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Exhibit Selection

Complications of Medial Patellofemoral Ligament Reconstruction: Common Technical Errors and Factors for Success

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Background: The role of medial patellofemoral ligament reconstruction in reestablishing patellofemoral joint stability has recently been reported with increasing frequency. The purpose of this study was to review the reported complications of medial patellofemoral ligament reconstruction, highlight the common technical errors, and discuss the potential complications that can arise from this procedure.

Methods: We review the literature on medial patellofemoral ligament reconstruction, including the reported causes of failure. In addition, we present three cases and discuss the multiple factors that are crucial for success, including patient selection, tunnel placement, graft isometry, and determination of the need for concurrent realignment surgery.

Results: The principles of surgical management require a thorough understanding of proper patient selection and of the interaction between the roles of the osseous and soft-tissue restraints on the patella. Creating a logical treatment algorithm based on pathoanatomy can elucidate the need for concurrent distal realignment procedures. Tunnel positioning is critical in recreating appropriate patellofemoral alignment. The reported complications include patellofemoral arthrosis, graft impingement, and graft failure.

Conclusions: Many of the complications that can arise from medial patellofemoral ligament reconstruction are the result of technical error and can be avoided by understanding the potential complications associated with this procedure.

The medial patellofemoral ligament is the primary soft-tissue stabilizer of the patella and prevents lateral patellar translation during the first 30° of flexion[1]. It remains isometric between full extension and 70° of flexion[2], and it has a mean tensile strength of 208 N at 26 mm of displacement[3]. Lateral patellar dislocation results in injury to the medial patellofemoral ligament in 87% of cases[4]. The role of medial patellofemoral ligament reconstruction in reestablishing the stability of the patellofemoral joint has recently been reported with increasing frequency[5,6]; however, to our knowledge, the long-term results have not been reported. We review the literature and report the common complications, highlight the common technical surgical errors, and discuss the potential complications of this procedure.

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

Reported Complications of Medial Patellofemoral Ligament Reconstruction

Restricted Range of Knee Motion

Thaunat and Erasmus[7] reported two cases of restricted knee motion after overtightening of the graft; one resulted in loss of flexion, and the other resulted in loss of extension. Both were treated successfully with percutaneous release of the medial patellofemoral ligament graft (see Case 3 below).

Arthrofibrosis

As with any procedure involving the knee, arthrofibrosis can occur after medial patellofemoral ligament reconstruction. Drez et al.[8] reported this complication in one of nineteen patients (see Case 2 below).

Recurrent Lateral Instability

Recurrent lateral instability can be caused by several factors. Lack of appropriate tensioning of the graft intraoperatively can lead to lateral patellar instability. Conversely, overtightening of the graft can cause increased strain on the graft and ultimately result in failure[9]. Postoperative trauma can also result in recurrence of patellofemoral dislocation and graft failure.

Medial Instability

Overtightening of the graft, particularly with concurrent lateral retinacular release, can lead to iatrogenic medial patellofemoral subluxation (see Case 1 below).

Patellofemoral Arthrosis

Overconstraint of the patella can lead to increased contact pressures in the patellofemoral joint[9] and subsequent arthrosis (see Cases 1 and 2 below).

Fracture

Thaunat and Erasmus[10] described two patients with an avulsion fracture of the patella at the fixation site secondary to trauma. In these two patients, a laterally directed force on the patella caused a traumatic repeat dislocation. Both patients were treated with open reduction and internal fixation. Steiner et al.[11] also reported a fracture of the adductor tubercle at the

Fig. 1-A

Fig. 1-B

Conventional lateral radiograph (**Fig. 1-A**) and axial computed tomography scan (**Fig. 1-B**) showing a femoral tunnel that is positioned too anteriorly and proximally relative to the isometric point (red dot). (Figure 1-A is reproduced, with permission of Elsevier, from: Bollier M, Fulkerson J, Cosgarea A, Tanaka M. Technical failure of medial patellofemoral ligament reconstruction. Arthroscopy. 2011;27[8]:1153-1159. Copyright [2011]. http://www.sciencedirect.com/science/journal/07498063.)

femoral tunnel that occurred during medial patellofemoral ligament reconstruction.

Christiansen et al.[12], Ellera Gomes et al.[13], Lippacher et al.[14], and Parikh and Wall[15] described iatrogenic patellar fractures after surgery. These fractures occurred because of violation of the anterior patellar cortex that had occurred intraoperatively during drilling of the patellar tunnel. Parikh and Wall[15] also reported avulsion fractures of the superior pole of the patella after medial patellofemoral ligament reconstruction; these were attributed to lateral retinacular release and excessive dissection at the superior aspect of the patella.

Graft Failure

Steiner et al.[11] described one patient in their series who had recurrence of lateral patellar instability secondary to graft loosening after a high-speed motor vehicle accident. This was treated with graft advancement.

Hemarthrosis and Wound Complications

Steiner et al.[11] and Nomura et al.[16] reported hemarthrosis as an early complication that was treated with irrigation and debridement. In addition to the one case of hemarthrosis, Nomura et al.[16] also reported one postoperative wound infection in their series of twenty-seven patients. Drez et al.[8] reported one case of superficial wound infection in a group of nineteen patients.

Implant Pain

Christiansen et al.[12] reported that three of fourteen patients in their series underwent screw removal six to twelve months after surgery for painful prominence at the site of the femoral interference screw. Steiner et al.[11] found that three of thirty-four patients required removal of painful implants at the femoral fixation site. Nomura et al.[16] reported pain at the fixation site in 57% of patients treated with staples and in 23% of patients treated with an integrated double-staple system.

Case Examples: Complications of Medial Patellofemoral Ligament Reconstruction

Institutional review board approval is not required by our facility for three or fewer case reports.

CASE 1. A thirty-nine-year-old woman with recurrent patellofemoral instability was treated elsewhere with medial patellofemoral ligament reconstruction and semitendinosus allograft after an Elmslie-Trillat procedure with lateral retinacular release and vastus medialis obliquus advancement was unsuccessful. She reported painful patellofemoral subluxation episodes. Examination revealed a positive medial patellar subluxation test and a tight medial patellofemoral ligament graft with medial patellar tilt.

Radiographs (Fig. 1-A) and computed tomography scans (Fig. 1-B) revealed an anteriorly and proximally positioned femoral tunnel. Arthroscopic examination showed medial patellar facet arthritis, which was due to joint overload, and medial patellar tilt (Fig. 2). Arthroscopic medial release, patellar chondroplasty, and open lateral imbrication were performed. These procedures allowed the patella to track centrally and unloaded the arthritic medial facet. Postoperatively, she reported pain relief and resolution of the shifting and popping symptoms.

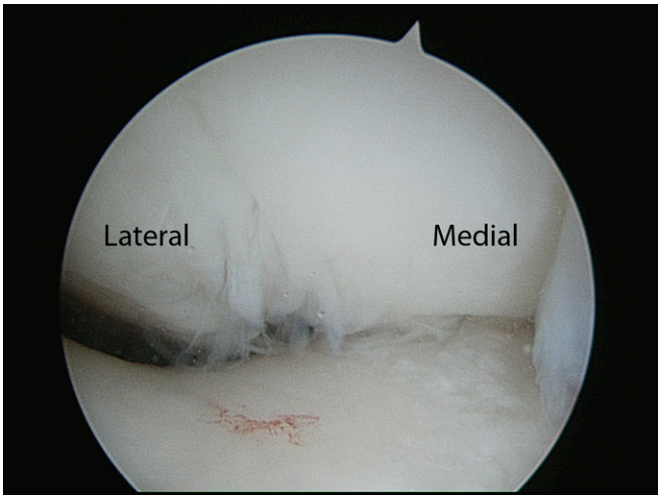

Fig. 2

Arthroscopic view showing medial tilt and medial patellar facet arthritis resulting from an overly tight graft. (Reproduced, with permission of Elsevier, from: Bollier M, Fulkerson J, Cosgarea A, Tanaka M. Technical failure of medial patellofemoral ligament reconstruction. Arthroscopy. 2011;27[8]:1153-1159. Copyright [2011]. http://www.sciencedirect.com/science/journal/07498063.)

CASE 2. A twenty-one-year-old man presented with recurrent patellar dislocation. Arthroscopy revealed substantial trochlear dysplasia and partial-thickness articular cartilage damage to the patella and the central aspect of the trochlea. He underwent an Albee osteotomy (elevation of the lateral aspect of the trochlea by 6 mm with tricalcium phosphate graft) and medial patellofemoral ligament reconstruction with a semitendinosus graft (double-stranded single loop) anchored to the patella with two suture anchors and anchored to the femur anterior to the adductor tubercle with a small spiked staple; the knee was tensioned in 30° of flexion (Fig. 3). His postoperative course was marked by pain and stiffness (range of motion, 0° to 90°). He subsequently underwent a second procedure to treat arthrofibrosis and pain. He had advanced articular cartilage erosion over the medial aspect of the femoral trochlea in addition to the changes noted at the index procedure (Fig. 4). He underwent medial and lateral retinacular releases, infrapatellar adhesion releases, and staple removal. He had substantial improvement postoperatively, with knee motion of 0° to 130° and appropriate patellar tracking.

CASE 3. A twenty-one-year-old woman presented with pain and symptoms of patellar instability. Clinical examination suggested patella alta and patellar subluxation. After nonoperative treatment was unsuccessful, she underwent tibial tubercle osteotomy with distalization and medialization and medial patellofemoral ligament reconstruction with gracilis tendon (double-stranded single loop). The graft was anchored to the patella with a suture anchor and anchored to the femur 1 cm anterior to the adductor

Fig. 3

Postoperative lateral radiograph after Albee osteotomy and medial patellofemoral ligament reconstruction. The femoral tunnel is positioned anteriorly.

tubercle with an extra-small staple; the knee was tensioned in 30° of flexion. All articular surfaces were normal.

Postoperatively, she had marked stiffness and pain with flexion (knee motion, 0° to 45°). Examination under anesthesia showed a range of motion of 0° to 90°, which improved with manipulation under anesthesia to 0° to 120°. Postoperative radiographs showed a femoral tunnel that was too anterior (Fig. 5). Arthroscopic evaluation showed a tight medial patellofemoral ligament graft, with the woven suture on the graft visible during arthroscopy. A partial resection was performed arthroscopically, and all observable sutures were removed with a shaver. Postoperatively, she had 0° to 135° of knee motion and was active and pain-free.

Factors Crucial for Successful Reconstruction

The factors crucial for successful reconstruction include patient selection, tunnel positioning, proper understanding of graft types and isometry, graft fixation, and assessment of the need for concurrent patellar realignment procedures.

Patient Selection

Medial patellofemoral ligament reconstruction is reserved for lateral instability of the patella and should be regarded as a stabilization procedure. Symptoms of excessive lateral patellar pressure, maltracking, and arthrosis may be better addressed by distal realignment procedures to unload the lateral patellofemoral cartilage. Because medial patellofemoral ligament reconstruction recreates the primary medial stabilizer of the patella, patellofemoral pain alone must be carefully differentiated from patellofemoral instability in the history and physical examination. Medial instability should also be carefully ruled out because it is a contraindication to medial patellofemoral ligament reconstruction and is especially likely to occur after overly aggressive lateral release.

Tunnel Positioning

As in anterior cruciate ligament reconstruction, correct positioning of the tunnels for the graft is critical to restoring the correct isometry and function of the graft[1,17,18].

Femoral Tunnel

Analysis of the medial patellofemoral ligament in cadaveric specimens has indicated that the single most important point affecting isometry is the femoral attachment site of the medial patellofemoral ligament[19]. The femoral tunnel should be placed at the anatomic insertion point of the ligament between the adductor tubercle and the medial femoral epicondyle[2,16,19]. The femoral attachment of the medial patellofemoral ligament is a mean of 15.4 mm wide, and it attaches a mean (and standard deviation) of 13.3 ± 2.4 mm proximal to the medial epicondyle and 6.2 ± 1.5 mm distal to the adductor tubercle[19,20].

Servien et al.[18] discussed the difficulty of reproducibly placing the femoral tunnel in an anatomic position; all twenty-nine of their positioning errors involved tunnels placed too anteriorly or proximally. Proximal malpositioning of the femoral tunnel has been shown by Elias and Cosgarea[21] to increase medial tilt and medial patellofemoral contact pressures, which can potentially lead to medial compartment arthritis. Anterior malpositioning of the femoral tunnel can also result in overload of the medial facet.

Patellar Tunnel

The patellar tunnel should begin at the anatomic insertion of the ligament on the proximal half of the medial border of the patella, and the tunnel should extend through the center of the patella in the sagittal plane. The mean width of the patellar

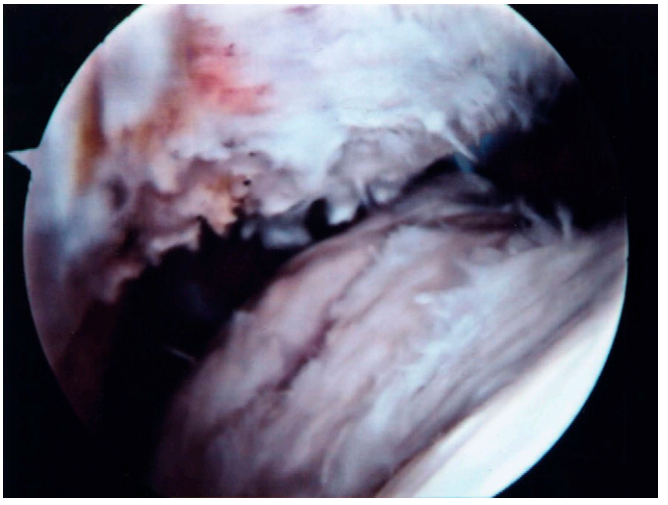

Fig. 4

Arthroscopic view showing advanced erosion over the medial trochlea after overtightening of the medial patellofemoral ligament reconstruction.

Fig. 5

Postoperative lateral radiograph showing femoral tunnel placement that is too anterior.

attachment is 17 mm at its insertion on the proximal two-thirds of the medial border of the patella[19]. Although the ideal position of the patellar tunnel has not been elucidated, the appropriate patellar tunnel position may vary in patients with patella alta.

Anterior placement of the patellar tunnel can result in violation of the anterior cortex. Christiansen et al.[12] and Lippacher et al.[14] described postoperative patellar fractures after medial patellofemoral ligament reconstruction. Christiansen et al.[12] reported an iatrogenic patellar fracture six weeks after surgery when the patient arose from a chair without support. It was found that violation of the anterior patellar cortex had occurred intraoperatively during drilling of the patellar tunnels.

Posterior placement of the patellar tunnel can violate the articular surface of the patella. Digital palpation of the articular surface of the patella and use of fluoroscopy can aid in guiding the tunnel positioning in the patella to avoid this complication (Fig. 6).

Graft Types and Isometry

Types

Multiple types of grafts for the reconstruction of the medial patellofemoral ligament have been described, including quadriceps tendon[19], hamstring tendon[12,22], adductor tendon[11], and synthetic grafts[14,23]. A cadaveric study by Hamner et al.[24] showed hamstring grafts to be substantially stiffer and stronger than the native medial patellofemoral ligament. When tensioning such a graft, this finding should be kept in mind to avoid the risk of overloading the medial patellofemoral cartilage.

Tensioning

Graft tensioning is perhaps the most important factor in a successful medial patellofemoral ligament reconstruction. The patella should be centered in the trochlear groove during the first 30° of flexion.

Overtensioning of the graft can lead to increased medial patellofemoral contact pressures. Using computational analysis, Elias and Cosgarea[21] found that a graft that was in the correct position but 3 mm too short decreased the lateral compressive force and increased the medial compressive force at 30° and 40° of flexion, while also increasing the maximum medial pressure. This scenario results in increased medial patellar tilt from overtensioning of the graft, and it can lead to medial patellar subluxation. These results were magnified if the femoral tunnel was malpositioned. Undertensioning of the graft can result in lack of adequate medial restraint and may lead to recurrent lateral patellofemoral instability.

Correctly recreated tension should approximate the patellar motion in the contralateral extremity, provided that the patient does not have bilateral involvement. In patients with bilateral symptoms, normal patellar motion should allow for two to three patellar quadrants of lateral translation. Note that the appropriate tension will be different in cases of altered anatomy such as trochlear dysplasia.

The studies on graft tensioning were modeled on normal knees, and isometric points and tensioning may therefore be different in knees with trochlear dysplasia or patella alta. In cases of trochlear dysplasia, the tendency is to tension the graft too

Fig. 6

Fluoroscopic images can be obtained intraoperatively to confirm appropriate placement.

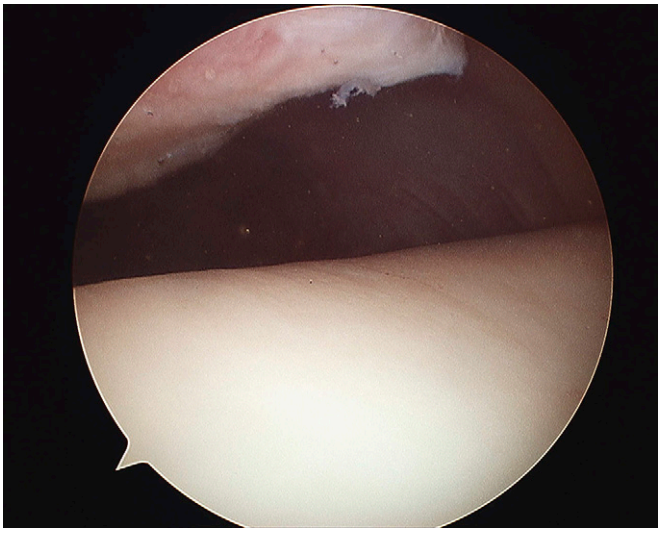

Fig. 7
Trochlear dysplasia, as noted in this arthroscopic view, can make it difficult to identify normal osseous landmarks.

tightly because of the lack of normal osseous landmarks[1] (Fig. 7). Patella alta can change the normal relationship between the patellar and femoral attachments of the medial patellofemoral ligament because it increases the required length of the medial patellofemoral ligament graft. This factor should be considered when tensioning the graft in the presence of patella alta.

Graft Fixation

Femoral Fixation

Multiple methods have been reported for fixation of the medial patellofemoral ligament graft to its femoral insertion, including sutures[13,19], washers[25], spiked washers[26], staples[16], and interference screws through blind-tunnel and through-tunnel grafts[12,27]. Mountney et al.[3] found that the through-tunnel tendon graft provided the strongest reconstruction, with a strength equal to that of the native ligament.

Implant Pain

Steiner et al.[11] reported that 10% of patients required removal of a prominent or painful screw after medial patellofemoral ligament reconstruction, and Nomura et al.[16] reported that 57% of patients who had staple fixation and 23% of those who had fixation with an integrated double staple had pain at the femoral fixation site. The selection of a fixation method that has a low profile and is secure can minimize pain at the femoral fixation site (Fig. 8).

Patellar Fixation

Patellar fixation of the medial patellofemoral ligament graft has also been performed with use of many methods, including interference screws through single and double patellar tunnels, EndoButtons (Smith & Nephew, Memphis, Tennessee)[25], and suture fixation using the docking technique[27].

Although it occurs less commonly in the patella than in the femur, implant pain is possible with more prominent fixation methods such as the EndoButton (Fig. 9).

Need for Concurrent Procedures

In cases of substantial malalignment, medial patellofemoral ligament reconstruction alone is often not enough to correct patellofemoral instability. Failure to address malalignment when reconstructing this ligament can lead to early failure and recurrence of lateral instability. Several other procedures can be performed concurrently with the reconstruction or as an alternative to it. Appropriate identification of the pathoanatomy and utilization of an appropriate treatment algorithm can define the optimum treatment that is fitted to the individual. A distance of >15 mm between the tibial tubercle and the trochlear groove or a Q angle of >14° in male subjects and 17° in female subjects is indicative of malalignment, which may require concurrent tibial tubercle osteotomy. Patella alta, indicated by an Insall-Salvati ratio of >1.2, may be better treated with distal advancement of a tibial tubercle osteotomy because medial patellofemoral ligament reconstruction alone could result in increased tension on the graft. For lateral tilt and substantial lateral retinacular tightness, a concurrent lateral release may be indicated.

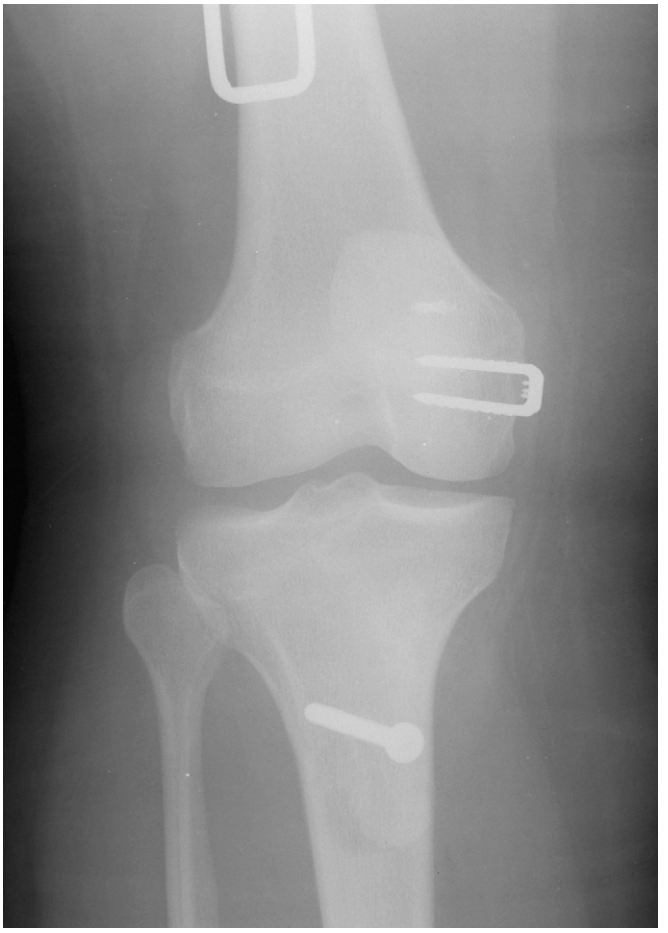

Fig. 8
Postoperative anteroposterior radiograph showing prominent hardware at the femoral tunnel.

Fig. 9

Postoperative clinical photograph showing prominent hardware at the patellar fixation site.

Summary

Medial patellofemoral ligament reconstruction is a viable option for correcting lateral patellofemoral instability without substantial malalignment. Many of the complications that can arise from this procedure are the result of technical surgical error and can be avoided by adherence to the following main principles.

Patient Selection

- The clinician should confirm that the patient has lateral patellofemoral instability (rather than isolated pain) and that no substantial arthrosis exists.
- Medial instability is a contraindication to the procedure.

Alternative or Concurrent Procedures

- Patellofemoral instability is often multifactorial, involving medial patellofemoral ligament incompetence, malalignment, joint hyperlaxity, and/or osseous abnormalities.
- The contributing factors to patellofemoral instability may be treated with alternative or concurrent procedures.

Graft Tensioning

- Appropriate graft tensioning is crucial for a successful medial patellofemoral ligament reconstruction.
- The reconstructed medial patellofemoral ligament should allow two to three patellar quadrants of translation, without overly constraining the patella.
- Comparison with the contralateral, normal side can be helpful in determining appropriate graft tension.
- Tensioning the graft with the knee in flexion, with the patella captured within the trochlear groove, can help to prevent overtightening of the graft.

Tunnel Placement

- The patellar tunnel should be drilled without violation of the anterior cortex or articular surface.
- Digital palpation of the articular surface while drilling the patellar tunnel can be helpful in directing the tunnel appropriately.
- Femoral tunnel placement is critical to the isometry of the medial patellofemoral ligament.
- Because the femoral tunnel can be difficult to place in the correct position, a larger incision with greater exposure or fluoroscopic visualization can aid in correct tunnel placement.

Graft Fixation

- Grafts should be chosen and placed to provide adequate strength and to prevent failure of the graft.
- Pain at the femoral and patellar tunnels should be avoided by minimizing implant prominence and loosening.

Understanding Abnormal Anatomy

- Many patients with patellofemoral instability have abnormal knee anatomy, including patella alta or trochlear dysplasia.
- Aberrant anatomy should be recognized, and the tensioning and positioning of the graft should be adjusted accordingly. ■

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References

1. Bicos J, Fulkerson JP, Amis A. Current concepts review: the medial patellofemoral ligament. Am J Sports Med. 2007;35:484-92.

2. Smirk C, Morris H. The anatomy and reconstruction of the medial patellofemoral ligament. Knee. 2003;10:221-7.

3. Mountney J, Senavongse W, Amis AA, Thomas NP. Tensile strength of the medial patellofemoral ligament before and after repair or reconstruction. J Bone Joint Surg Br. 2005;87:36-40.

4. Sallay PI, Poggi J, Speer KP, Garrett WE. Acute dislocation of the patella. A correlative pathoanatomic study. Am J Sports Med. 1996;24:52-60.

5. Conlan T, Garth WP Jr, Lemons JE. Evaluation of the medial soft-tissue restraints of the extensor mechanism of the knee. J Bone Joint Surg Am. 1993;75:682-93.

6. Desio SM, Burks RT, Bachus KN. Soft tissue restraints to lateral patellar translation in the human knee. Am J Sports Med. 1998;26:59-65.

7. Thaunat M, Erasmus PJ. Management of overtight medial patellofemoral ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2009;17:480-3. Epub 2009 Jan 9.

8. Drez D Jr, Edwards TB, Williams CS. Results of medial patellofemoral ligament reconstruction in the treatment of patellar dislocation. Arthroscopy. 2001;17:298-306.

9. Beck P, Brown NA, Greis PE, Burks RT. Patelllofemoral contact pressure and lateral patellar translation after medial patellofemoral ligament reconstruction. Am J Sports Med. 2007;35:1557-63.

10. Thaunat M, Erasmus PJ. Recurrent patellar dislocation after medial patellofemoral ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2008;16:40-3. Epub 2007 Nov 1.

11. Steiner TM, Torga-Spak R, Teitge RA. Medial patellofemoral ligament reconstruction in patients with lateral patellar instability and trochlear dysplasia. Am J Sports Med. 2006;34:1254-61. Epub 2006 Mar 27.

12. Christiansen SE, Jacobsen BW, Lund B, Lind M. Reconstruction of the medial patellofemoral ligament with gracilis tendon autograft in transverse patellar drill holes. Arthroscopy. 2008;24:82-7. Epub 2007 Nov 5.

13. Ellera Gomes JL, Stigler Marczyk LR, César de César P, Jungblut CF. Medial patellofemoral ligament reconstruction with semitendinosus autograft for chronic patellar instability: a follow-up study. Arthroscopy. 2004;20:147-51.

14. Lippacher S, Reichel H, Nelitz M. [Patellar fracture after patellar stabilization]. Orthopade. 2010;39:516-8. German.

15. Parikh SN, Wall EJ. Patellar fracture after medial patellofemoral ligament surgery: a report of five cases. J Bone Joint Surg Am. 2011;93:e97(1–8).

16. Nomura E, Horiuchi Y, Kihara M. A mid-term follow-up of medial patellofemoral ligament reconstruction using an artificial ligament for recurrent patellar dislocation. Knee. 2000;7:211-215.

17. Philippot R, Chouteau J, Wegrzyn J, Testa R, Fessy MH, Moyen B. Medial patellofemoral ligament anatomy: implications for its surgical reconstruction. Knee Surg Sports Traumatol Arthrosc. 2009;17:475-9. Epub 2009 Feb 19.

18. Servien E, Fritsch B, Lustig S, Demey G, Debarge R, Lapra C, Neyret P. In vivo positioning analysis of medial patellofemoral ligament reconstruction. Am J Sports Med. 2011;39:134-9. Epub 2010 Oct 7.

19. Steensen RN, Dopirak RM, Maurus PB. A simple technique for reconstruction of the medial patellofemoral ligament using a quadriceps tendon graft. Arthroscopy. 2005;21:365-70.

20. Wijdicks CA, Griffith CJ, LaPrade RF, Johansen S, Sunderland A, Arendt EA, Engebretsen L. Radiographic identification of the primary medial knee structures. J Bone Joint Surg Am. 2009;91:521-9.

21. Elias JJ, Cosgarea AJ. Technical errors during medial patellofemoral ligament reconstruction could overload medial patellofemoral cartilage: a computational analysis. Am J Sports Med. 2006;34:1478-85. Epub 2006 May 9.

22. Schöttle PB, Schmeling A, Rosenstiel N, Weiler A. Radiographic landmarks for femoral tunnel placement in medial patellofemoral ligament reconstruction. Am J Sports Med. 2007;35:801-4. Epub 2007 Jan 31.

23. Nomura E, Inoue M, Osada N. Anatomical analysis of the medial patellofemoral ligament of the knee, especially the femoral attachment. Knee Surg Sports Traumatol Arthrosc. 2005;13:510-5. Epub 2005 May 13.

24. Hamner DL, Brown CH Jr, Steiner ME, Hecker AT, Hayes WC. Hamstring tendon grafts for reconstruction of the anterior cruciate ligament: biomechanical evaluation of the use of multiple strands and tensioning techniques. J Bone Joint Surg Am. 1999;81:549-57.

25. Schock EJ, Burks RT. Medial patellofemoral ligament reconstruction using a hamstring graft. Oper Tech Sports Med. 2001;9:169-75.

26. Nomura E, Inoue M. Hybrid medial patellofemoral ligament reconstruction using the semitendinous tendon for recurrent patellar dislocation: minimum 3 years' follow-up. Arthroscopy. 2006;22:787-93.

27. Ahmad CS, Brown GD, Stein BS. The docking technique for medial patellofemoral ligament reconstruction: surgical technique and clinical outcome. Am J Sports Med. 2009;37:2021-7. Epub 2009 Jun 22.