100-N lateral subluxation force under both testing conditions. While loading of the native medial patellofemoral ligament was greatest in full extension, the reconstruction of the medial patellofemoral ligament reduced the ligament load and lateral patellar displacement compared with those parameters after the medial transfer of the tibial tubercle, regardless of the knee flexion angle. On the basis of their results, the authors concluded that reconstruction of the medial patellofemoral ligament was better than medial transfer of the tibial tuberosity for stabilizing patellar movement under a laterally directed force. However, reconstruction of the medial patellofemoral ligament does not address potential osseous problems and can also result in overload of the medial patellofemoral cartilage^{60,61}.

Trochleoplasty

Trochleoplasty has been used with equivocal results, as reported in the European literature. Concerns about possible serious and irreversible articular and subchondral injury to the trochlea have limited its use in the United States.

Indications for a sulcus-deepening trochleoplasty include abnormal patellar tracking with a J-sign, usually manifested by a tibial tubercle-trochlear groove distance of greater than 10 to 20 mm²³, and/or a dome-shaped trochlea noted on a perfect lateral radiograph with overlap of the posterior condyles in a patient with recurrent patellar instability⁶⁸. In a trochleoplasty, cancellous bone is exposed in the trochlea by elevating a strip of cortical bone around the edge of the trochlea. The new trochlear sulcus is created proximal and 3° to 6° lateral to the previous sulcus by removing cancellous bone. The trochlear bone shell is then impacted into the new sulcus and fixed with two small staples (Fig. 4). The bone can also be secured with resorbable sutures^{69,70}.

Verdonk et al. reported equivocal results at eighteen months (range, eight to thirty-four months) after trochleoplasty in thirteen knees in twelve patients⁷¹. Their indication for the operation was patellar pain with or without recurrent patellar instability. According to the Larsen-Lauridsen scoring



Deepening Trochleoplasty (Dejour)

Fig. 4

To perform a trochleoplasty, a deeper sulcus is created by removing cancellous bone in the trochlear groove and repositioning the cortical bone. (Reprinted, with permission, from: Dejour D, Le Coultre B. Osteotomies in patello-femoral instabilities. *Sports Med Arthrosc.* 2007;15:44.)

system, which takes into account crepitus, range of motion, and stiffness, seven patients had a poor score. Because the authors included patients with patellar pain but no evidence of instability, their results are not comparable with those of other studies^{68-70,72,73}. Although there were no postoperative patellar dislocations, postoperative arthrofibrosis was found in five of the thirteen knees.

Several investigators have reported improved subjective outcome scores in the short term after trochleoplasty^{68,69,72,73}. Furthermore, there is an improvement in radiographic measurements, including a decrease in boss height or an increase in trochlear depth^{68,70}. Preoperative degenerative changes of the patellar or trochlear articular cartilage have been associated with fair or poor results^{69,73}. Like Verdonk et al.⁷¹, Donell et al. reported several cases that were complicated by postoperative arthrofibrosis⁶⁸. Von Knoch et al. reported what we believe to be the largest study on trochleoplasty with the longest follow-up to date⁷⁰. Trochleoplasty and medial reefing, with or without reconstruction of the medial patellofemoral ligament, was performed in forty-five knees in thirty-eight patients followed for a mean of 8.3 years (range, four to fourteen years). The most recent score, according to the system of Kujala et al.⁴⁵, averaged 94.9 points (range, 80 to 100 points), but no preoperative scores were available for comparison. One patient had a positive apprehension test and subluxation postoperatively, but no patient had a postoperative patellar dislocation. The depth of the trochlea increased, and the trochlear boss height was reduced. Although the trochleoplasty was effective in preventing future patellar dislocations, it did not halt the progression of patellofemoral arthritis. In fact, at the time of the latest follow-up, ten knees had osteoarthritic changes in the patellofemoral compartment that were grade 2 or worse according to the system of Iwano et al.⁷⁴ and fifteen (43%) of thirty-five knees had worsening of preoperative patellofemoral pain.

Concerns about the viability of the articular cartilage after trochleoplasty were addressed in a study by Schottle et al.⁷⁵. Two osteochondral biopsy specimens from each of

three patients under the age of twenty-one years were obtained at the time of a second arthroscopic procedure for the treatment of lateral patellofemoral adhesions at six, eight, and nine months after trochleoplasty. Using the International Cartilage Repair Society scale⁷⁶ to rate the cartilage, the authors found that tissue in the trochlear groove remained viable, with retention of distinctive hyaline architecture and composition and only a few minor changes in the calcified layers.

Trochleoplasty may not be the only option for patients with recurrent patellar instability and trochlear dysplasia. Steiner et al. reported the results of reconstruction of the medial patellofemoral ligament in patients with trochlear dysplasia⁶⁰. There was a significant improvement in the scores derived with the systems of Kujala et al.⁴⁵, Lysholm and Gillquist⁷⁷, and Tegner and Lysholm⁴⁷ ($p < 0.001$) and no recurrent dislocations at the time of the latest follow-up. Furthermore, there was no significant association between the severity of the dysplasia and the scores derived with the systems of Kujala et al. ($p = 0.07$), Lysholm and Gillquist ($p = 0.32$), and Tegner and Lysholm ($p = 0.38$).

Tibial Tubercle Transfer

Several types of distal realignment have been described for the treatment of patellar instability. A medial transfer of the tibial tubercle (an Elmslie-Trillat procedure)⁷⁸ and anteromedialization of the tibial tubercle⁷⁹ have both been successful in the treatment of patellar instability⁸⁰⁻⁸⁷. Anteromedial tibial tubercle transfer has had success as a treatment both for instability due to patellar malalignment and for pain due to distal or lateral articular damage⁴². When the tibial tubercle is transferred anteromedially, the patella engages earlier in flexion and offloads the damaged distal articular cartilage.

Biomechanically, overmedializing the tubercle (>15 mm past the original insertion site) can increase contact pressures in the medial patellar facet and medial compartment⁸⁸. On the basis of these data, Kuroda et al. recommended avoiding overmedialization of the tibial tubercle in patients with a varus knee or degenerative changes of the medial compartment and in those who have had a medial meniscectomy⁸⁸.

Nakagawa et al. performed an Elmslie-Trillat procedure in forty-five knees in thirty-nine patients for the treatment of recurrent dislocation of the patella⁸². They assessed their outcomes both at an average of forty-five months and at an average of 161 months. Although instability did not increase with time, there were six postoperative dislocations, two of which became recurrent in patients with ligamentous laxity. A longer length of time between the first dislocation and the operation was correlated with a poorer result. Degenerative changes noted on radiographs were also correlated with increased pain and worse clinical results. Ninety-one percent (forty-one) of the forty-five knees had a good or excellent Fulkerson score⁷⁹ at the time of the first follow-up; however, only 64% (twenty-nine) of the forty-five knees had a good or excellent score at the time of the final follow-up. Thus, Nakagawa et al. recommended performing the Elmslie-Trillat procedure before degenerative changes are seen in the patellofemoral joint.

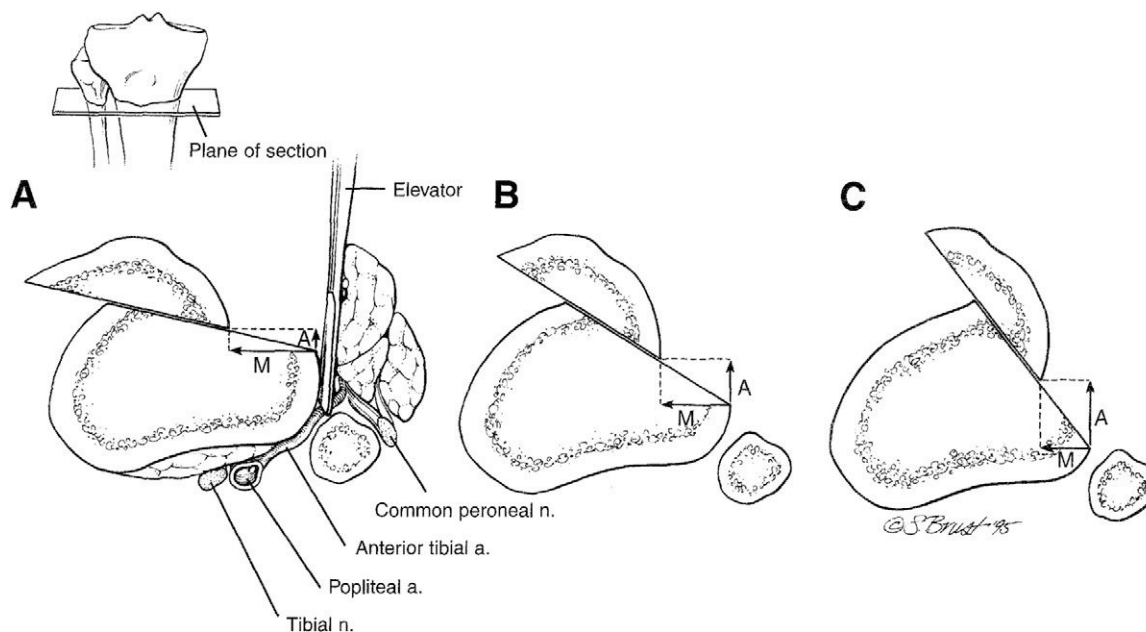


Fig. 5

Tibial tubercle realignment. A: A flat (no-angle) osteotomy allows medialization of the tibial tubercle. The elevator protects the neurovascular bundle. B: A steeper cut for equal anteriorization and medialization of the tibial tubercle. C: A very steep cut provides maximum anteriorization of the tibial tubercle with less medialization. (Reprinted, with permission, from: Buuck DA, Fulkerson JP. Anteromedialization of the tibial tubercle: a 4- to 12-year follow-up. *Op Tech Sports Med.* 2000;8:136-7.)

Carney et al. reviewed the results of the Elmslie-Trillat procedure for the treatment of recurrent subluxation and dislocation of the patella in fifteen knees in fourteen patients⁸⁹. The authors compared the outcomes at a mean of three years with those at a mean of twenty-six years and found no difference in instability between the two time-periods. Although not significant, there was a trend toward a worsening Cox score⁹⁰ with time, which occurred even though the articular cartilage was grossly intact.

Koeter et al. reported the results of medial realignment of the tibial tubercle for patients with either painful lateral maltracking (with no instability) or patellar instability for longer than one year and a tibial tubercle-trochlear groove distance of >15 mm⁸⁶. There was no difference in the distance of the medial displacement between the groups. A mean of 5.7 mm of distalization of the tibial tubercle was achieved in nine patients with lateral maltracking and twenty-two patients with patellar instability. At two years postoperatively, although the patients with patellar instability had more variable outcomes, both groups had improvement in all scores, with no significant difference noted between the groups. Thus, the authors advocated a medial transfer, with or without distalization, for patients with either patellar maltracking or patellar instability.

Diks et al. found that a tibial tubercle transfer provided better results for patients with patellar maltracking and no instability than for patients with isolated patellar instability⁸³. Tibial tubercle transfer was performed in forty-three knees, twenty-seven with objective evidence of patellar instability and sixteen with a laterally tracking patella. The mean duration of follow-up

was thirty-seven months. The transfers in the patients with patellar instability were, overall, more effective in improving stability, doing so in 96% (twenty-six) of the twenty-seven patients, than they were in improving pain (63% of the patients). On the other hand, a higher percentage of patients (81%, thirteen of sixteen) with patellar maltracking had good pain relief.

Barber and McGarry advocated the use of the modified Elmslie-Trillat procedure for treatment of patellofemoral instability without evidence of arthritis⁸⁷. These authors performed a medial translation of the tibial tubercle hinged on a distal periosteal flap along with an arthroscopic lateral retinacular release and medial capsular reefing for patients with at least three recurrent patellar dislocations or subluxations that had been resistant to a minimum of three months of physical therapy or bracing. Of thirty-five patients followed for a mean of ninety-eight months, 91% (thirty-two) had no additional subluxations or dislocations. Furthermore, there was improvement in the IKDC⁶⁵, Fulkerson knee⁷⁹, and Lysholm and Gillquist⁷⁷ scores.

Fulkerson et al. described anteromedialization of the tibial tubercle to address degenerative changes of the articular cartilage⁷⁹ (Fig. 5). In a cadaver model of this procedure, pressure was shown to be decreased on the lateral patellar facet at lower angles of flexion (up to 30°) whereas pressure was equalized between the medial and lateral patellar facets at greater angles of flexion⁸⁵. There was slight superior migration of the contact area of the patellofemoral joint with distalization⁸⁵. Cadaver studies have also demonstrated that anteromedialization decreases the contact pressures on the trochlear side overall, primarily on the

TABLE I Grades of Recommendation for Summaries or Review of Orthopaedic Surgical Studies

Grade	Description
A	Good evidence (Level-I studies with consistent findings) for or against recommending intervention.
B	Fair evidence (Level-II or III studies with consistent findings) for or against recommending intervention.
C	Poor-quality evidence (Level-IV or V studies with consistent findings) for or against recommending intervention.
I	There is insufficient or conflicting evidence not allowing a recommendation for or against intervention.

lateral and central areas of the trochlea⁸⁸. However, pressures are elevated on the medial aspect of the trochlea and the proximal-medial aspect of the patella at all flexion angles, and thus caution should be used when performing an anteromedialization procedure in patients with medial-sided defects⁸⁸.

Buuck and Fulkerson reviewed their results with anteromedialization at an average of 8.2 years postoperatively⁸¹. Their indications for the procedure were painful patellofemoral maltracking (subluxation or tilt) with degenerative changes on the distal and lateral aspects of the patella. Poorer results were associated with Outerbridge⁹¹ grade-3 or 4 lesions in the central or medial aspects of the trochlea. Notably, three of the six fair or poor results were in patients who had compensation claims or were involved in litigation. Overall, 74% (thirty-one) of the forty-two patients had a good or excellent result at an average of 8.2 years postoperatively.

Pritsch et al. reported their results of tibial tubercle transfer for treatment of recurrent patellar instability, anterior knee pain, and evidence of maltracking on a dynamic computed tomography scan⁸⁵. Sixty-nine knees followed for a median of 6.2 years had a significant improvement between the preoperative and postoperative Lysholm and Gillquist⁷⁷ and Karlsson⁹² score categories of instability, pain, and stair-climbing ($p < 0.001$). However, patients who had had only instability preoperatively did better than patients with pain or both pain and instability preoperatively. A better outcome was correlated with male sex, intact patellar articular cartilage, and symptoms of patellar instability. Physical examination findings that correlated with a

worse prognosis included a positive patellar grind test, retinacular pain, a positive patellar tilt test, and a positive J-sign. The duration of follow-up was also positively correlated with better Lysholm and Gillquist⁷⁷ and Karlsson⁹² scores, which the authors attributed to the need for quadriceps recovery in the short term. Furthermore, there was no deterioration of the results with time.

Pidoriano et al. found that the location of articular cartilage damage in the patellofemoral joint correlated with the outcome after anteromedialization⁸⁰. Of thirty-six patients (thirty-seven knees), 56% (twenty) had the procedure performed because of patellar instability. All twenty-three patients with distal and lateral patellar lesions were extremely satisfied with the result of the procedure. There was a 95% rate of good-to-excellent results (if no Workers' Compensation claim was involved), and 87% had good-to-excellent pain relief. The authors recommended not proceeding with the operation if medial, proximal, or diffuse lesions were present on the patella or if central lesions were present on the trochlea. Interestingly, the Outerbridge⁹¹ classification of the lesion had no effect on the outcome.

Palmer et al. also reported satisfactory results after anteromedialization for treatment of both instability and painful patellar maltracking⁸⁴. In a study of eighty-four patients followed for a mean of 5.6 years, the result was good to excellent in 80% of patients with dislocation and 71% of patients with pain from maltracking. There was no significant difference in outcome between the groups, leading the authors to recommend anteromedialization of the tibial tubercle with distalization as an effective procedure for both instability and pain due to maltracking. Predictors of poor postoperative results were postoperative anterior knee pain and a previous realignment procedure.

Fracture of the proximal part of the tibia or of the tibial tubercle after tibial tubercle transfer has been reported by several authors^{86,93,94}. All cases occurred within three months after the operation and were attributed to early weight-bearing. Suggested preventive measures have included avoidance of step cuts⁸⁶, an osteotomy of at least 5 cm in length and 0.75 cm in thickness to avoid fracture of the tuberosity⁸⁶, protected weight-bearing over six to eight weeks in a hinged knee brace, and advancement to full weight-bearing once the osteotomy site is fully healed⁹³⁻⁹⁵.

Overview

The evaluation and treatment of patellar instability continue to evolve. The importance of a thorough physical examination and an accurate diagnosis cannot be stressed enough. We typically

TABLE II Grades of Recommendation for the Treatment of Acute Patellar Dislocation and Chronic Patellar Instability with Associated Factors

Disorder	Treatment	Grade of Recommendation
Acute patellar dislocation	Early medial-sided repair or nonoperative treatment	A
Chronic patellar instability with associated factors		
Patella alta	Tibial tubercle realignment	C
Medial patellofemoral ligament injury	Medial patellofemoral ligament reconstruction	C
Trochlear dysplasia	Trochleoplasty	C
Elevated tibial tubercle-to-trochlear groove distance	Tibial tubercle realignment	C

recommend nonoperative treatment with patellar bracing and therapy for primary patellar dislocations. We aspirate the effusion acutely to allow the patient to regain quadriceps strength and control. However, if a patient has a loose body after a dislocation, we recommend arthroscopy for removal or possibly fixation of the fracture fragment, in which case a medial repair will usually be performed simultaneously. When there is an extensive medial-sided injury, such as a femoral avulsion of the medial patellofemoral ligament in association with an extensive retinacular injury or avulsion of the vastus medialis obliquus, repair is usually recommended as well.

When physical therapy and bracing have failed, the surgical options should be tailored to the underlying pathological condition. The literature provides little support for the performance of an isolated lateral release for the treatment of patellar instability. Recurrent patellar instability can be addressed with either a reconstruction of the medial patellofemoral ligament or a distal patellar realignment. Reconstruction of the medial patellofemoral ligament can be performed in patients with recurrent instability, with or without trochlear dysplasia, who have a normal tibial tubercle-trochlear groove distance and a normal patellar height. Distal realignment procedures can be used in patients who have an increased tibial tubercle-trochlear groove distance or patella alta. A standard medialization of the tibial tubercle can be performed if there is a normal patellar height and trochlear

anatomy and an increased tibial tubercle-trochlear groove distance. Distalization of the tubercle can be added if there is concomitant patella alta, and anteromedialization of the tubercle is performed if there is lateral and/or distal patellar facet chondrosis. To avoid overloading the patella, a tubercle osteotomy should not be performed if there is associated medial or proximal patellar chondrosis.

While there is good evidence (Table I) for the nonoperative treatment of an acute patellar dislocation, most of the current surgical treatments for chronic patellar instability are based on Level-IV evidence (Table II). Prospective randomized trials are necessary to determine the optimal surgical treatment for chronic patellar instability. ■

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