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Arthroscopic popliteus bypass graft for posterolateral instabilities of the knee

A new surgical technique

Introductory remarks

The anatomy of the knee is complex, and particularly that of the posterolateral corner ([8]; ◘ Fig. 1). The popliteus tendon complex has a static and a dynamic function. The popliteus muscle–tendon (PLT) itself acts in a dynamic function as an active internal rotator of the tibia and adjusts the postural equilibrium during standing [14]. The static biomechanical function of resistance against passive external rotation of the tibia is achieved in combination with the arcuate complex (AC; [11]). The AC mainly comprises the popliteofibular ligament, the fabellofibular ligament, popliteomeniscal fibers, and multiple extensions of the popliteus tendon to the tibia and to the posterior capsule (◘ Fig. 1). Thereby, the AC represents the primary static stabilizer to external rotation [10, 15, 21]. The most prominent structure of the AC is the popliteofibular ligament (◘ Fig. 1, 2a, b).

The great importance of the AC for stabilization of the tibia against external rotation especially in flexion has been described previously [10, 15, 17]. If the AC is injured, primary posterior translation and coupled external rotation [13, 21] increases. With an isolated injury of the posterior cruciate ligament (PCL), a posterior instability of up to 10 mm in 90° of flexion results [16]. Additional dissection of the PLT results in a dorsal instability of up to 15 mm in the posterior drawer test in 90° of flexion. These biomechanical results indicate that a dorsal instability of more than 10 mm in 90° of flexion results

Fig. 1 ▲ Dorsal anatomy of the right knee of a human cadaver with the posterolateral corner, consisting out of the lateral collateral ligament (*LCL*), the popliteus complex, and the posterolateral capsule. The popliteus complex is created by the popliteus tendon and the arcuate complex (*AC*). The most prominent structure of the AC is the popliteofibular ligament. This ligament mainly secures the static stabilizing function of the popliteus muscle–tendon complex (*PLT*)

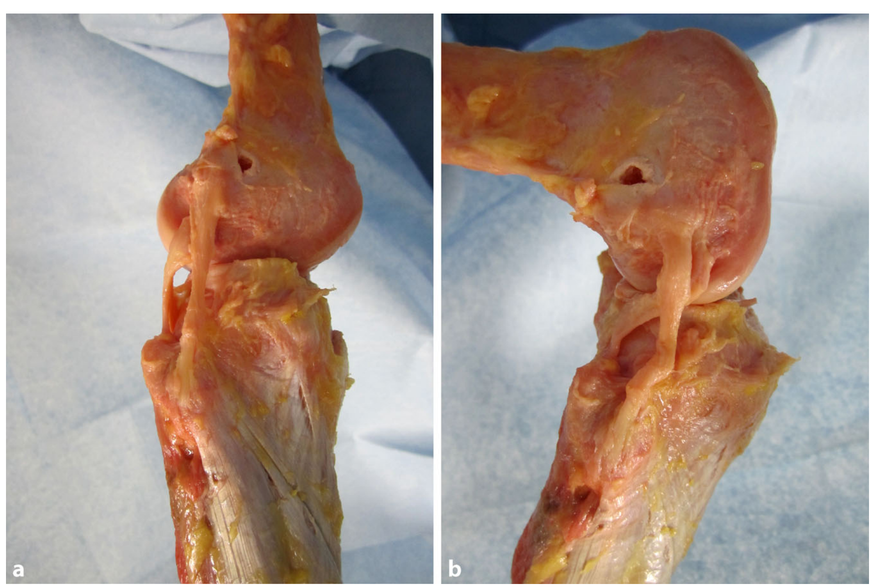

Fig. 2 ▲ Lateral anatomy of the right knee of a human cadaver in **a** extension and **b** 90° of flexion. The femoral footprint of the popliteus muscle–tendon is on average 1.2 cm distal of the femoral footprint of the lateral collateral ligament (distance center to center) [2]

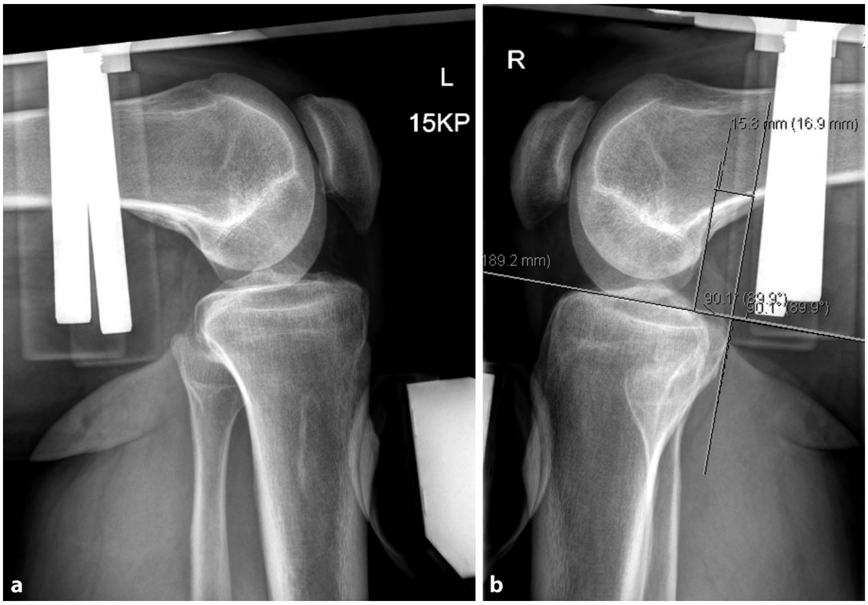

Fig. 3 ▲ Stress x-rays with a Telos device. A combined posterior cruciate ligament (*PCL*) and posterolateral corner injury (right knee) is presented with a side-to-side difference in the posterior drawer test of 13 mm

in a combined posterolateral rotational instability [16]. Up to 70 % of all PCL injuries are combined injuries with additional lesions of the posterolateral corner [8, 16].

For an exact analysis of the kind of instability (dorsal, lateral, rotational, posterolateral, or combined), it has to be considered that the main constraint against tibial external rotation from 0 to 30° is the LCL, while the arcuate complex becomes dominant towards increasing flexion, exhibiting its main function at 90° of flexion [3, 5, 9]. In addition, the LCL is the main stabilizer against varus stress in 0–30° extension. In this study, patients with a posterolateral rotational instability including a posterior drawer of more than 10 mm underwent reconstruction of the popliteus complex with a popliteus bypass graft in combination with PCL reconstruction. LCL was additionally reconstructed only if a lateral instability in 10° of flexion was evident.

The first anatomical reconstruction of the popliteus complex with an anatomical popliteus bypass graft was described by Werner Müller in 1982 [12]. Thereafter, numerous surgical techniques to reconstruct the static stabilizing function of the PLT have been described [1, 4, 6, 7, 18, 20, 22, 23]. Most of these are extraanatomical techniques with limited capacity to stabilize the posterolateral corner. With anatomical techniques for the reconstruction of the posterolateral corner, good and excellent results have been described [9, 19]. However, the described techniques are basically open surgical procedures, without the advantages of an arthroscopic technique.

We therefore developed a novel arthroscopic procedure for anatomic reconstruction of the popliteus complex with a popliteus bypass graft [2]. In this paper, the operative technique is presented in detail.

Surgical principles and objectives

The goal of the surgical procedure is to regain the static stabilizing function of the popliteus complex. The dynamic stabilizing function of the popliteus complex should thereby be preserved. These goals should be achieved by an arthroscopic procedure with exact and anatomic tunnel placement [2].

Advantages

- Restoration of the anatomy and biomechanics of the knee by anatomical reconstruction
- Proper visualization of anatomical landmarks, which is not possible with open techniques
- Utilization of small incisions with a greater likelihood of lower infection rates, lower rates of scar tissue formation, less postoperative pain, faster rehabilitation, and more aesthetic incisions
- Preparation and visualization of the peroneal nerve are not necessary

Disadvantages

- Requires advanced arthroscopic skills
- Requires experience in PCL and PLT surgery due to the demanding technique
- The use of special instruments is strongly recommended (i. e., tibial drill guide)
- A flat learning curve

Indications

- Posterolateral rotational instabilities of the knee joint

Contraindications

- Fixed dorsal position of the tibia (i. e., after ACL reconstruction)
- Systemic diseases like rheumatoid arthritis, autoimmune diseases, etc.
- Neuromuscular disorders
- Anatomic deformities and acute fractures around the knee
- Obesity (relative)

Patient information

- General risk factors related to arthroscopic surgery: infection, complex regional pain syndrome, deep vein thrombosis, pulmonary embolism, neurovascular iatrogenic injuries, failure
- Duration of hospital stay: 3–4 days
- Persistent instability
- Arthrofibrosis with limited range of motion
- Possible development of degenerative joint disease over time
- Graft harvesting from the contralateral side

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Arthroscopic popliteus bypass graft for posterolateral instabilities of the knee. A new surgical technique

Abstract

Objective. An arthroscopic technique for the reconstruction of the posterolateral corner combined with posterior cruciate ligament (PCL) reconstruction was developed.
Indications. Posterolateral rotational instabilities of the knee. Combined lesions of the PCL, the popliteus complex (PLT) and the posterolateral corner. Isolated PLT lesions lacking static stabilizing function.
Contraindications. Neuromuscular disorders; knee deformities or fractures; severe posterolateral soft tissue damage.
Surgical technique. Six arthroscopic portals are necessary. Using the posteromedial portal, resect dorsal septum with a shaver. Visualize the PCL, the lateral femoral condyle and the posterolateral recessus with the PLT. Dissect the popliteomeniscal fibers; retract PLT until sulcus popliteus is visualized. Drill a 6-mm tunnel anteriorly into the distal third of the sulcus popliteus. Visualize femoral footprint of the PLT and place an anatomical drill tunnel. Pull the popliteus bypass graft into the knee and fix with bioscrews. Fix the reconstructed PCL. In cases of additional LCL injury, reconstruct LCL with autologous graft.
Postoperative management. Partial weight-bearing for 6 weeks, range of motion exercises, quadriceps-strengthening exercises on postoperative day 1. Full extension allowed immediately with flexion limited to 20° for 2 weeks, to 45° for up to week 4, and to 60° up to week 6. Use a PCL brace for 3 months, running and squatting exercises allowed after 3 months.
Results. In the 35 patients treated, no technique-related complications. After 1 year, 12 patients had a mean Lysholm Score of 88.6 (± 8.7) points and a side-to-side difference in the posterior drawer test of 2.9 (± 2.2) mm (preoperative 13.3 [± 1.9] mm).
Conclusion. Low complication risk and good and excellent clinical results after arthroscopic posterolateral corner reconstruction.

Keywords

Knee · Posterior cruciate ligament · Posterolateral instability · Popliteus tendon · Posterolateral corner

Arthroskopisches „Popliteus Bypass Graft“ für posterolaterale Rotationsinstabilitäten des Kniegelenks. Eine neue operative Technik

Zusammenfassung

Operationsziel. Entwicklung einer neuen arthroskopischen Technik zur kombinierten Rekonstruktion der posterolateralen Ecke und des hinteren Kreuzbands (HKB).
Indikationen. Posterolaterale Rotationsinstabilitäten des Kniegelenks. Kombinierte Läsionen des HKB, des Popliteuskomplexes (PLT) und der posterolateralen Ecke. Isolierte PLT-Läsionen mit posterolateraler Instabilität.
Kontraindikationen. Neuromuskuläre Störungen, Kniedeformitäten und -frakturen, schwere Weichteilschäden in der posterolateralen Region.
Operationstechnik. Notwendig sind 6 arthroskopische Portale. Über das posteromediale Portal wird das dorsale Septum reseziert und HKB sowie posterolateraler Rezessus mit dem PLT dargestellt. Am Hiatus popliteus werden popliteomeniskale Fasern durchtrennt, die Popliteussehne aus dem Sulcus luxiert und der distale Anteil des Sulcus popliteus dargestellt. Bohren eines 6-mm-Bohrkanals von ventral in das distale Drittel des Sulcus popliteus. Der femorale Popliteussehnenansatz wird dargestellt und ein anatomischer femoraler Bohrkanal gesetzt. Einziehen des Grazilissehnentransplantats als „Popliteus Bypass Graft“ und Fixation mit Biotenodeseschrauben. Fixation des HKB-Transplantats. Bei einer LCL-Instabilität zusätzliche Rekonstruktion des LCL.
Postoperative Behandlung. Bodenkontaktbelastung für 6 Wochen, Orthese mit Bewegungslimitierung für 3 Monate, Quadrizepskräftigungsübungen direkt postoperativ. Sofort volle Streckung, sukzessive Beugungsfreigabe bis 90° über 6 Wochen. Joggen oder tiefe Kniebeugen frühestens nach 3 Monaten.
Ergebnisse. Keine technikspezifischen Komplikationen bei 35 behandelten Patienten. Nach 1 Jahr hatten 12 Patienten einen mittleren Lysholm-Score von 88,6 (± 8,7) Punkten und eine radiologisch gemessene dorsale Instabilität im Seitenvergleich von 2,9 (± 2,2) mm (präoperativ 13,3 [± 1,9] mm).
Schlussfolgerung. Niedrige Komplikationsraten und gute erste klinische Ergebnisse nach arthroskopischer Rekonstruktion der posterolateralen Ecke.

Schlüsselwörter

Knie · Hinteres Kreuzband · Posterolaterale Instabilität · Popliteussehne · Posterolaterale Ecke

- Possibility of iatrogenic damage to the infrapatellar branch of the saphenous nerve or the peroneal nerve
- Prolonged rehabilitation protocol: full extension is allowed immediately, flexion is limited, brace for 3 months (i. e., Jack PCL, Albrecht, Munich, Germany)
- Clinical assessment at 3, 6, 9, and 12 months
- Surgical failure may require another open procedure
- Running and squatting exercises are allowed after 3 months
- High-level sports may commence 6–9 months after surgery
- Return to work/sports activities are dependent on the type of work/sports

Preoperative and diagnostic work-up

- Patient history
- Clinical assessment with posterior drawer and Dial tests
- Anterior and medial instability should be ruled out
- Lateral stability test in full extension (LCL) and 10° and 90° of flexion

Fig. 4 ▲ Positioning in an electrical leg holder

- External rotation test at 30, 60, and 90° in comparison to the contralateral side
- Brace test (optional, to test whether patient's symptoms improve by using a PCL brace)
- Fixed dorsal drawer should be ruled out
- MRI assessment of the knee
- Anterior–posterior, lateral, and long x-ray views (in clinically suspected cases of axis deviation)
- Stress x-rays with anterior and posterior drawer of both knees (◻ **Fig. 3**)
- Preoperative management to assure good range of motion (> 0–0–100°)
- Intensive quadriceps strengthening preoperatively
- Side which is planned for operation should be marked prior to surgery

Surgical instruments and implants

- Arthroscopic instruments: hook, grasper, shaver (4 mm blade, not too sharp), radiofrequency electrode, guide wires, tendon harvester, drill bits in different sizes (6–10 mm), WORM (Arthrex, Naples, FL, USA)
- Drill guide for PCL reconstruction and a special drill guide for arthroscopic posterolateral corner reconstruction (Tibial Popliteal Marking Hook, Arthrex, Naples, FL, USA)
- Biointerference screws for graft fixation in different diameters (5–9 mm) (Milagro, DePuy Mitek, Norderstedt, Germany or Swivelock, Arthrex, Naples, FL, USA, etc.)

Anesthesia and positioning

- General or spinal anesthesia
- Supine position
- Non-sterile thigh tourniquet
- Electrical leg holder (Maquet, Germany; ◻ **Fig. 4**)

Surgical technique

(■ Figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16)

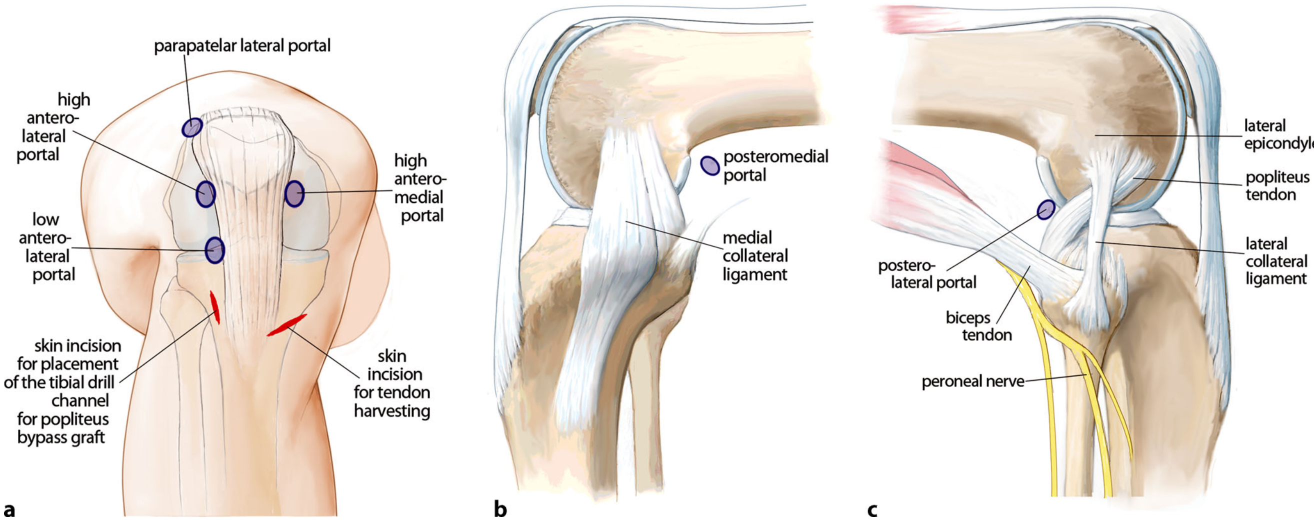

Fig. 5a–c ▲ For arthroscopic popliteus reconstruction, the following six arthroscopic portals are necessary: a low and a high anterolateral, a high anteromedial, a posteromedial, a posterolateral, and a lateral portal. After diagnostic arthroscopy hamstring tendons from the ipsilateral side (semitendinosus and gracilis tendon for the posterior cruciate ligament [*PCL*] graft) and a gracilis tendon from the contralateral side for the popliteus bypass graft are harvested in a typical manner. For the popliteus bypass graft a double-stranded graft (11–12 cm long) is used

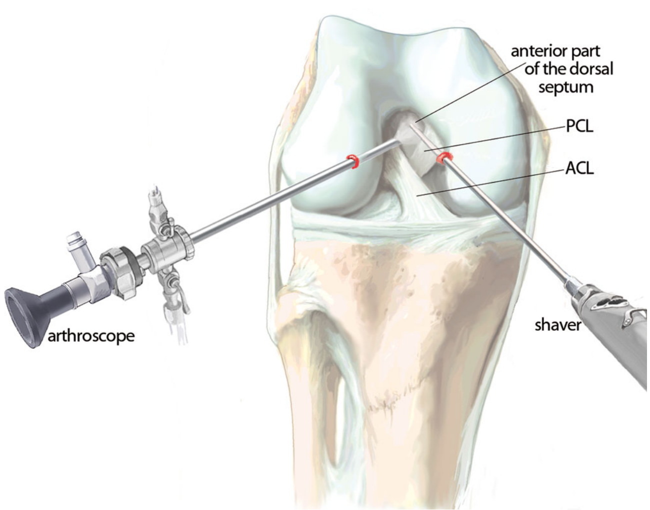

Fig. 6 ▲ Arthroscopic view in a right knee. The procedure begins with the resection of soft tissue between both cruciate ligaments. A shaver is advanced from anterior between the anterior cruciate ligament (*ACL*) and posterior cruciate ligament (*PCL*) and the cranial parts of the dorsal septum are resected

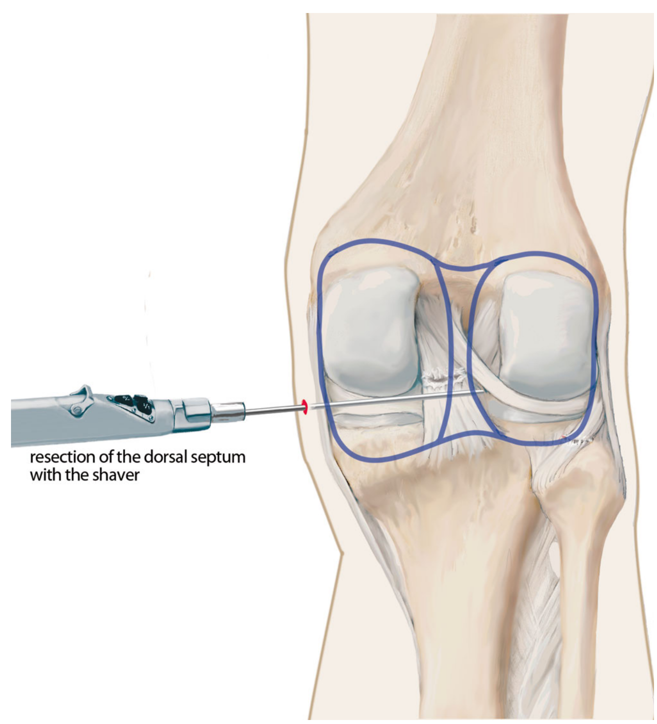

Fig. 7 ▲ The arthroscope is inserted through the high anterolateral portal in the posteromedial recessus. A posteromedial portal is installed under visual control. Resection of the dorsal septum with a shaver from posteromedial portal. Care should be taken to protect dorsally located vessels and nerves

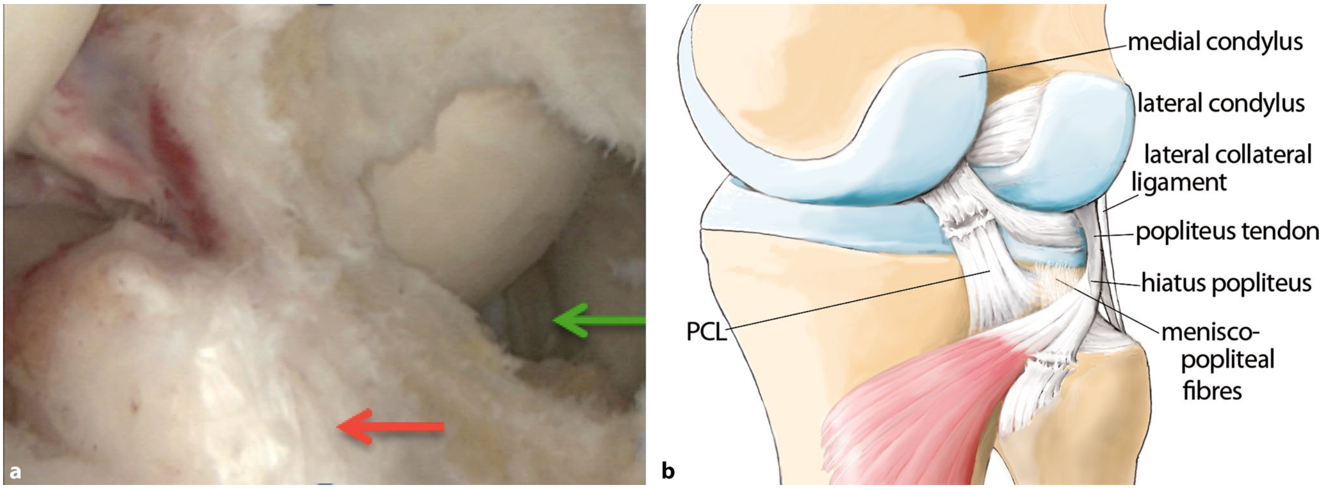

Fig. 8 ▲ **a** Arthroscopic view from posteromedial portal in a right knee and **b** sketch of setup: Torn fibers of the posterior cruciate ligament (PCL; *red arrow*), the lateral femoral condyle, the dorsal septum (partially resected) and the popliteus tendon (*green arrow*) are exposed. A posterolateral portal was installed under visual control. Care must be taken to remain anterior of the biceps tendon to avoid injury to the peroneal nerve. **b** The schematic drawing shows a torn PCL and a ruptured popliteofibular ligament (classified as a posterolateral corner injury type A according to Fanelli)

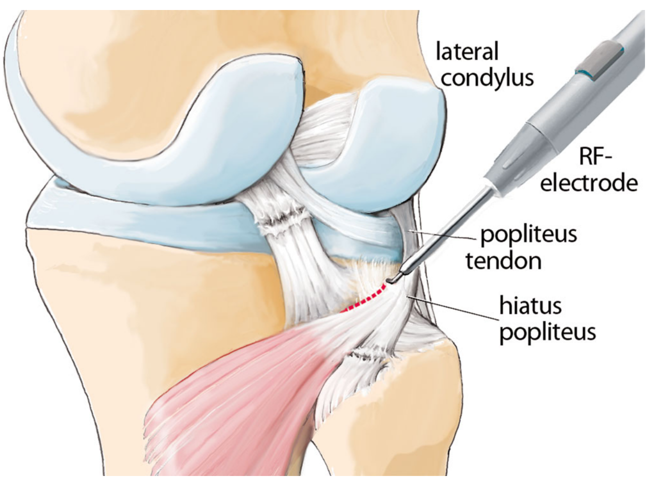

Fig. 9 ▲ Exposure of the popliteus tendon by resection of popliteomeniscal fibers with a radiofrequency electrode through a posterolateral portal. Care should be taken not to injure the popliteus tendon. If a radiofrequency electrode is used for dissection of the popliteomeniscal fibers, care should be taken not to injure the cartilage at the posterolateral tibial plateau. Customarily, only the lateral popliteomeniscal fibers must be dissected along a length of 1–2 cm

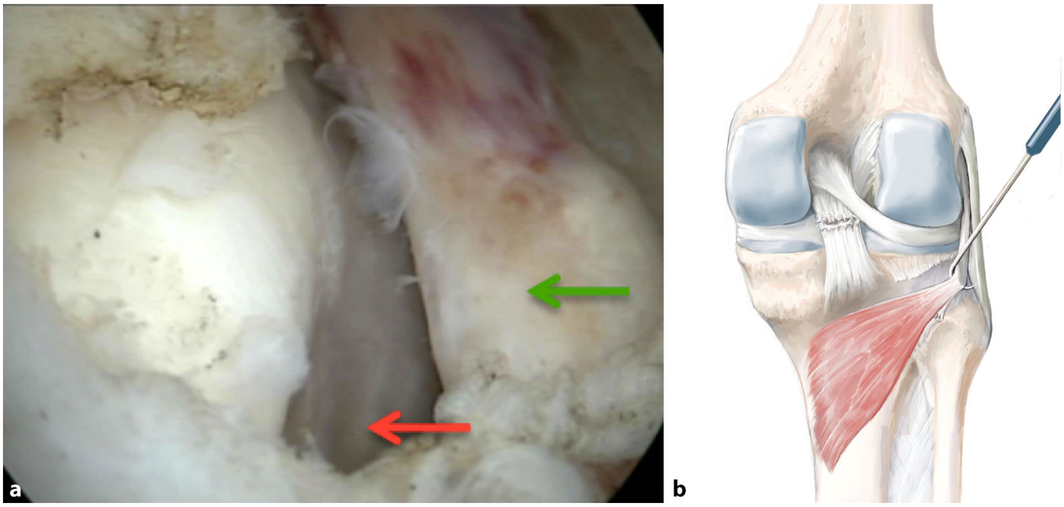

Fig. 10a, b ◀ The popliteus tendon (*green arrow*) is retracted with a hook and the sulcus popliteus (*red arrow*) can be visualized. The arthroscope enters from posteromedial (right knee). The arcuate complex is observed to be wrapped onto the tendon, leading to a loss of the static stabilizing function of the popliteus tendon. In such cases, the popliteus tendon may be easily retracted to expose the sulcus

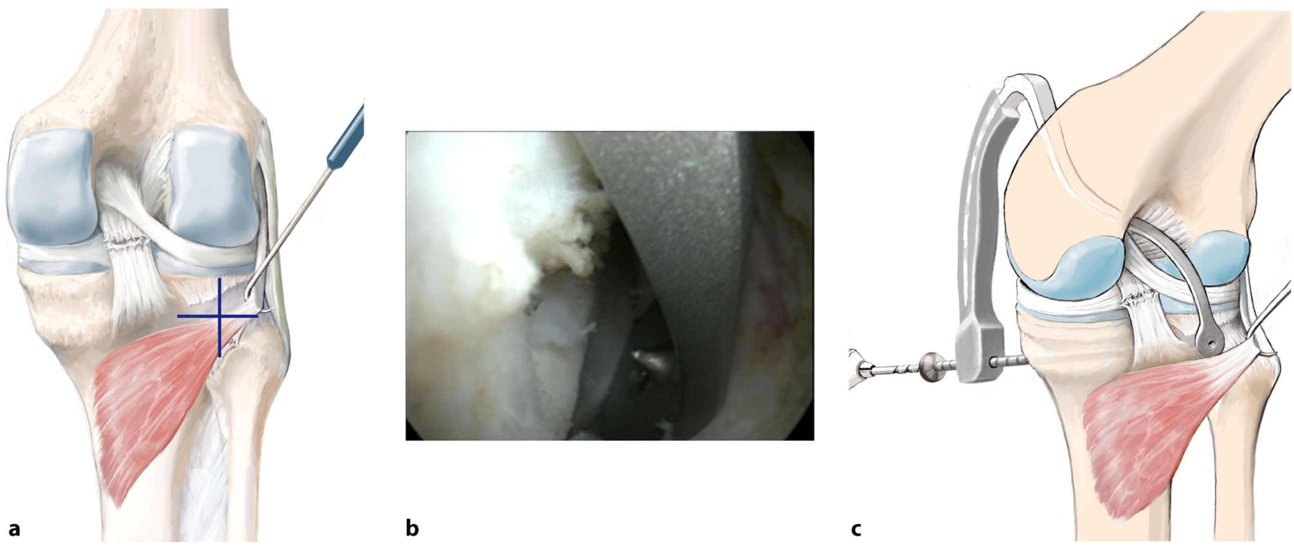

Fig. 11 ▲ **a** The proper location of the tibial drill channel for the popliteus bypass graft is at the crossing of a horizontal line at the tip of the fibular head with a vertical line at the medial edge of the fibular head. **b** A special drill guide (through the anteromedial portal; Tibial Popliteal Marking Hook", Arthrex, Naples, FL, USA) is positioned in the distal third of the sulcus popliteus. **c** A useful technique to ensure correct tibial tunnel placement is to palpate the fibular head with the tip of the drill guide and to position the center of the tip of the drill guide 5–7 mm below the cranial edge of the popliteus tendon. A guide wire is positioned in the distal part of the sulcus popliteus. The anterior start point of the drill guide is positioned between the lateral edge of the tibial tuberosity and the medial edge of Gerdy's tubercle. The tibial tunnel was drilled with a 6-mm cannulated drill. It has been shown that the presented arthroscopic technique is highly accurate and reliable [2]. Therefore, intraoperative fluoroscopy to check the location of the tunnel is optional

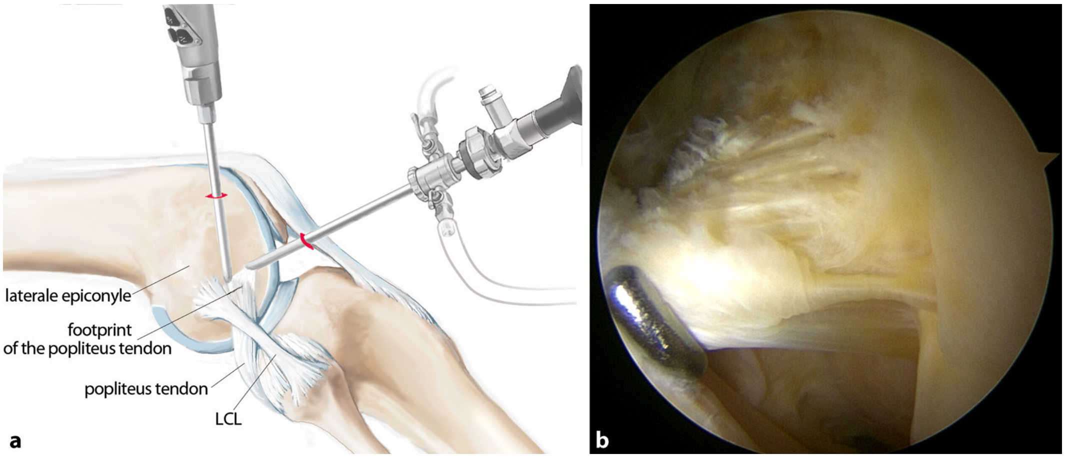

Fig. 12 ▲ **a** For anatomic placement of the femoral tunnel, the arthroscope was introduced in the high anterolateral portal. At 20–30° of knee flexion, a shaver blade (which should not be too aggressive) is inserted in a dorsocaudal direction through a lateral parapatellar portal and directly placed 1 cm dorsal to the craniolateral edge of the patella to expose the femoral origin of the popliteus tendon. For optimal visualization of the femoral footprint of the popliteus tendon, anterior and distal fibers of the knee capsule at the lateral femoral condyle must be resected. **b** An arthroscopic view through the anterolateral portal at the femoral footprint of the popliteus tendon (right knee) is shown. The tendon is retracted with a hook to expose the femoral footprint. Percutaneously, a 2.3-mm guide wire is placed directly in the femoral footprint of the popliteus tendon. The femoral tunnel is drilled with a 5-mm drill

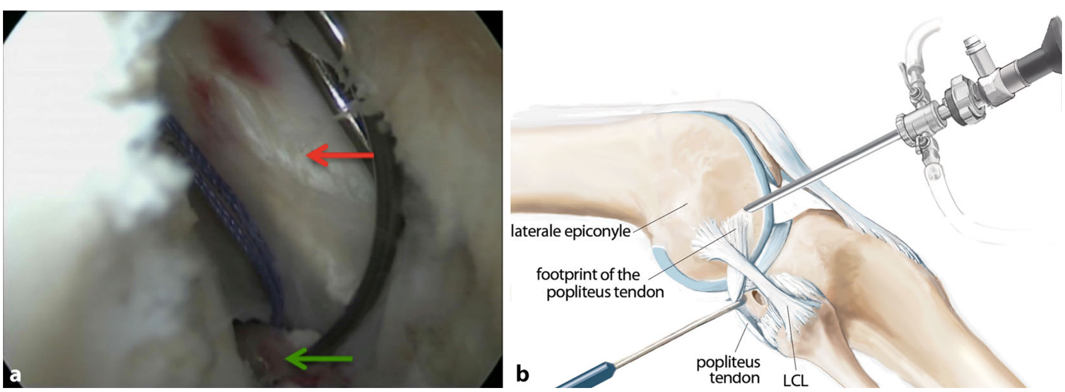

Fig. 13 ▲ **a** Arthroscopic view from posteromedial portal (right knee) and **b** sketch of procedure. A suture loop is inserted in the posterolateral recessus through the tibial tunnel (*green arrow*) as a shuttle for the popliteus bypass graft. Then, a bent suture grasper is inserted through the lateral incision for the installation of the femoral tunnel and is advanced into the posterolateral recessus along the popliteus tendon (*red arrow*) to grasp the suture loop. Care must be taken not to interpose soft tissue between the shuttle loop and the femoral drill tunnel

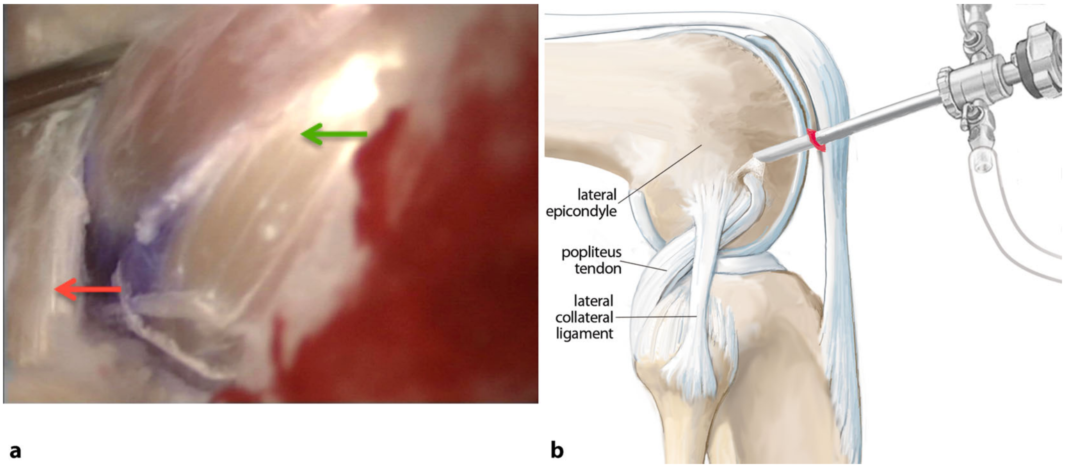

Fig. 14 ◂ **a** Arthroscopic view from anterolateral (right knee) and **b** sketch of procedure. The popliteus bypass graft (single-stranded semitendinosus or double-stranded gracilis tendon, *green arrow*) is pulled through the tibial tunnel in the femoral tunnel. Care must be taken to assure that the graft is located under the lateral collateral ligament (*LCL*; seen in the image directly dorsal to the guide wire for the cannulated bioscrew, *red arrow*)

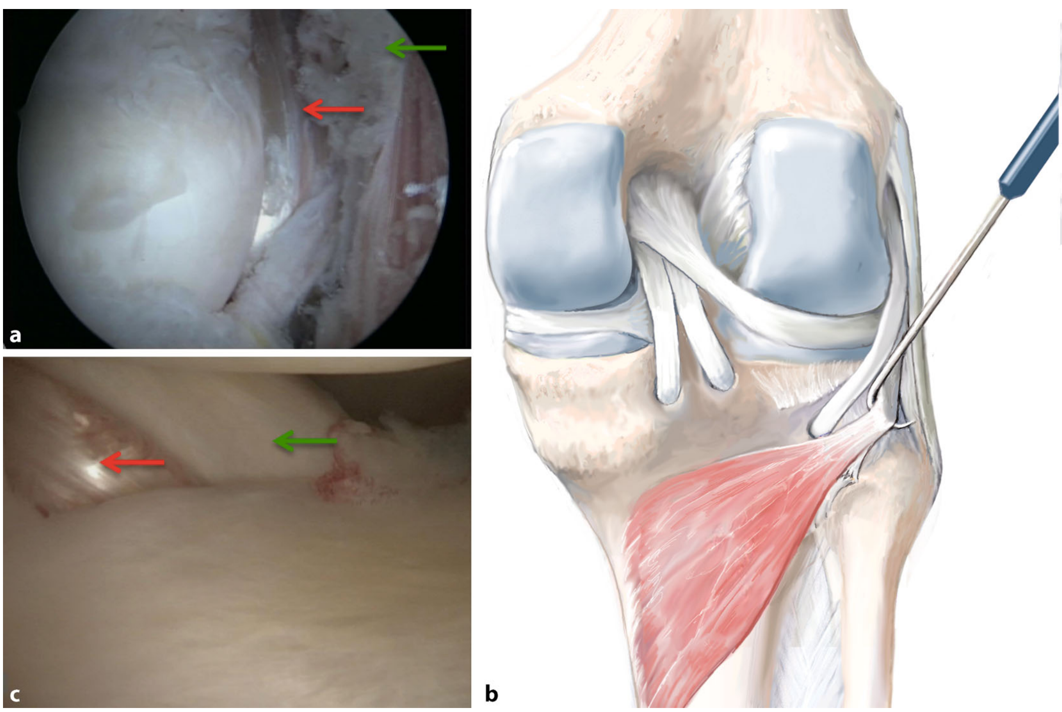

Fig. 15 ◂ Arthroscopic view (right knee) from **a, b** posteromedial and **c** anterolateral/intraarticular portals. The popliteus bypass graft (*red arrow*) is located under the popliteus tendon (*green arrow*) in the sulcus popliteus. The fixation of the graft is performed at first at the femoral side with a bioscrew (diameter 5 mm). The screw is percutanously implanted through a nithinol guidewire

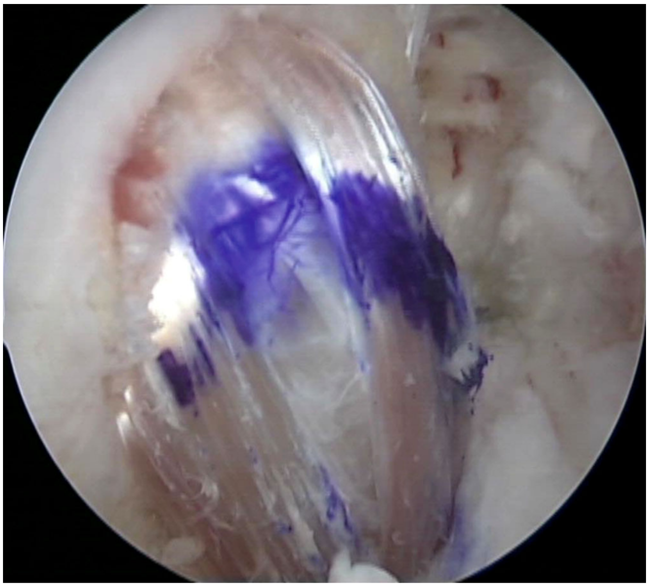

Fig. 16 ▲ Arthroscopic view from anterolateral. The posterior cruciate ligament (*PCL*) graft is visualized. After reconstruction and fixation of the PCL, the popliteus bypass graft is fixed at the tibial side with a bioscrew (diameter 6 mm). During fixaton the knee is flexed 90° and 10–20° internally rotated. The LCL needs to be additionally reconstructed only if a lateral instability in 10° of flexion is evident (classified as a posterolateral corner injury type B or C according to Fanelli)

Postoperative management

- Wound dressing until postoperative day 2
- Partial weight-bearing (10–20 kg) for 6 weeks
- PCL brace for 3 months (i. e., Jack PCL, Albrecht, Unterschleißheim, Germany) with limited range of motion 0–0–20° for 2 weeks, 0–0–45° for 2 weeks and 0–0–60° for further 2 weeks. 0–0–90° until week 8 and then free range of motion.
- Range-of-motion exercises in the prone position and passive flexion against quadriceps contraction up to 60° allowed from postoperative day 1
- Quadriceps strengthening exercises are allowed from postoperative day 1
- Active knee flexion is not allowed for the first 6 weeks postoperatively
- Proprioception loading exercises should be included
- Running and squatting exercises are begun after 3 months from the index procedure

Results

To date, 35 patients have received a popliteus bypass graft due to a posterolateral rotational instability in combination with a PCL reconstruction. No intra- or postoperative complications have been observed so far. After 1 year, 12 patients (6 women) were examined (study still continuing). The mean age was 35.3 (± 13.6) years with a mean body mass index of 27.1 (± 3.6). The mean time from trauma to surgery was 11 (3–42) weeks. Among all patients who underwent surgery as described above, 3 patients received an additional LCL reconstruction, 1 patient underwent an additional ACL reconstruction, 1 patient had an additional high tibial osteotomy due to 7° of varus deformity (one-stage procedure), and 1 patient had an additional torsional osteotomy of the femur due to torsional deformity after femoral shaft fracture (two-stage procedure). The mean postoperative Lysholm Score was 88.4 (± 8.7) points, whereas the mean Tegner Score was preoperatively 5.6 (± 1.8) and 4.9 (± 1.0) points during follow-up. The Visual Analog Scale function was 2.8 (± 1.5; 0 complete function, 10 no function) and the Visual Analog Scale pain was 1.9 (± 1.8; 0 no pain, 10 maximal pain). In the preoperative stress x-rays with the Telos device, the mean side-to-side difference in the posterior drawer test in 90° of flexion was −13.3 (± 1.9) mm and postoperatively the mean side-to-side difference was −2.9 (± 2.2) mm. The Dial Test was negative in 10 of 12 patients.

The arthroscopic technique of posterolateral corner reconstructions has a low complication rate and leads to good and excellent clinical results.

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Compliance with ethical guidelines

Conflict of interest. R. Akoto, T. Drenck, M. Heitmann, C. Pahl, and A. Preiss state that there are no conflicts of interest. The operation technique was developed on human cadaver specimens in cooperation with Arthrex, Naples, USA. K.-H. Frosch received grants from Arthrex, Naples, USA.

The study was approved by the Ethics Committee of the Hamburg Chamber of Physicians and was carried out according to existing rules and regulations of the Asklepios Campus Hamburg, Semmelweis University Budapest (PV4458).

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Fachnachrichten

Implantat zur Regeneration des Knorpels und Knochens

Forscher der Universität und des Universitätskrankenhauses Straßburg haben ein neues lebendes und dreidimensionales Implantat entwickelt, um den Gelenkknorpel nach einer Degeneration oder einer Verletzung zu regenerieren.

Derzeit kommen zwei Strategien beim Knorpelwiederaufbau zum Einsatz: Das Einsetzen einer Prothese oder die Injektion von Patienteneigenen Chondrozyten (Knorpelzellen) in das Gelenk. Eine gleichzeitige Behandlung des Knochens wäre optimal, da Knorpeldegenerationen oftmals auch den darunter liegenden Knochen schädigen. Die Forscher haben deshalb ein Implantat entwickelt, das sowohl den Knorpel als auch den Knochen repariert.

Das Implantat besteht aus zwei Teilen:
- einer Membran aus Kollagen oder Polymeren, die über nanogroße Speicher mit Knochenwachstumsfaktoren zur Reparatur des Knochen verfügt
- einer Hydrogelschicht mit Hyaluronsäure und aus dem Knochenmark des Patienten gewonnenen Stammzellen zur Regeneration des Knorpels.

Vorklinische Studien wurden bereits begonnen und das Implantat zum Patent angemeldet. Die erste klinische Studie mit Menschen soll an 62 Patienten mit Knieverletzungen in drei Ländern durchgeführt werden.

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