6 Revision Anterior Cruciate Ligament Reconstruction

Robert A. Magnussen and G. Demey

Introduction

Revision anterior cruciate ligament (ACL) reconstruction is increasingly common. These procedures must be carefully planned and are often fraught with technical difficulties. The surgeon must address the following questions prior to surgery:

- How are the previous tunnels positioned?
- Which graft should be used?
- Is a one-stage or two-stage reconstruction required?
- What graft fixation will be utilized?

To answer the questions, the cause of failure of the prior ACL reconstruction should be identified. The answers to these critical questions will guide the revision surgery and ensure the avoidance of technical errors that could compromise results.

Causes of Failure

It is important to obtain a detailed clinical history, including the initial injury mechanism and information about the prior reconstruction such as graft type, surgical technique, and intraoperative findings including meniscal and articular cartilage status. One should also determine the postoperative rehabilitation protocol, the time to return to sport, and any subsequent surgical procedures such as the resection of the cyclops lesion or subsequent meniscal tear.

Technical Error

Technical error is the most common cause of recurrent instability following ACL reconstruction.

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Incorrect Tunnel Position

This error is by far the most common. The positions of tibial and femoral tunnels can be evaluated on plain radiographs (see analysis of the causes of failure) and computed tomography (CT) scans. Our experience has been that three-dimensional CT reconstructions are quite useful in evaluating tunnel position.

Errors in femoral tunnel position are more common than those involving the tibia, but both can be present. On the femur, tunnels are often too anterior (Fig. 6.1), leading to impingement in the notch and a loss of extension. Placement of the femoral tunnel too far posterior can lead to graft laxity in flexion or excessive tension in extension. Vertical positioning in the notch is also common, leading to poorer control of tibial rotation.

In the tibia, the tunnel may be too far posterior, leading to a vertical graft that poorly controls anterior translation (Fig. 6.2), or too far anterior, leading to impingement of the graft in the notch with extension. Similarly, lateral tunnel placement can lead to impingement of the graft on the medial border of the lateral femoral condyle, possibly leading to abrasion and graft rupture.

Fig. 6.1 Lateral plain radiograph demonstrating anterior femoral tunnel malposition

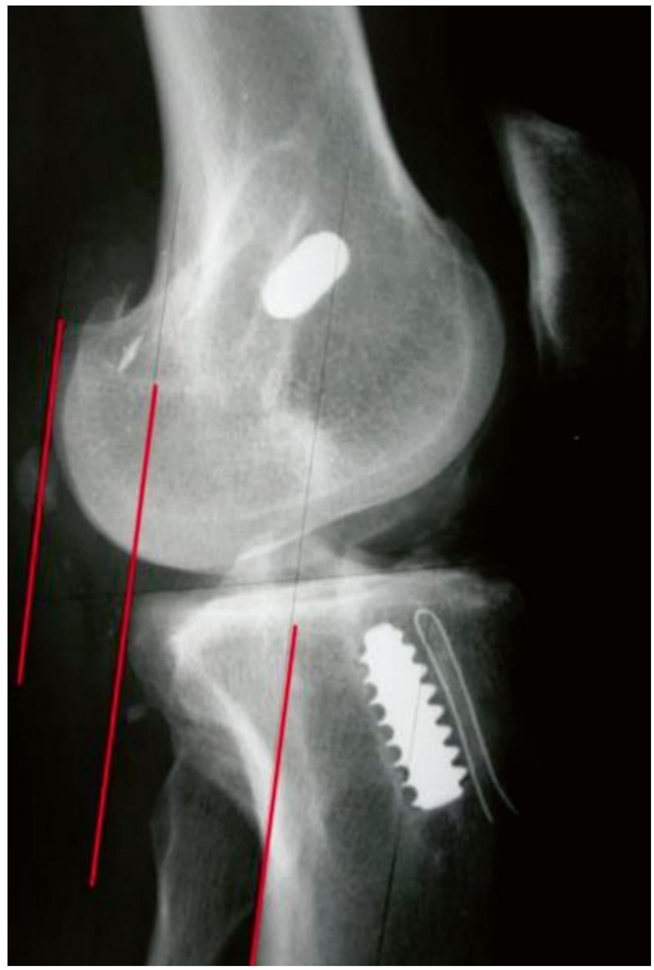

Fig. 6.2 Lateral stress radiograph demonstrating anterior tibial translation that is poorly controlled by a vertical graft with a too-posterior tibial tunnel

Poor Fixation

Graft fixation may be inadequate or insufficient. This problem can occur when there is inadequate contact between an interference screw and the bone block of a patellar tendon graft. Advancing the screw too far or not far enough can lead to this problem, as can divergence of the screw and graft. Additionally, poor bone quality may diminish the fixation strength of an appropriately placed screw. This problem commonly occurs in the cancellous bone of the tibia, which is why we prefer to utilize double fixation in the tibia.

Poor Graft Quality

Use of a graft that is too small or of poor quality can lead to early reconstruction failure. The quality of allograft tissue is variable and highly dependent on the sterilization process.

Associated Lesions

Lesions of the posteromedial or posterolateral corner that are not addressed at the time of ACL reconstruction frequently lead to persistent postoperative instability and failure. Of specific interest is whether a medial meniscectomy is required. Excision of significant portions of the medial meniscus can lead to increased stress on the graft and contribute to failure. Excessive posterior tibial slope ($\alpha > 13°$) can also contribute to increased graft stress and failure (Fig. 6.3).

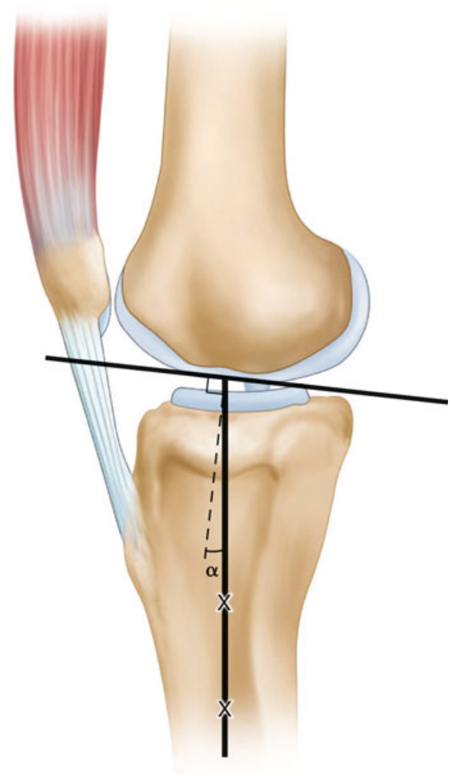

Fig. 6.3 Drawing of a lateral view of a proximal tibial demonstrating measurement of the posterior tibial slope based on the angle (α) between the long axis of the tibia and medial joint line

Re-traumatic Rupture

True traumatic graft ruptures are rare causes of failure and are ultimately a diagnosis of exclusion. To affirm this cause, we prefer to have a documented examination objectively describing control of the anterior laxity by the previous reconstruction and a significant traumatic reinjury. Reinjury is rarely caused by trivial injuries and is often accompanied by a “pop” and hemarthrosis. Patients often attribute failure of their prior reconstruction to a trivial trauma, and it is critical to rule out other etiologies of failure, so the mistakes of previous surgeries are not repeated at revision.

Biologic Failure

Biologic failure has been described as failure of the ACL graft tissue to revascularize and undergo ligamentization. The ligamentization process is significantly slower and often incomplete in allografts, making them more susceptible to this mode of failure. This etiology is again a diagnosis of exclusion.

Analysis of Failure Causes

The preoperative evaluation should be complete.

Clinical Examination

In addition to signs of anterior laxity, one should identify the scars from previous surgeries, palpate the patella and tibia to identify any bone loss if a prior patellar tendon graft was taken, search for any additional instability (especially posterolateral or posteromedial corner), and evaluate for excessive recurvatum, varus or valgus alignment, or diffuse ligamentous laxity.

Review of the Initial Operative Report

Critical information includes the type of graft and fixation that were used as well as any information regarding intraoperative complications or challenges.

Radiographic Examination

One should obtain:

- Anteroposterior and lateral radiographs of the knee at 30° of flexion in a single-leg stance.
  - These views allow for evaluation of tunnel position in both the coronal and sagittal planes. Additionally, they allow for assessment of tunnel enlargement.
- Objective radiographic measurements of anterior laxity (anterior tibial translation with differential Telos).
  - These views allow quantitative evaluation of anterior laxity and comparison to the contralateral side.
- Bilateral standing anteroposterior radiographs in 30° of flexion (Schuss view).
  - This view is the most sensitive for detection of tibiofemoral osteoarthritis.
- Axial patellar view in 30° of flexion.
  - This view detects patellofemoral arthritis and patellar maltracking.
- Long cassette views of the lower extremities if malalignment is suspected clinically.
  - This view determines the mechanical axis and can influence decision-making regarding the need for associated osteotomy.

CT with 3D Reconstructions

This study is essential. It not only gives precise information on the positioning of the tunnels but also quantifies bone defects that are often poorly assessed on plain radiographs. Analysis of the axial cuts is particularly useful in evaluating the relationship of the femoral tunnel with the notch (in terms of orientation, positioning, and filling). Ideal positioning is indicated when the femoral tunnel is visible on the cut in which the notch forms the shape of a Roman arch (Fig. 6.4). The axial cuts also allow evaluation of graft fixation, the position of the interference screw, and its resorption. A complete description of the femoral tunnel position requires information from both the axial and sagittal cuts, making its analysis difficult.

On the tibial side, the axial cuts allow analysis of the position of the tibial tunnel. Sagittal plane analysis details tunnel orientation and graft fixation. Again, evaluation of the exact point of entry of the tunnel into the joint is complex and requires the use of data from several cuts.

The diameters of the tunnels and any other bony defects can be easily assessed with CT images. Bone loss near the entry site of the tunnel into the joint is especially important (Fig. 6.5). In the case of a bony defect greater than 15 mm, there is a risk of a windshield-wiper effect and subsequent graft loosening. Bone graft fillers may be utilized in these cases (see surgical technique below). In case of revision following failed double-bundle surgery, this type of tunnel enlargement is frequently seen.

The 3D reconstruction allows one to integrate information from numerous planes into a single image and is the single most important aid in understanding tunnel position. While quantitative analysis is difficult, the general graft position and tunnel orientation can be qualitatively assessed (Fig. 6.6). These views provide an accurate preview of the

Fig. 6.4 Axial CT image demonstrating ideal positioning of ACL femoral tunnel in this plane. Note the tunnel centered on the cut in which the notch resembles a Roman arch

Fig. 6.5 A 3D CT reconstruction of part of a distal left femur viewed from proximally. One can visualize the prior femoral tunnel and note its improper vertical position in the femoral notch

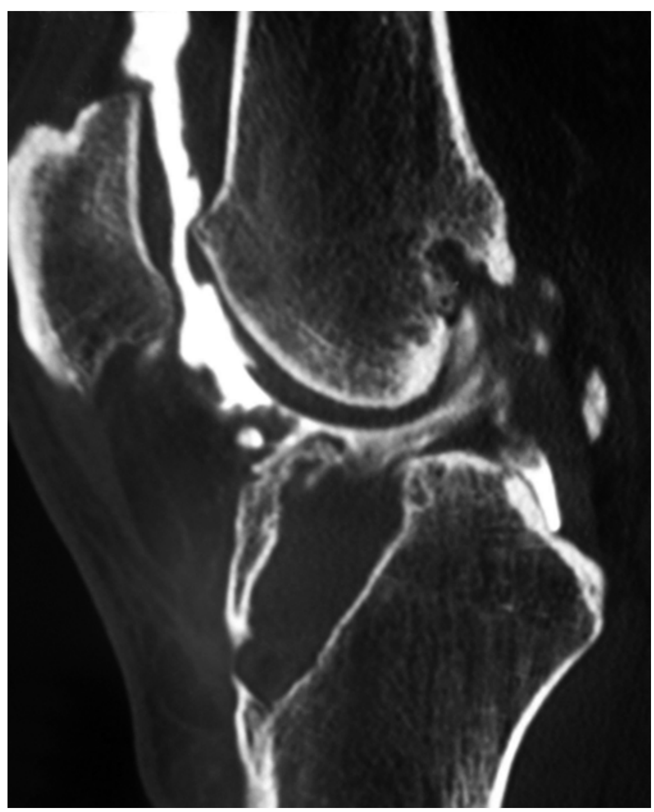

Fig. 6.6 A sagittal CT image of a knee demonstrating enlargement of the ACL tibial tunnel

view of the notch that will be encountered intraoperatively and are indispensable planning tools.

MRI

It allows the evaluation of the appearance of the prior graft and determination of the status of the menisci and articular cartilage. It is quite useful in the diagnosis of graft failure and other predictors of outcome but is less useful than CT for preoperative planning.

Surgical Technique

General

Our preferred technique for revision ACL is nearly identical to that for primary ACL reconstruction (see Chap. 5). The primary difference occurs when repeat harvest of the ipsilateral patellar tendon is not possible, requiring contralateral harvest. Other considerations include the impact of previous tunnels and bone loss on placement of the tunnels for the revision surgery.

An image intensifier can be quite useful in case of removal of retained hardware or if an associated osteotomy is performed.

Physical examination is repeated under anesthesia to assess the degree of anterior laxity and detect any associated instability.

Choice of Graft

Patellar tendon autograft is our preferred graft for revision ACL reconstruction in order to attain bone-to-bone fixation. In addition, bone blocks can help fill an expanded tunnel if tunnels from the prior surgery are to be reused. We consider re-harvest of an ipsilateral patellar tendon to be possible 18 months after prior harvest. When re-harvesting, the scar frequently must be enlarged.

However, any pathology related to the prior harvest (short tendon, dehiscence on the prior tendon harvest site, or significant bone loss at either the patella or tibia) is an indication to harvest the contralateral patellar tendon. This decision must be made preoperatively in order to inform the patient and to drape appropriately.

When ipsilateral re-harvest or contralateral harvest is impossible, we prefer a quadriceps tendon autograft. It provides a broad, thick tendon with a bone block.

Joint Exploration

Anterolateral and anteromedial portals are made. A systematic assessment of the joint should be performed evaluating all articular cartilage surfaces and the menisci. The shaver is used to clear fat and scar tissue and achieve a clear view of the notch (Fig. 6.7). A limited notch plasty with a small osteotome may be helpful to aid in visualization. It is imperative to fully visualize the posterior part of the lateral wall of the notch in order to ensure appropriate femoral tunnel placement (Fig. 6.8).

Fat pad resection is generally minimized, but some resection is required to allow accurate tibial tunnel placement (Fig. 6.9).

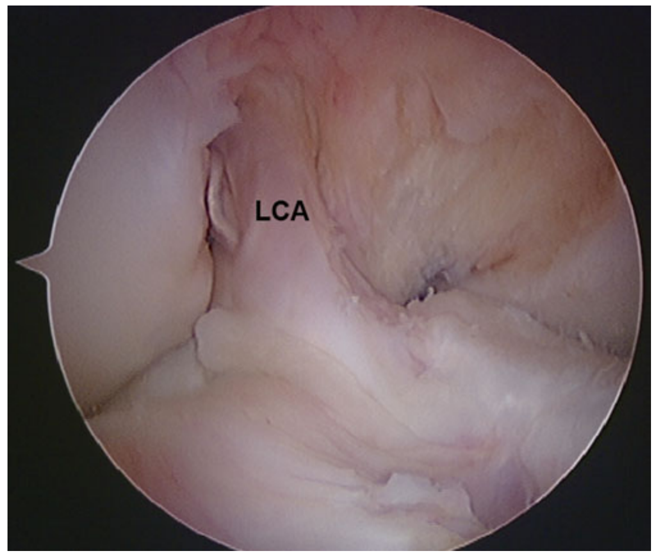

Fig. 6.7 An arthroscopic view of the notch in a right knee demonstrates a vertical ACL graft with the tibial tunnel placed too far posterior

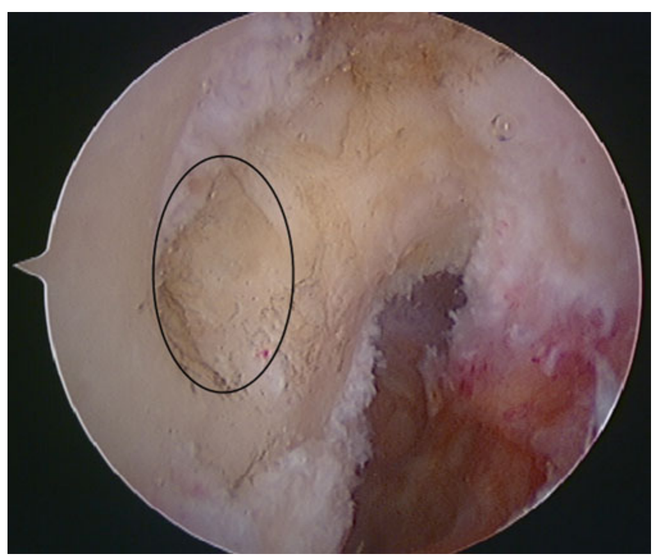

Fig. 6.8 An arthroscopic view of the lateral wall of the notch in a right knee with clear visualization of the posterior portion of the lateral femoral condyle. The prior femoral tunnel is clearly visible in a too-anterior position (*circle*)

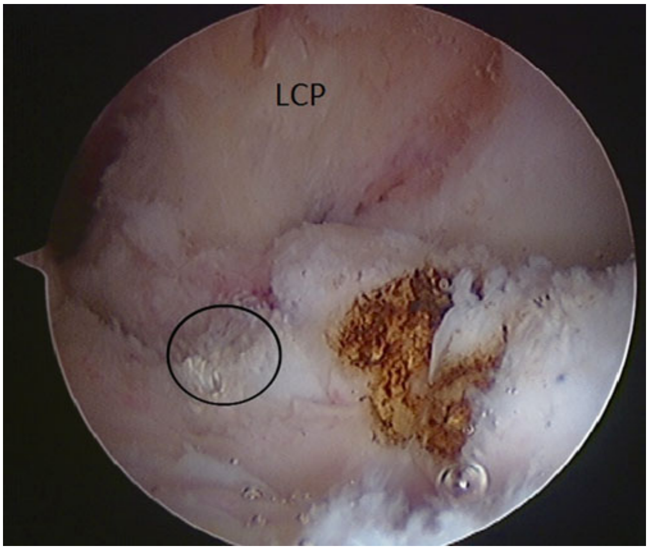

Fig. 6.9 Arthroscopic view of the tibial surface following resection of fat and scar. Note the too-posterior tibial attachment point of the prior graft (*circle*)

Tunnel Placement

There are two scenarios: the tunnels from the initial reconstruction are correctly positioned or there is an error in the position of one or both.

Previous Tunnels Are Correctly Positioned

- Removal of hardware

  When the original position of the tunnels is correct, the previous hardware is often an obstacle to tunnel preparation and placement of the new graft. If the original hardware was metal and intraosseous (such as a metal interference screw), it must be removed. It is therefore important to have the appropriate screwdriver available. This information should be gleaned from the original operative report.

  In the tibia, we find it useful to remove all hardware, including any cortical fixation (staples or screws) in addition to intraosseous hardware. On the femoral side especially, fluoroscopy can be useful in identifying and extracting hardware that has become overgrown by bone.

- Drilling of the tunnels

  If the original tunnels are well placed, they are frequently reusable. It is often sufficient to drill a second time through the same tunnel at the desired diameter, especially in the tibia.

  The tibial tunnel is created as in the prior ACL reconstruction by first placing a guide wire through the old tunnel then over-drilling with a drill, the diameter of which is equal to the desired tunnel size (usually 9 mm) (Fig. 6.10). Care must then be taken to clean the tunnel with a curette and/or shaver to remove any residual material (absorbable fixation, etc.) still in the tunnel (Fig. 6.11).

  If tunnel expansion is demonstrated in the preoperative workup, this finding may affect graft choice. The size of the bone block can be enlarged to a point to deal with this problem. Tunnel enlargement near the joint surface may potentially affect the graft position, which must be carefully monitored. However, the enlargement usually affects only cancellous bone, making achieving solid fixation the primary difficulty.

  Backup fixation is routinely used on the anterior tibia. The cortical fixation ensures appropriate graft tension and minimizes stress on the primary fixation. The cortical fixation is performed with a FiberWire loop passed through the bone block graft and tied over a bone bridge on the tibial tuberosity. Primary fixation is generally achieved with an interference screw 9 or 11 mm in diameter. If significant tunnel expansion has occurred, this fixation may not be sufficient. In this case, a useful trick is to place a second interference screw to augment the first. This second screw will both aid in fixation and help fill the area of osteolysis.

  The femoral tunnel is generally performed using an "outside-in" technique with a standard drill guide and guide pin. Often the prior femoral tunnel was made by the "all-inside" technique and cannot be easily recreated using our preferred "outside-in" technique. In this case, the tunnel is drilled in the standard outside-in manner and may intersect the previous tunnel near the notch. As fixation is achieved on the tibial cortex using a press-fit technique as with a primary reconstruction, this intersection has no effect on fixation.

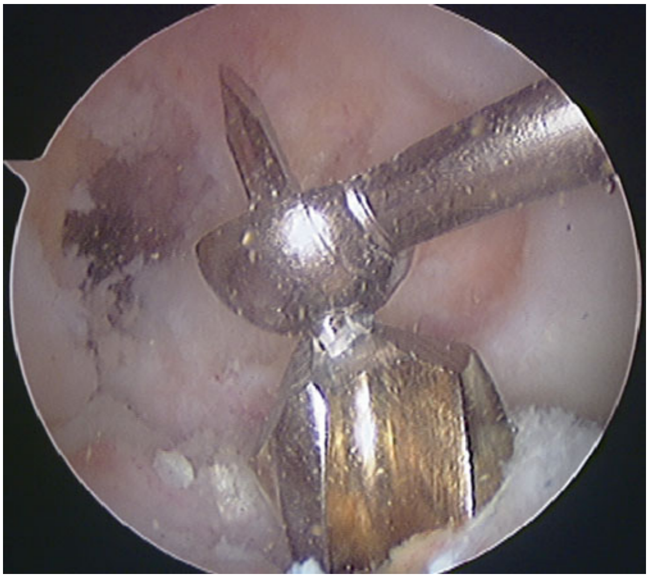

Fig. 6.10 Arthroscopic view demonstrating over-drilling of the guide pin with a 9 mm drill. Note the use of a curette to prevent guide pin advancement during drilling

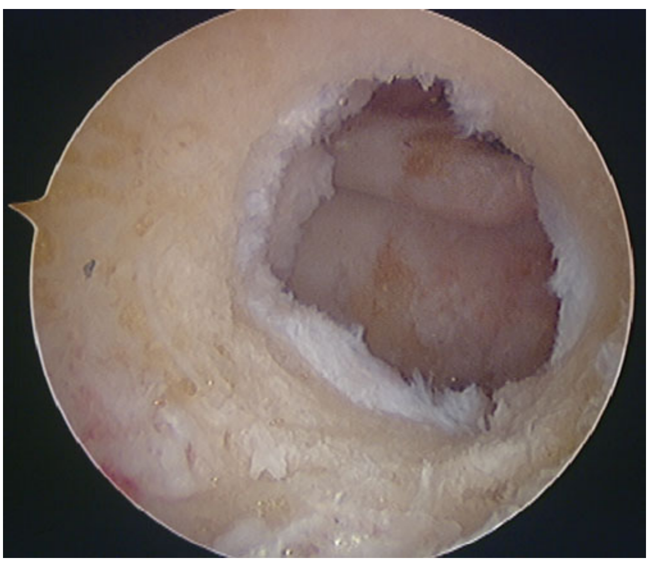

Fig. 6.11 View with the arthroscope through the tibial tunnel demonstrating its clean appearance after drilling and removal of scar tissue

Incorrect Prior Tunnel Position

- Hardware

  As above, hardware must be removed if it will interfere with creation of the new tunnels. However, it may be difficult to remove the hardware in the femur. In the case of poor positioning of the femoral tunnel, it may be possible to leave the old hardware in place. Unnecessary removal of hardware may weaken the bone or lead to enlargement of bony defects and should be avoided.
- Tunnels

  Malposition of the tibial tunnel

  It is easy to drill a new tunnel in anatomic position if the initial tibial tunnel is very poorly positioned. Prior hardware can be ignored and the new tunnel can then be drilled in the usual manner.

  In contrast, if the previous tunnel was only slightly offset from the ideal position, particularly if the previous tunnel was too posterior, independent tunnel entry into the joint cannot be achieved. The resulting tunnel is then very large, complicating both accurate graft positioning and fixation. One can compromise tibial tunnel position a bit without affecting outcome, but this solution has its limits. In case of excessive enlargement of an already malpositioned tibial tunnel, consideration should be given to a two-stage reconstruction (see below).

  In practice, it seems much easier to correct a tibial tunnel that is placed far too anterior and much harder to deal with a tunnel placed too far posterior. Too far lateral tibial tunnels can also be observed, although this malpositioning is generally small and correctable by placing the interference screw on the lateral side of the new graft.

  If the original hardware proves impossible to remove, or removal of the initial hardware will lead to a very large tunnel opening, it may be best to leave it in place. The new tunnel can then be drilled next to the old hardware in an anatomic position.

  Malposition of the femoral tunnel

  If the femoral tunnel is poorly positioned (commonly noted to be vertical in the notch), it is quite easy to drill a new tunnel in the correct position on the lateral wall using the "outside-in" technique (Fig. 6.12a, b). This type of tunnel placement generally completely avoids any intersection with the old tunnel (Fig. 6.13). Because the femoral bone block is fixed in the lateral cortex and the lateral part of the condyle, fixation will be solid even if the aperture is enlarged.

  When tunnels are only slightly malpositioned, it is easier to correct a femoral tunnel placed too far posterior and harder to correct a femoral tunnel placed too far anterior. The drilling of a second femoral tunnel in these cases may lead to increased risk for femoral fracture. A two-stage reconstruction may be indicated (see below).

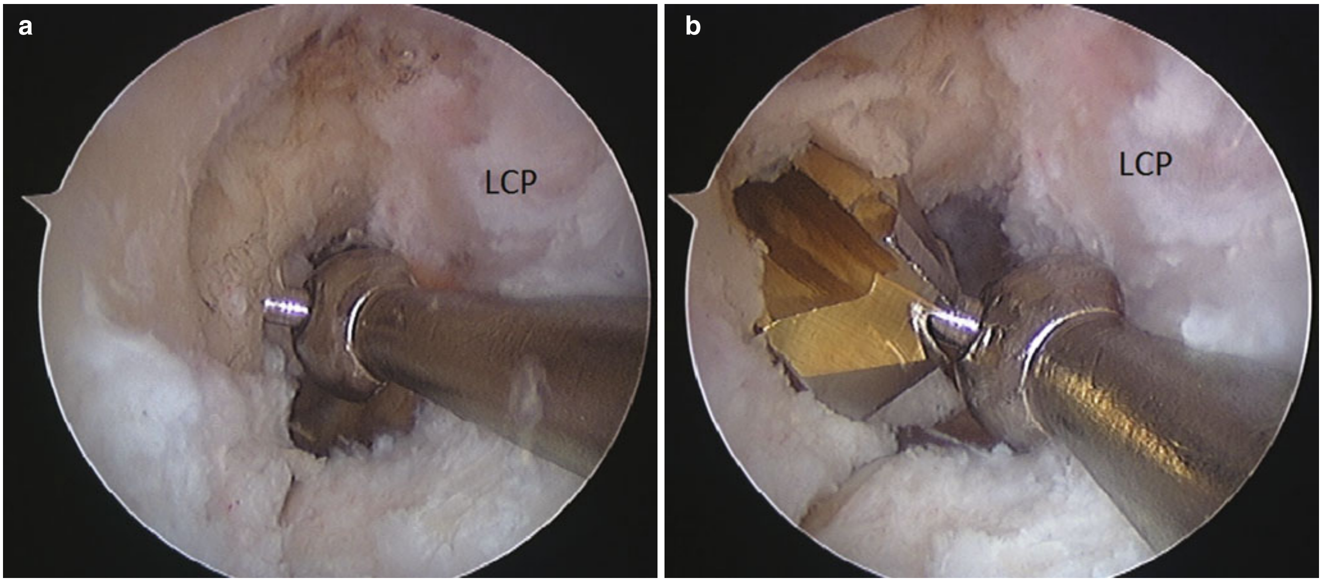

Fig. 6.12 (**a**, **b**) Arthroscopic view of a new femoral tunnel being drilled. The prior femoral tunnel can be visualized superiorly in the notch in Fig. 6.12

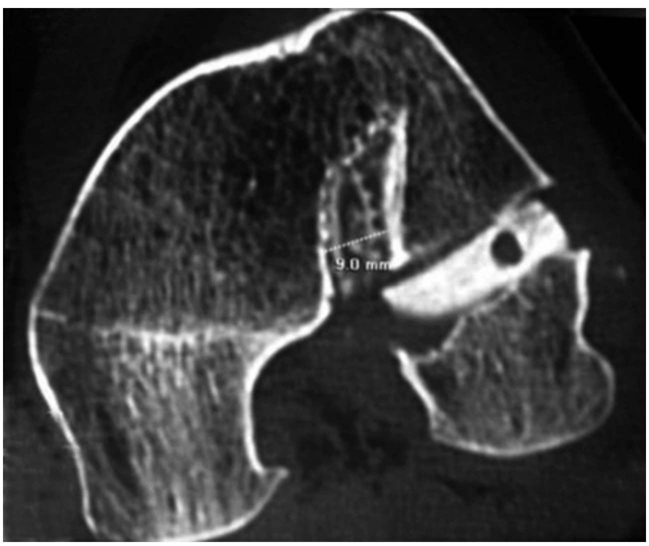

Fig. 6.13 Axial CT cut of the distal femur of a left knee. The previous vertical femoral socket is seen as in the new femoral tunnel drilled with the "outside-in" technique

Fixation

When the prior tunnels are used, the fixation of a new graft can also be performed in the usual way by interference screws and a cortical backup on the tibia.

In the case of a bone defect or poor bone quality, we recommend the use of two screws in the same tunnel associated with cortical backup. This can be achieved with a FiberWire® loop through bone tunnels on the anterior tibia or use of a wire through the bone block around a screw with a washer (Fig. 6.14).

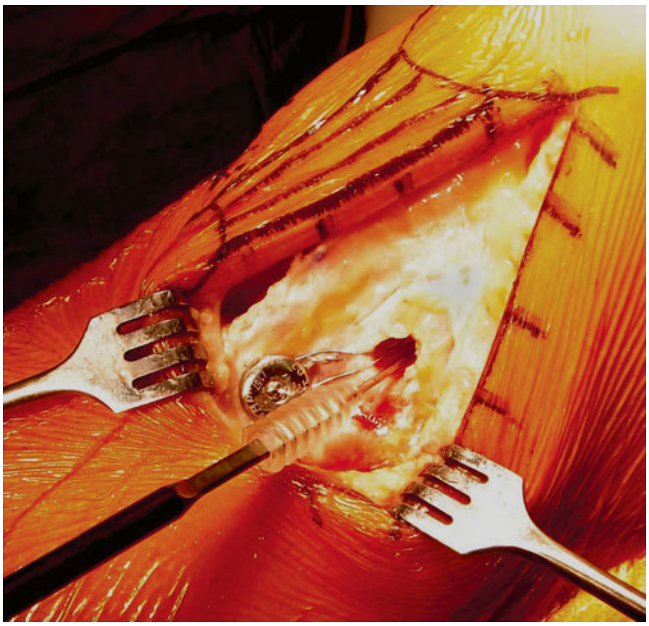

Fig. 6.14 Intraoperative view of double tibial fixation achieved with a wire through the bone block fixed with a screw and washer as well and an interference screw

Two-Stage Reconstruction

When there is significant bone loss that may compromise fixation and positioning of the new graft, a two-stage reconstruction is indicated. The first stage includes removal of the prior graft and hardware followed by bone grafting of the tunnels. The iliac crest should be prepped into the operative field. The previous graft is then completely excised using a shaver and/or basket. The tunnels are cleaned, fibrosis excised and the previous hardware removed. Fluoroscopy may be useful for locating intraosseous hardware. The cleaned tunnels can be grafted with cancellous bone from the anterior iliac crest. ACL reconstruction is then performed 3–6 months later.

This procedure is rarely performed in our practice and should be considered in extreme cases including severe tunnel enlargement or failed double-bundle reconstruction in which the two tunnels have eroded into one large defect (Fig. 6.15a–f). The exception is the case of slightly posterior tibial tunnel or slightly anterior femoral tunnel. In these cases, attempts to correct the tunnel position will likely lead to an enlarged entry site into the joint and placement of the graft in the same position as in the prior reconstruction. In these cases, we recommend a two-stage reconstruction even in the absence of tunnel enlargement.

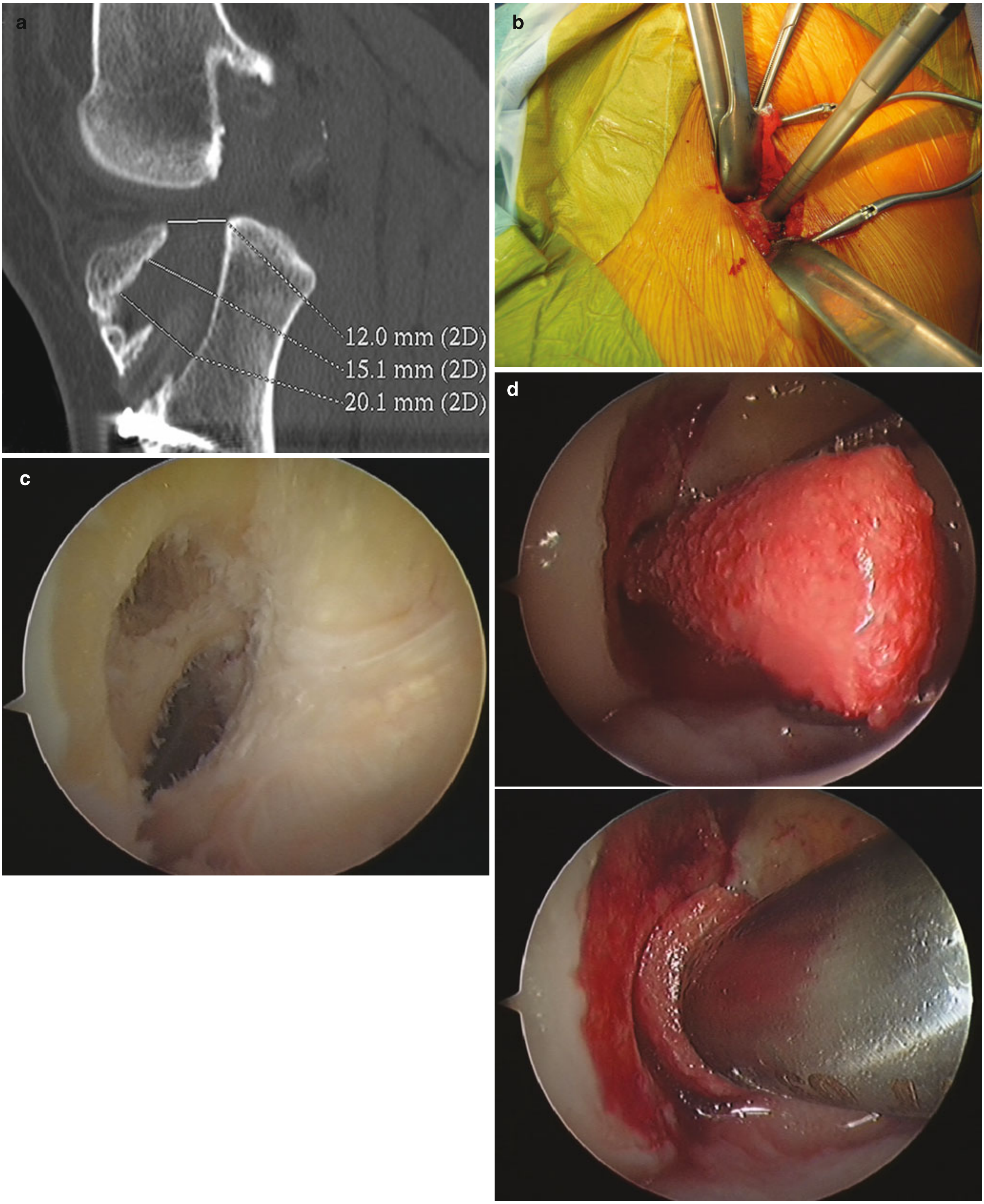

Fig. 6.15 (**a**) Sagittal CT image demonstrating tunnel enlargement and coalescence following a double-bundle reconstruction. A two-stage reconstruction is indicated. (**b**) Iliac crest bone harvest. (**c**) Debridement of the femoral tunnel. (**d1**, **d2**) Femoral tunnel grafting with cancellous bone. (**e**) Tibial tunnel grafting with cancellous bone. (**f**) Postoperative radiographs

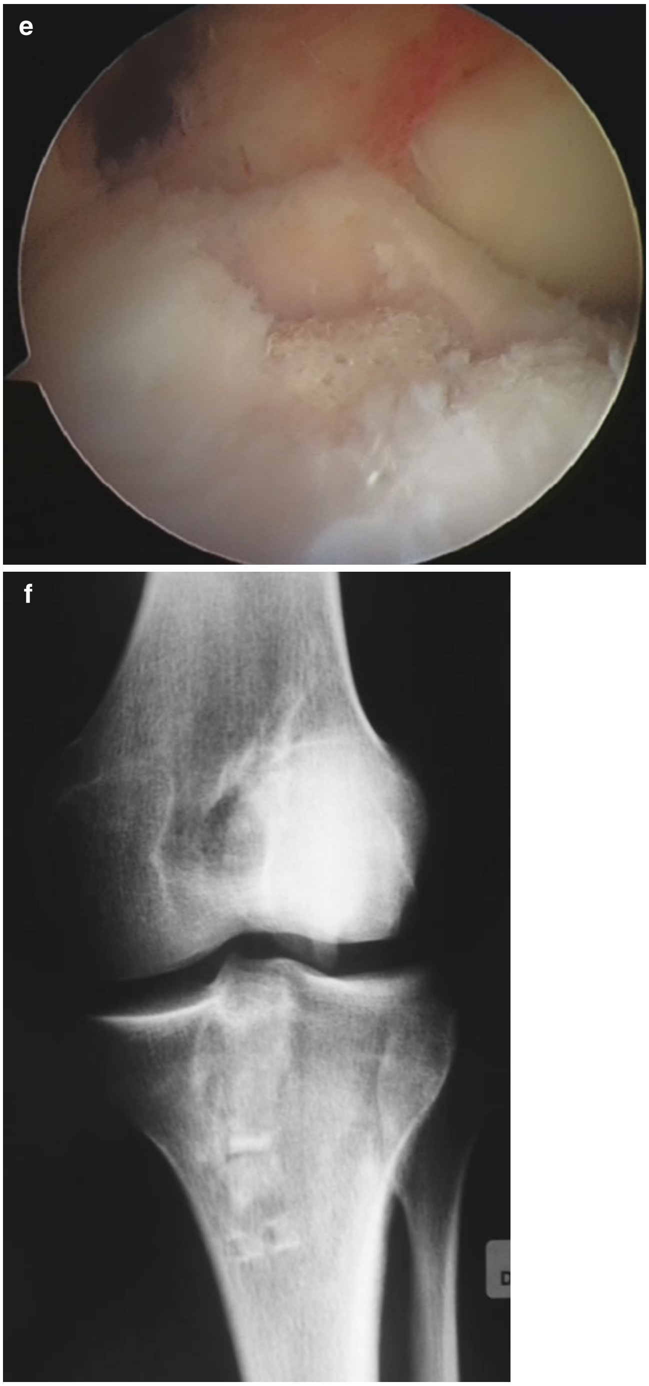

Fig. 6.15 (continued)

Combined Procedures

In specific clinical situations, revision ACL reconstruction can be combined with additional procedures to improve the odds of successful outcome or address associated pathology.

ACL Reconstruction and Valgus-Producing High Tibial Osteotomy

The addition of a valgus-producing high tibial osteotomy is indicated in the presence of early medial tibiofemoral arthritis or in cases with significant genu varum, especially associated with a lesion of the posterolateral corner ligament complex. In case of significant isolated genu varum (tibial in most cases), the osteotomy is designed to protect the graft as increased stress in the medial compartment likely contributed to the failure of the initial graft. We consider genu varum to be significant when the hip-knee-ankle angle exceeds 6° of varus. In cases of an associated injury to the posterolateral corner, the osteotomy will serve to protect both the ACL reconstruction and repair of the posterolateral corner injury (Fig. 6.16a, b).

A detailed description of the performance of the osteotomy is found in Chap. 16 and will not be repeated here.

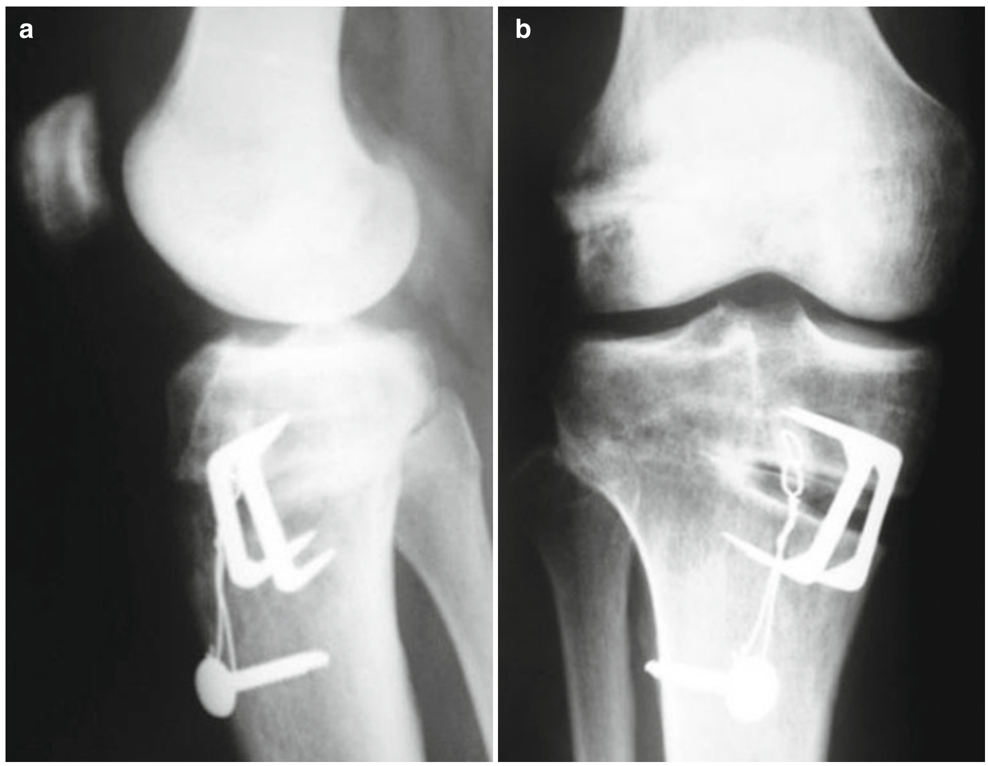

Fig. 6.16 Anteroposterior (**a**) and lateral plain (**b**) radiographs demonstrating the postoperative appearance of a right knee following revision ACL reconstruction and associated opening-wedge high tibial osteotomy

ACL Reconstruction and Anterior Tibial Closing Osteotomy

This procedure is rarely indicated; however, it must be considered in patients with a failed ACL reconstruction combined with a tibial slope greater than 14° (Fig. 6.17). The osteotomy is performed to reduce anterior tibial translation induced by excessive posterior tibial slope. This technique does not alter the position of the anterior tibial tuberosity. Preservation of the anterior tibial cortex in this region helps can limit postoperative hyperextension.

The surgical approach is identical to the valgus-producing high tibial osteotomy. The graft is harvested and the femoral and tibial tunnels are created prior to performance of the osteotomy. The anterior closing-wedge osteotomy is performed by preserving a posterior hinge centered at the junction of the PCL facet of the tibia with the posterior tibial cortex, just distal to the PCL insertion (Fig. 6.18). An anteroposterior guide pin is placed on both sides of the patellar tendon just proximal to the anterior tibial tuberosity about 4 cm below the joint line. The pins are placed with an upward trajectory and should meet the posterior tibial cortex near its junction with the PCL facet. The anterior portion of the superficial MCL medially and the proximal portion of the tibialis anterior origin laterally will need to be elevated to provide complete visualization (Fig. 6.19a). The positioning of the pins is controlled by fluoroscopy (Fig. 6.19b).

The osteotomy is performed with an oscillating saw below the pins on both sides of the patellar tendon. A second osteotomy is then created. When planning the degree of correction, the calculation must take into account the measured bone abnormality, but also the clinical abnormality. A patient with significant recurvatum will tolerate a larger correction. We generally aim to reduce the tibial slope by about 5°. As about 1 mm of anterior closure allows for a correction of about 2°, the second osteotomy should begin between 2 and 3 mm proximal to the first and converge posteriorly. The posterior hinge should be retained and the posterior cortex is fenestrated with a 3.2 mm drill bit in order to aid in closure (Fig. 6.20). The bone wedge is removed and the osteotomy is closed. A new radiograph is obtained and if correction is appropriate, the osteotomy is secured by a staple on both sides of the patellar tendon (Fig. 6.21). The tibial tunnel is then over-drilled using the same diameter drill used to create the tunnel. The graft is passed. Double fixation with wire around a screw as well as an absorbable interference screw is preferred (Figs. 6.22 and 6.23).

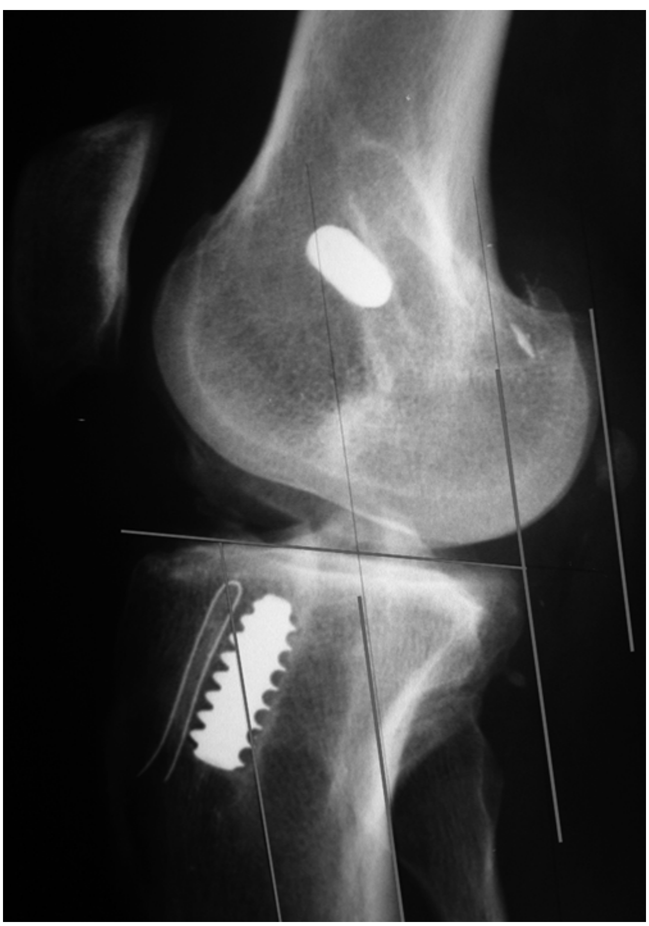

Fig. 6.17 Lateral stress radiograph of a knee demonstrating a failed ACL reconstruction (increased anterior tibial translation noted) associated with a tibial slope greater than 14°

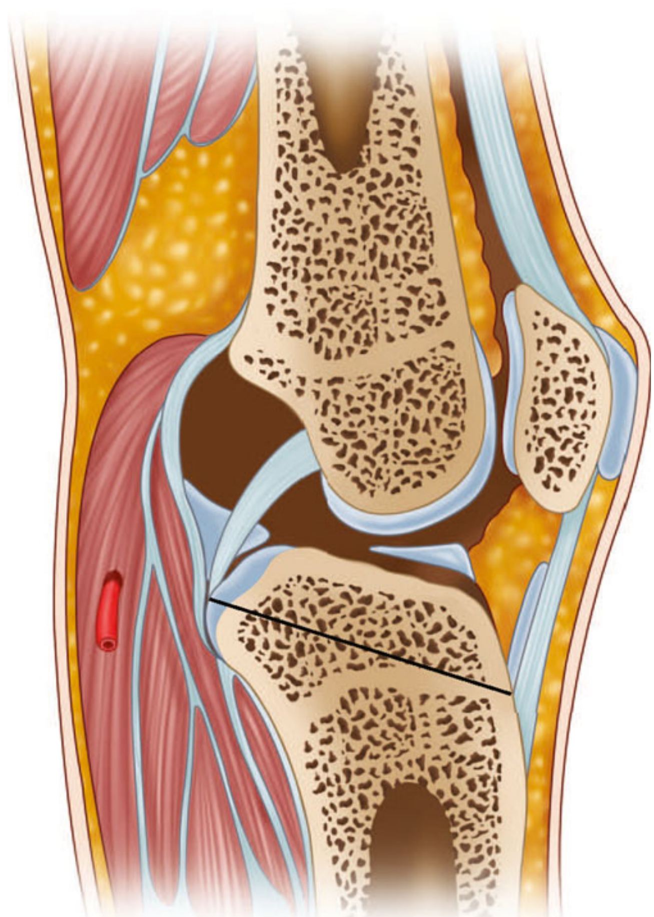

Fig. 6.18 Drawing of a sagittal section though the proximal tibia demonstrating the path of the anterior closing osteotomy. Anteriorly, the cut is just proximal to the anterior tibial tuberosity. The posterior hinge is centered at the junction of the PCL facet and posterior tibial cortex just distal to the PCL insertion

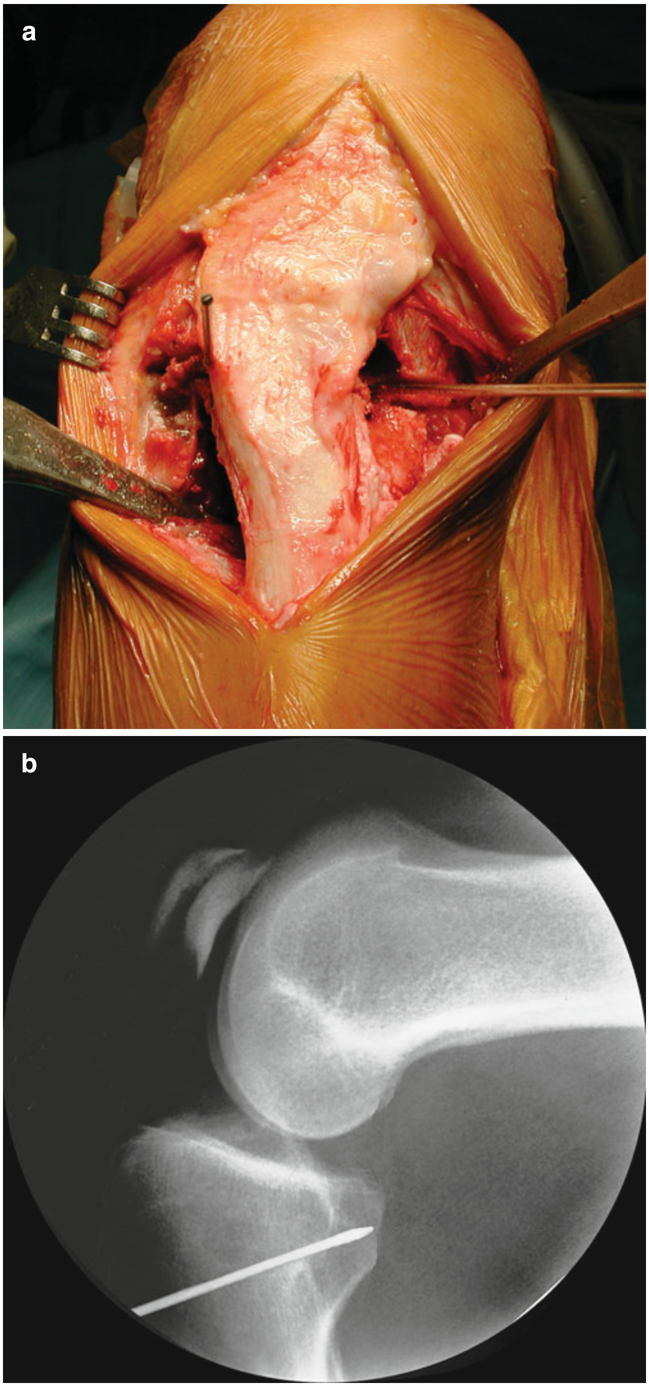

Fig. 6.19 (**a**) Intraoperative photo demonstrating the insertion of two guide pins into the anterior cortex of a right knee. The pins are placed just above the tibial tuberosity. Note the elevation of the superficial MCL medially and tibialis anterior muscle laterally to provide complete visualization. (**b**) Intraoperative fluoroscopic image of a proximal tibia demonstrating placement of the two guide pins prior performance of the anterior closing-wedge osteotomy. Note the pins track proximally toward the junction of the PCL facet and posterior tibial cortex

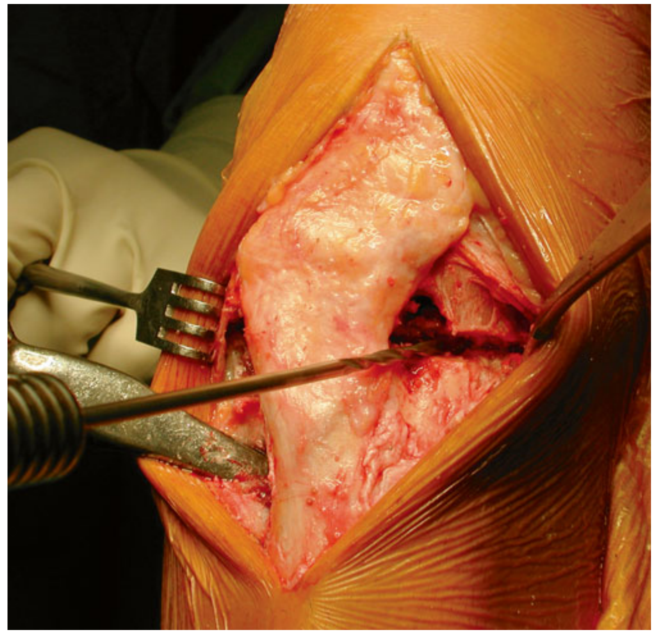

Fig. 6.20 Intraoperative photograph demonstrating fenestration of the posterior tibial cortex with a 3.2 mm drill

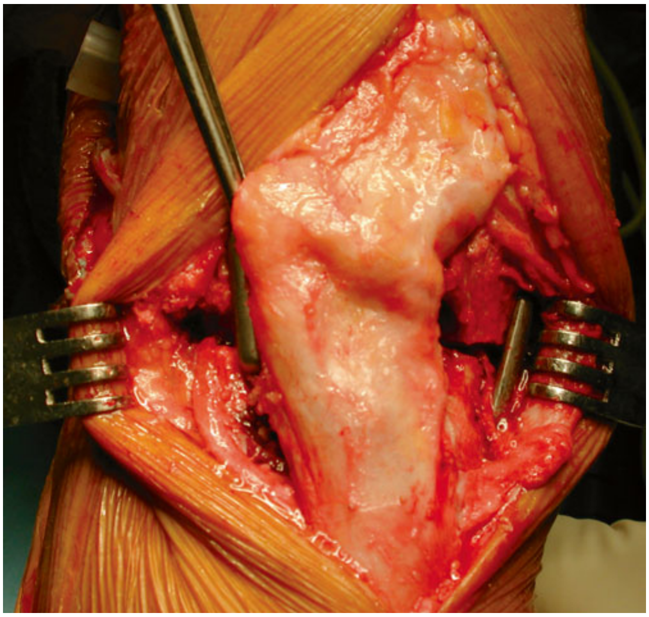

Fig. 6.21 Intraoperative photo demonstrating staples placed on either side of the patellar tendon to achieve secure fixation of the closed osteotomy

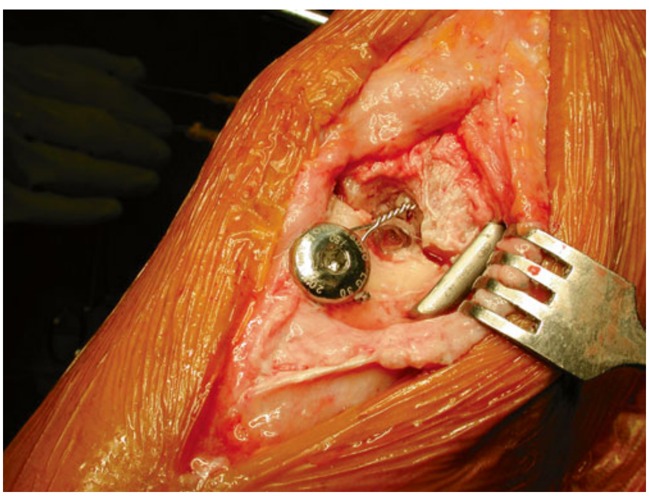

Fig. 6.22 Intraoperative photo demonstrating double tibial fixation

Fig. 6.23 Postoperative plain lateral radiograph demonstrating double tibial fixation. Note correction of the excess posterior tibial slope as well as the anterior tibial translation

Reefing of Posteromedial Soft Tissues

Reefing of the posteromedial soft tissues is usually sufficient to control any hyperextension secondary to the anterior deflection osteotomy. Rarely, posterolateral reefing is also required.

Reefing is performed by placing a retention suture in the superficial medial collateral ligament and oblique popliteal ligament and advancing the semimembranosus. This procedure is useful for control of anterior tibial translation in single-leg stance and control of recurvatum. Rehabilitation will include bracing to block full extension for 45 days.

Lateral Extra-Articular Tenodesis

A lateral extra-articular tenodesis is performed to protect the new ACL graft and allow better control of the pivot shift. We prefer to utilize the semitendinosus to achieve extra-articular tenodesis. The specifics of the technique are described in Chap. 5 and will not be detailed here (Fig. 6.24).

The lateral tenodesis is justified for several reasons in revision cases. The presence of prior tunnels potentially alters tunnel position and may compromise control of the laxity. The addition of an extra-articular tenodesis may better control the laxity and associated pivot shift. Additionally, failure of the prior graft demonstrates that this patient is prone to repeat instability and everything should be done to potentially increase stability. Neither the surgeon nor the patient wants to face another failure.

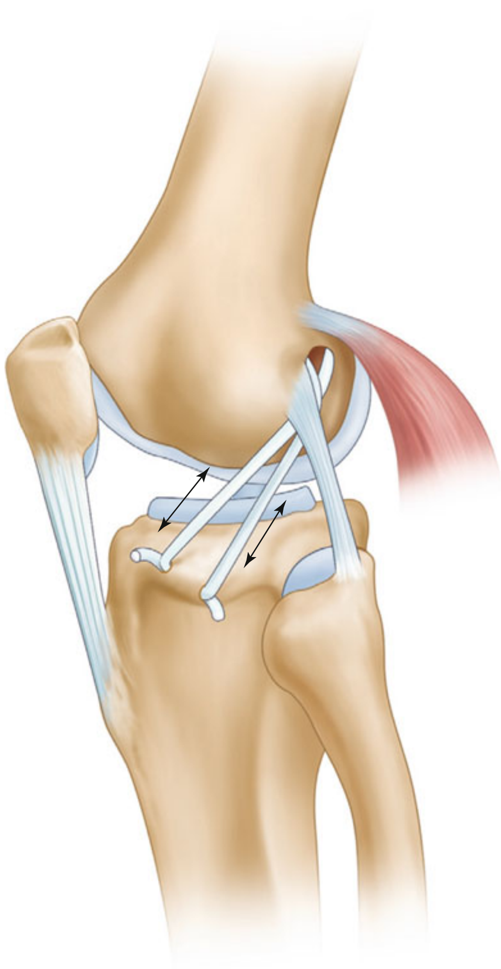

Fig. 6.24 Diagram demonstrating the completed lateral extra-articular tenodesis

Conclusion

Successful revision ACL reconstruction requires a detailed analysis of the reason for failure of the prior reconstruction. The etiology of prior failure, prior graft choice, prior surgical technique, and previous tunnel placement influence the revision surgical technique. A two-stage surgery is discussed but is rare in our practice. The technique of "outside-in" drilling combined with cortical fixation solves most technical challenges. Associated injuries and anatomical factors must be taken into account and be treated either by bony procedures (valgus-producing or anterior closing tibial osteotomies) or by soft tissue procedures (lateral extra-articular tenodesis or repair of associated ligamentous injuries).