# New techniques for anterior cruciate ligament revision surgery

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**Summary**

Similiar to the development in joint replacement surgery, revision surgery is becoming more and more important in Anterior Cruciate Ligament (ACL) surgery. Localisation and volume of previous tunnels are crucial for planning revision surgery. Based on these different tunnel conditiones, a new grading system has been developed indicating the difficulty of the upcoming revision surgery. Evaluation of our more than 500 cases of ACL revision surgery demonstrated in 74% malposition of the previous bone tunnels as the reason for graft failure and revision. Severely abnormal tunnel position allows in generally for new tunnel drilling in the correct position (Grade 1 revision). Isolated tibial tunnel dilation is seen mainly following ACL reconstruction using bone-patellar tendon-bone grafts (BPTB). In most of these cases the femoral tunnelI is obliterated by the bone block of the BPTB (Grade II). In these cases, bone grafting of the tibial tunnel alone is frequently neccessary. Severe dilation of both the tibial and femoral tunnels are seen mainly following ACL reconstruction using hamstrings with graft fixation far away from the anatomical side (Grade III). In these cases bone grafting of the both old and drilling of new tunnels in the correct position as a one stage procedure might be a possible solution. On the tibial side the tunnels may be positioned or dilated too far anteriorly and/or posteriorly or medially. In some instances the opening of the old tunnel by osteotomy may be the safest approach for revision, especially if the old graft is still functioning but loose. A new technique for harvesting bone grafts from the iliac crest using specially designed bone cutting tubes was developed. 20 – 70 mm long and 8 – 15 mm large cortico-cancellous grafts may be cut out of the crest using a single 2 – 3 cm incision. The previous enlarged tunnels are reamed up in order to excise the sclerotic wall and achieve a cylindric form. An iliac crest graft with a diameter 1 mm more than the tunnel will be inserted press-fit. Then the new tunnel is drilled at its correct position. This allows single stage procedure in many of the grade III revision cases. Rehabilitation depends on the revision grade. Grade 1 revisions are treated postoperatively like primary ACL reconstructions. Grade II and III revisions using more or less amounts of bone grafting have to be rehabilited delayed with partial weight bearing for about 6 weeks. Results: Between 1/93 and 12/95 108 failed ACL reconstructions underwent revision surgery, all performed by one surgeon (HHP). During the same time 288 ACL ruptures have been reconstructed in this center (HHP). 16 patients (15%) were lost for follow up. The remaining 92 patients were 32 women, 64 men. The age range was 28 years (17 – 44). The overall IKDC rating at 3.3 (2 – 6) years followup demonstrates, that early revision has better results than late ones (p.01). But the best results still are obtained with primary reconstruction using correct tunnel positions (p.01).
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**Key words:** ACL reconstruction, ACL revision surgery, tunnel dilation, bone grafting, grading system

## Introduction

About 100.000 anterior cruciate ligament (ACL) reconstructions are performed currently in Europe per year. Inspite of the significant improvements of the intraarticular techniques, there is an obvious increase in the number of failures following these reconstructive proceduresdur to the increasing numbers of primary reconstructiones. Revision ACL surgery is technically demanding and requires a great deal of personal theoretical and clinical experience. Careful preoperative planning is vital. Technical considerations include skin incisions, tunnel size and placement, identification of exact hardware types and location, and an analysis of notch size and notch impingement. In cases of large, capacious tunnels, cystic changes, or osteolysis, often secondary to the use of prosthetic ligaments, staging of the reconstruction might be favourable. In cases of significant varus thrust and additional lateral or posterolateral instability, osteotomy must be considered either in combination with the ACL reconstruction or as a two stage procedure. The patient's co-operation and motivation are crucial. Already disappointed because of failed primary ACL surgery, mental preparation of the patient is imperative. The patient should understand his problem and know the potential outcome without having false expectations, and must maintain a positive mental outlook.

## Causes of failure

Graft failures may result from a number of factors acting either alone or in combination (Table 1) (5) and are mostly caused by problems involving the surgical technique (1,8). The most frequent cause for failure in a study of 350 revisions following ACL reconstruction and all operated from the senior author (H.H.P.) was in 74% improper tunnel placement with or without impingement (Figure 1). Also Wetzler et al. (1998) (7) estimated the incidence of malposition to be between 70 and 80%. Due to better understanding, and the use of drill guides, tunnels are in a more acceptable, but often still not ideal position. Therefore the new tunnel will involve parts of the previous one, which results in a very large tunnel. In addition, with distant graft fixation techniques, such as Endobutton-tape fixation, tunnel dilation is also seen more frequent (Bungee and windshield wiper effect) (2). In order to avoid staged surgery, new techniques for primary stable grafting of the enlarged tunnels allowing immediate reconstruction had been developed.

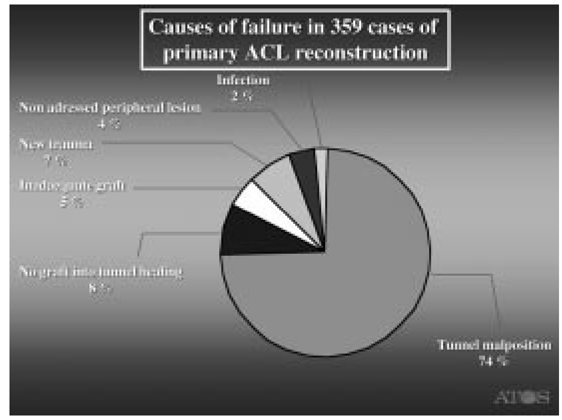



Fig. 1. Reasons for failure in 350 ACL reconstructions

## Indications

Indications for revision ACL-reconstruction are:

1. subjective feeling of instability during the normal daily and sports activities.

| Preoperative | Intraoperative | Postoperative |
|---|---|---|
| State of secondary constraints | Inadequate notchplasty | Improper graft incorporation |
| State of menisci | Improper tunnel placement | Improper rhabilitation |
| State of cartilage | Improper tensioning | Trauma |
| | Inadequate fixation | |
| | Faulty selection/harvest of graft | |

Table 1. Factors causing graft failure (Vergis et al 1995) (2)

2. functional instability with or without pain under weight bearing.

3. Objective anterior laxity (during the clinical examination) with positive Lachman test and significant KT-1000 side-to-side difference.

## New grading system of ACL revision surgery

For the planning of a revision case concerning the difficulty of surgery and eventually staging it seemed to be appropriate to develop a classification system based on previous tunnel positions, tunnel enlargement, cartilage and meniscal conditions, and eventual deficiant secondary restraints. Grade I indicates a simple revision similiar to primary reconstruction, whereas Grade IV (Table 1). is the most difficult one, involving multiple surgical steps (bone grafting, osteotomy, peripheral ligament reconstruction, meniscal allograft etc.) (figs. 8a, 10a, 26a, 33).

## Graft selection

In Europe, autografts generally are used in primary ACL surgery as well as in revision surgery. Synthetic grafts, originally used in these so-called salvage procedures, have been abondend. Allografts are rarely available in Europe. Allografts are used only in cases of bilateral multidirectional revision instabilities (6).

For autograft tissue there are multiple sources. These include patellar tendons, hamstrings or quadriceps tendons, from either the injured or non-injured leg. Theoretically this allows up to six revisions for one knee or 3 revisions if both knees are involved. The main advantage of the patellar tendon is the possibility of harvesting it with a large bone block from the tibial attachment in order to fill up spacious bone tunnels.

If for the previous reconstruction a BPTB graft was used, in most cases the bone block or the graft was fixed in the femur close to the notch wall using an interference screw. After removal of the screw, a new tunnel posterior to the interference srew may be drilled leaving a sufficiant large and stable bone bridge between the screw defect and the new tunnel. A semitendinosus and gracilis tendon is our first choice for this second reconstruction. The second choice would be a quadriceps tendon graft. If hamstrings were used as a graft at the primary reconstruction, a BPT graft or a quadriceps graft from the same knee could be harvested. If these graft sources are not available in the injured knee due to the use for previous reconstructions, a graft would be harvested from the controlateral knee.

## Hardware removal

Hardware removal may be the most challenging part of the procedure. Radiographic evaluation is vital to determine direction and position of screws, staples or wires. Such information is necessary to determine whether hardware might compromise the drilling of a new tunnel or whether it can be left in place. In ACL revision surgery, the availability of a collection of special instruments for hardware extraction is imperative. They should include all sizes of screwdrivers and multiple sizes of coring reamers. Furthermore, a counterclockwise reversed thread for removing stripped interference screws can be used. The alternative for broken AO screws is a reversed threaded internal drill bit, both with clockwise and counter clockwise thread, depending on from which end the screw must be removed. Also a bone harvesting tube, matching the size of the screw, may be inserted under fluoroscopic control over the screw for retraction (Fig. 2) Staples can be removed most easily by using an elevator rather

Fig. 2. Hardware removal

than an extractor or osteotome. Small chisels and gouges can be helpful for removing any bone, covering the screws. In cases where removing hardware might result in excessive loss of bone, necessitating bone grafting or staging of the procedure, it is better to leave it in place and change the tunnel direction (4). Removal of prosthetic ligament devices can present problems. All intraarticular synthetic material should be completely removed (4). Often, in cases of severe abrasion synovitis, this has to be combined with synovectomy.

**Revision notchplasty**

Notchplasty in revision cases eliminates impingement and facilitates correct femoral tunnel placement. This should also include removal of posterior osteophytes.

**Bone grafting for enlarged tunnels**

All Grade II-IV revisiones demands in generally for bone grafting. A new atraumatic harvesting technique for cylindric bone blocks has been developed: The iliac crest is exposed using a 2 cm incision. Two K-wires mark the internal and external wall of the iliac crest (Figures 3, 4). A 6 to 8 cm long cortico-cancellous bone graft is harvested using specially designed bone cutting tubes with an external diameter ranging from 12 to 16 mm (Figures 5, 6). Due to the V-form of the ileum, the plug is wedge-shaped at its distal end. The harvested bone is divided into one cylindrical and one wedge-shaped plug (Figure 7).

**Bone tunnel revision and placement of new graft**

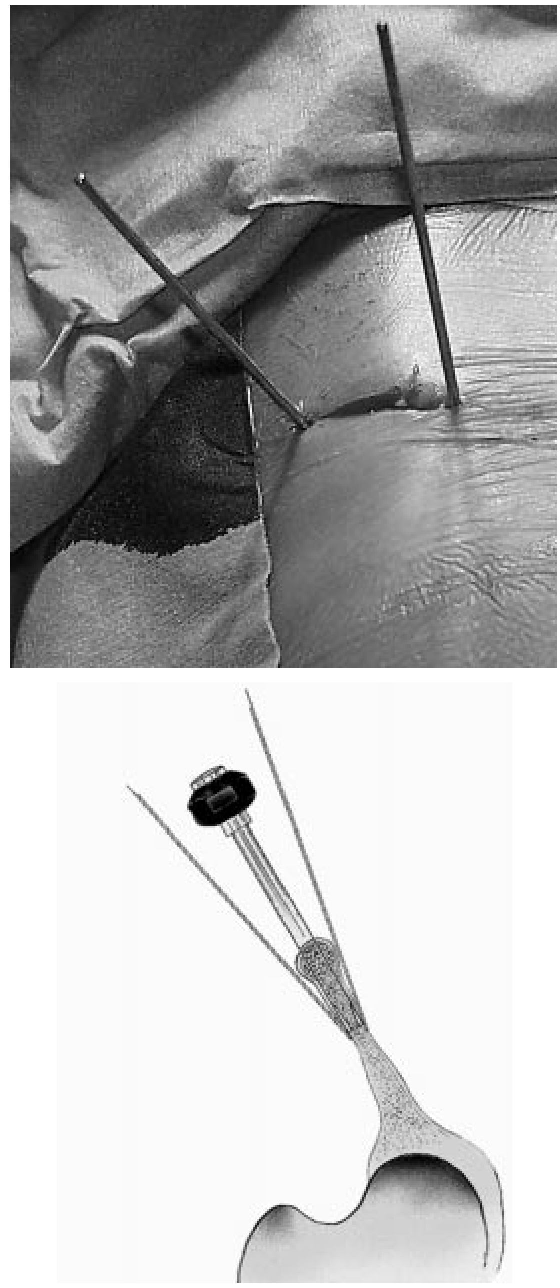


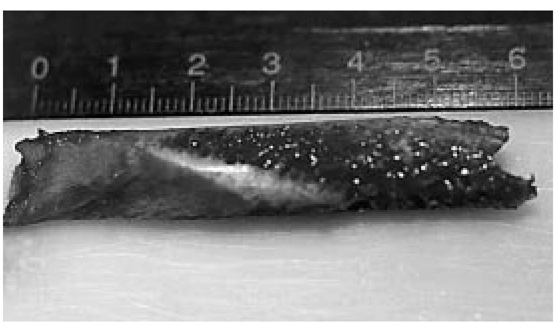
Fig. 3+4. Iliac crest with 2 mm incision. K-wires marks direction of bone wall

**Grade I:**

**a) Narrow femoral tunnel and tibial tunnel in correct position**

**b) Femoral ± tibial tunnel far away from correct position**

The previous tunnel is located in quadrant 1 or 2 on both the femoral and tibial side according to the classification of Har-



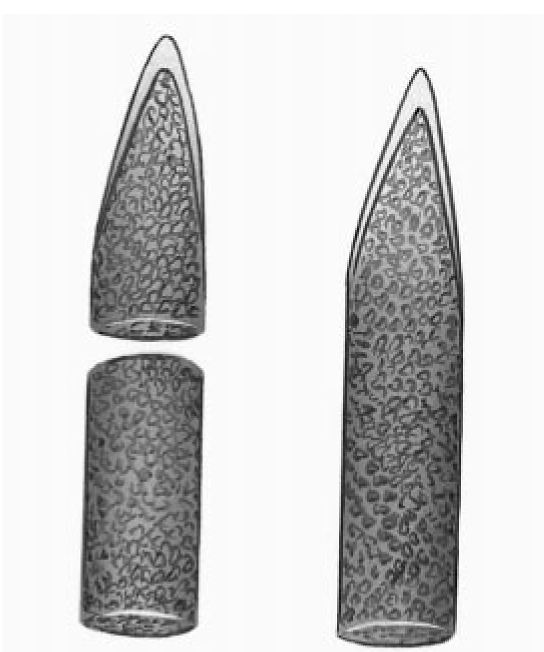



Fig. 5+6. Harvested cortico-cancellous bone graft with spezial bone cutting tubes

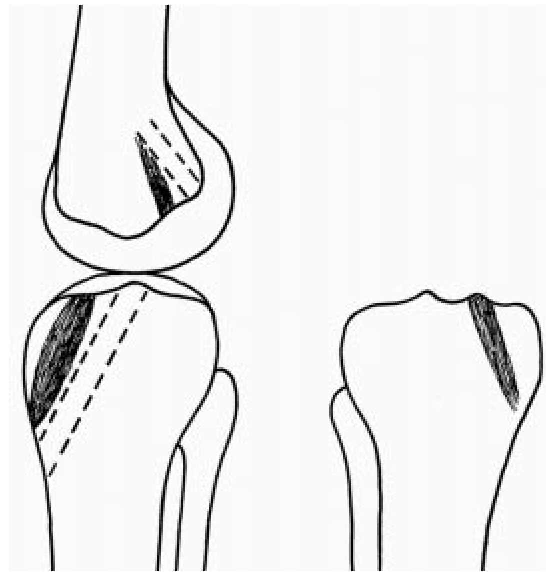


Fig. 8 a. Grade I. Small femoral tunnel and tibial tunnel in correct position


Fig. 8 b. Both tunnels too far anterior

ner (1). In these cases new tunnels have to be drilled in the correct position. Hardware may be disregarded or removed if complicating the new tunnels' drilling. If the femoral tunnel is just slightly more anterior, the tunnel can be expanded posteriorly and

Fig. 9. Semitendinosus/gracilis graft in completely new tunnels

again, the new tunnel can be drilled divergent to the old tunnel (Fig. 9). If this is not possible, a graft bone plug can be used. Because of drilling the femoral tunnel with the knee flexed to 120, all to 130 degrees, the tunnels are directed perpendicular to Blumensaat's line. Since most of the tunnels in revision cases had been positioned in a more oblique direction (flat angle to Blumensaat's line), it is easy to avoid the old tunnel even in cases of less anterior position.

**Grade II:**

**Large tibial tunnel + small femoral tunnel or previous tunnel closed by bone block of initial graft** (Fig. 10a, 10b)

In such a case drilling of a new femoral tunnel is easy, leaving a bone bridge between the previous and the new tunnel. The dilated tibial tunnel is bone grafted and a new tunnel is driled in a correct position under fluoroscopic control in a one stage operation.

Two different technical steps allow the revision of the tibial tunnel: a) opening of the previous tunnel by osteotomy and b) tunnel expansion with resection of the sclerotic wall.

**a) opening of the previous tunnel by osteotomy**

A K-wire is positioned into the old tunnel manually. If the tibial entrance is obliterated, a drill guide is used for the placemnet of the K-wire. Using an oscillating saw,

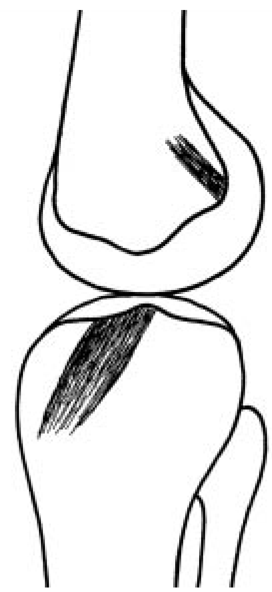


Fig. 10 a. Grade II. Large tibial tunnel + small femoral tunnel or previous tunnel closed by bone block or initial graft

Fig. 10 b. Large, capacious tibial tunnel (postop. Hamstring graft) two parallel cuts are performed in direction of the K-wire medially and laterally to it in a distance of about 8 – 10 mm. The resulting triangular bone chip is removed using a small osteotom (Figs. 11, 12).

The opened tunnel can now be debrided easily including removal of the old graft (Figs. 13, 14). If the tunnel is slightly anteriorly located, the tunnel can be expanded posteriorly and filled up anteriorly with a bone graft. If the previous tunnel is located too far posteriorly, a posterior bone grafting is necessary.

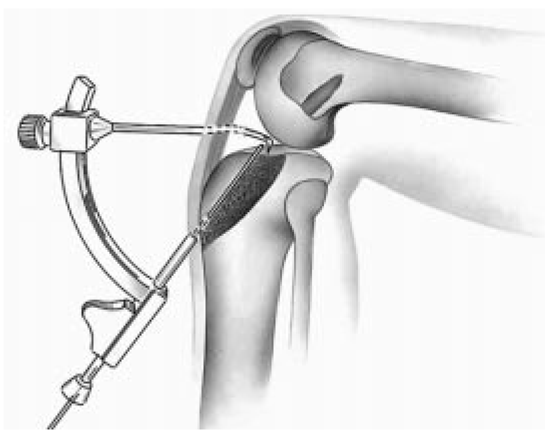


Fig. 11. Placement of a 2.5 mm drill along the anterior border of the previous tunnel

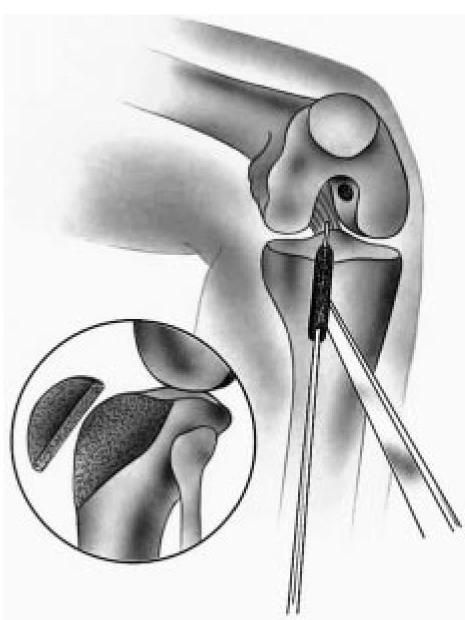


Fig. 12. Opening the tunnel by removal of a 8 – 10 mm bone chip

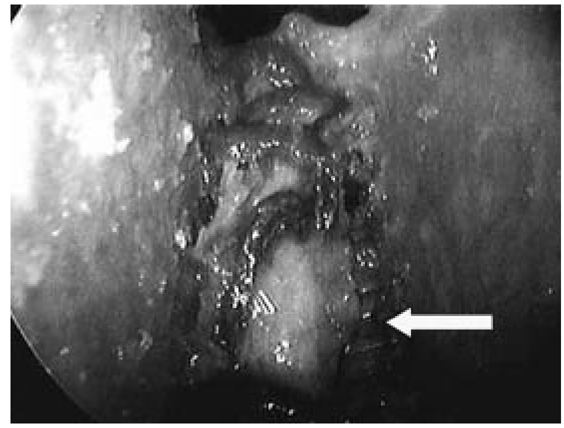


Fig. 13. Old hamstring graft in situ

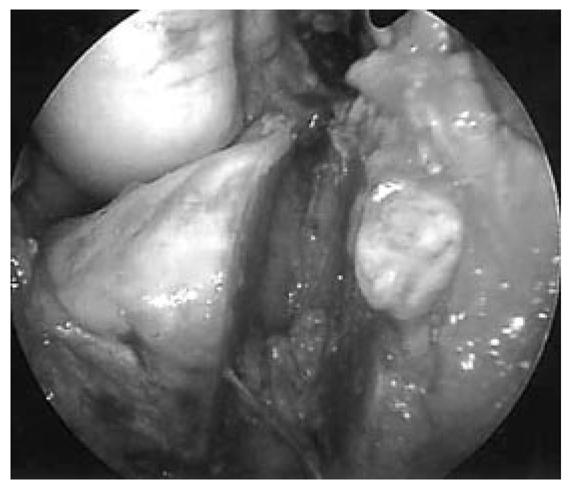


Fig. 14. Debrided tunnel

The new ACL graft is inserted into the new femroal tunnel and than into the opened tibial tunnel. The graft itself is fixed by tying the holding sutures over a distal bone-bridge (see paragraph graft fixation). Finally, the triangular bone chip is replaced into the osteotomy and fixed with a staple (Figs. 14, 15). In most cases, this fixation is sufficient and an additional interference screw is not necessary.

Alternatively, a resorbable interference screw fixation for both the graft and the bone plug is possible. The CT-scan confirms the correct position of the graft (Figs. 17, 18).

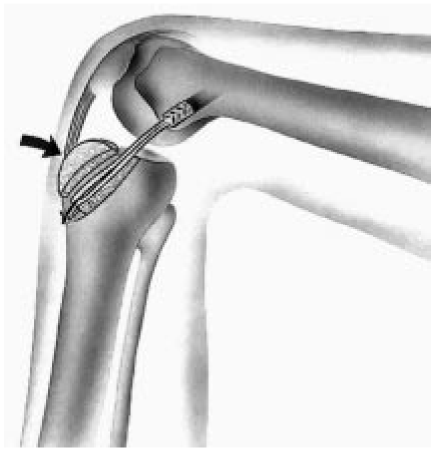


Fig. 15. Replacement of bone chip

Fig. 16. Axial drawing of reconstruction. From posterior to anterior bone graft; tendon graft and bone chip with staple

Fig. 17. Axial CT-scan

Fig. 18. Sagittal CT-scan

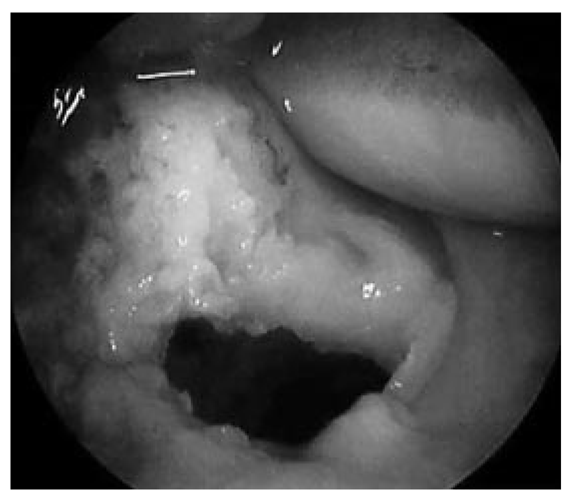


Fig. 19. Graft removed from tunnel

**b) tunnel expansion with resection of sclerotic wall and bone grafting.**

A K-wire is positioned into the old tunnel manually. If the tibial entrance is obliterated, a drill guide is used for the placemnet of the K-wire.

The distal entrance of the tibial tunnel is overdrilled, the old graft is removed (Fig. 19) and the previous tibial tunnel is debrided. The K-wire is drilled slightly into the notch wroof in order tostabilize it into a central positon in th tunnel. Than the tunnel is enlarged to a cylindric form by overdrilling of the K-wire. By this means the sclerotic tunnel wall is also resected. A cylindric iliac crest bone is impacted into the tibial tunnel preesfit (Figs. 20, 21). Now a new tibial tunnel is drilled under fluoroscopic controll in the correct position. If the previous tunnel was too far medial positioned, involving the cartilage posterior to the anterior horn of the medial meniscus, the bone graft should be harvested slighly oblique to the iliac crest in order to fit exactly to the surface of the tibial plateau. In this case, the periosteum of the graft should be preserved in order to encourage the repair with fiber cartilage.

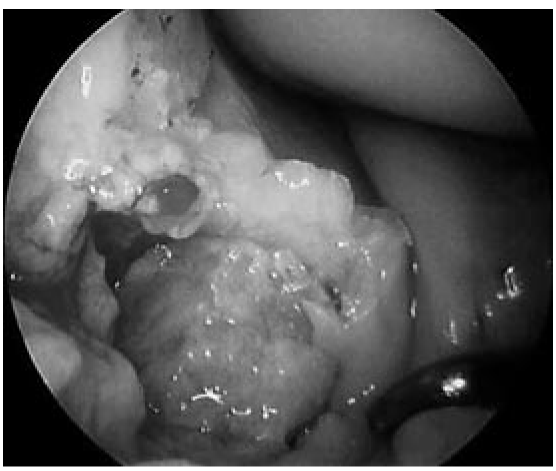


Fig. 20. Tunnel grafted with cylindric bone from illiac crest

Fig. 21. Previous and new tunnel in CT-scan

Another cause of failure of an ACL reconstruction may be the elongation of an intact and well positioned graft or initial fixation failure. This is seen mainly following reconstructiones in which soft tissue grafts (hamstrings etc.) were used (Fig. 22). In these cases the tibial tunnel is opened by osteotomy as described above and the graft, including its osseus ingrowth zone, is mobilized (Figs. 23, 24). The graft is then refixed and the removed bone chip of the osteotomy is repositioned and fixed it with a staple (Fig. 25).

**Grade III:**

**Large femoral + tibial tunnel** (Fig. 26a)

In these revision cases, widening of both femoral and tibial tunnel occurs mainly after ACL reconstruction using hamstrings fixed far away from the anatomical side (Fig. 26b). For the dilated tibial tunnel the technique described above for grade II revision may be used. The dilated femoral tunnel has to be filled up using iliac crest bone graft similiar to the techni-

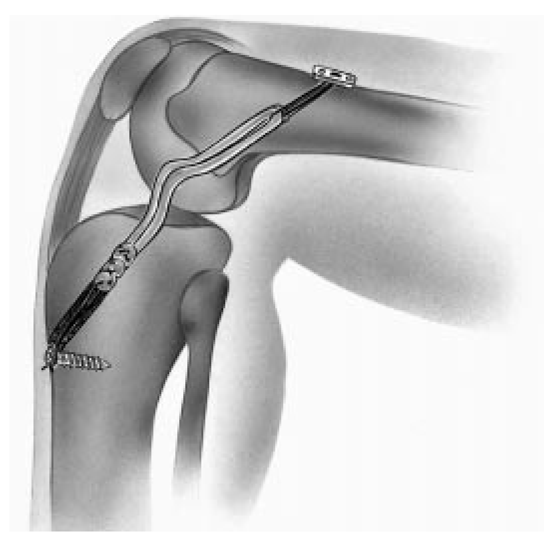


Fig. 22. Loosening of tibial fixation with intact hamstring graft

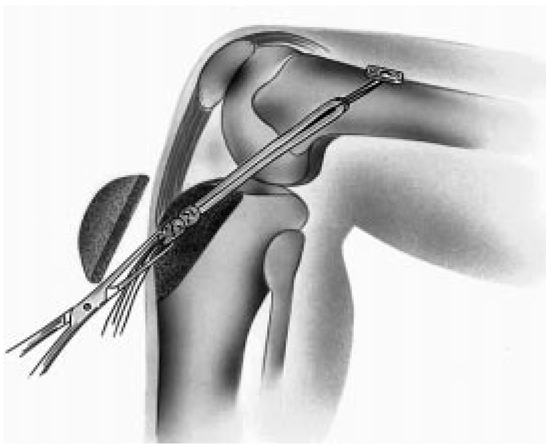


Fig. 23. Opening the tibial tunnel by osteotomy and mobilization of the graft

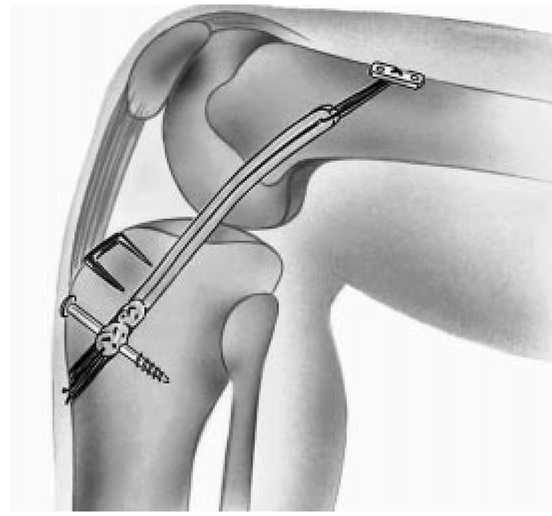


Fig. 25. Graft refixed under tension

Fig. 24. Mobilized graft with bone shell

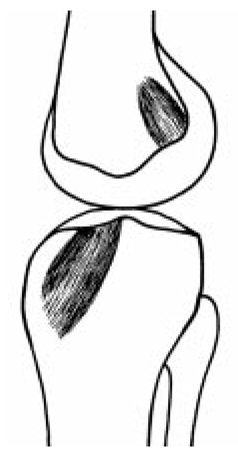


Fig. 26 a. Grade III. Large femoral + tibial tunnel (e.g.postop hamstrings)

Fig. 26 b. Sagittal CT-scan: femoral and tibial tunnel dilation after ACL reconstruction with quadruple hamstring graft

que described above for closed tibial tunnel revision. Then a new tunnel has to be drilled in the correct position. The tunnel width is measured using impactors in half milimeters steps (Figure 27). A K-wire is inserted through the impactor and drilled into the condyle. The K-wire is overdrilled using a drill bit matching the width of the tunnel entrance (Figure 27). The drill bit may be changed against a bone cutting tube in order to gain cancellous bone for grafting. Then a sufficiant long cylindric cortico-cancelous bone graft is harvested according to the technique already described. The plug is introduced into the prepared femoral tunnel using one of the harvesting tubes. If it does not fill out the old tunnel entrance completely, a wedge-shaped plug is impacted additionally. Now the new tunnel can be drilled in the correct position (Figs. 29, 30). Using a bone-patellar tendon graft (BPT) with a bone block only from the tuberositas, or a bone-quadriceps tendon graft, the bone block is pulled into

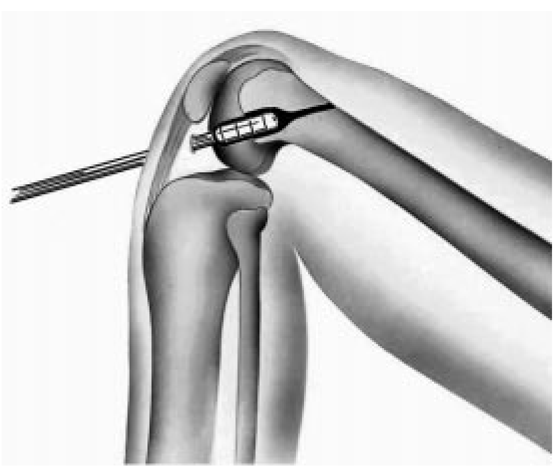


Fig. 27. Sizing of the tunnel using an impactor

Fig. 28. Tunnel expansion

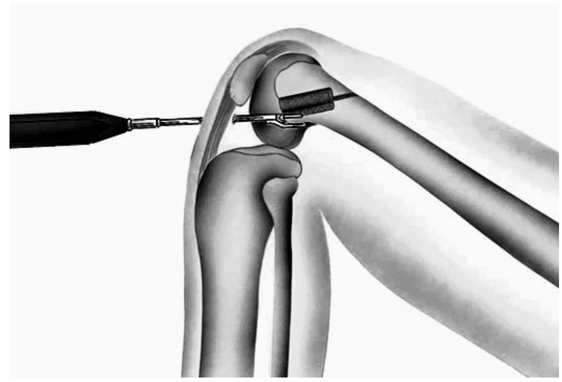


Fig. 29. Femoral drill guide in correct position

Fig. 30. Redrill of tunnel

the femoral tunnel using a holding suture and impacted pressfit (Figs. 31, 32). Sometimes, in cases of large, capacious tunnels, a staged procedure procedure may be necessary with primary bone grafting and ACL reconstruction 6 months later. In no case we had to convert the procedure into an „over the top" two incision technique.

**Grade IV:**

**Grade III and additional lesions of secondary restraints osteoarthritis ± PCL** (Fig. 33)

In these cases the new femoral and tibial tunnels are drilled as described in Grade II and III. In addition secondary restraints are reconstructed by adequate graft techniques, the PCL is replaced or an osteotomy is performed at the same time, if possible.

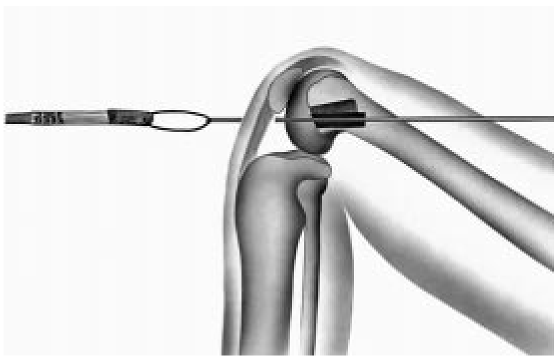


Fig. 31. Bone block of BPT graft is pulled into the femoral tunnel and impacted pressfit

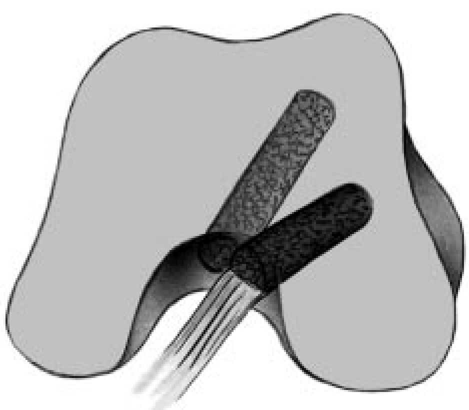


Fig. 32. Scetch of grafted and new tunnel

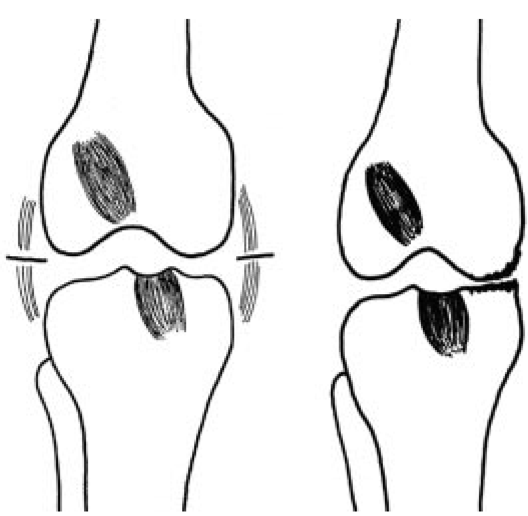


Fig. 33. Grade IV. Additional lesions of secondary restraints ±osteoarthritis ± PCL

A meniscal allograft may be implanted simultaneously or in staged procedure.

### Graft fixation

For graft fixation a press fit technique on the femur is used, if possible. An additional interference screw fixation is rarely necessary. On the tibial side, a bone bridge is created by drilling a 4.5 mm drillhole 10 mm distal to the tibial tunnel outlet and combining both drill holes using a curved clamp. A Deschamp ligatur needle helps to pass the holding sutures beneath the bone bridge. The holding sutures (Krackow sutures, baseball sutures using Ethibond Nr 2 or 3, Ethicon) of the graft are tied over the bone bridge in full extension.

### Rehabilitation

In revision cases of grade I, accelerated rehabilitation can generally be used safely. In cases of additional extensive bone grafting or high tibial osteotomy (grades II to IV), partial weight bearing is necessary for at least 6 weeks. If secondary restraints are reconstructed, a brace is also mandatory.

### Clinical experience and results

Between 1/1993 and 12/1995 108 failed ACL reconstructions underwent revision surgery all performed by one surgeon (HHP). During the same time 288 ACL ruptures have been reconstructed in this center (HHP). 16 patients (15%) were lost for followup. The remaining 92 patients included 32 women and 64 men. The age range was 28 years (17 – 44). The overall IKDC rating at 3.3 (2 – 6) years follow-up is shown on table 3. It demonstrates that early revision has better results than late ones (p,01). But the best results still are obtained with primary reconstruction using correct tunnel position (p,01). Conclusion

| IKDC rating | Total revisions | Early revisions | Late revisions | Primary |
|---|---|---|---|---|
| | % | % | % | reconstructions |
| A | 10 | 17 | 3 | 25 |
| B | 44 | 57 | 40 | 57 |
| C | 31 | 21 | 39 | 17 |
| D | 15 | 5 | 18 | 1 |

Table 2. IKDC scoring system

Based on our 585 ACL revision cases between 1988 and 1999, we have found that it is possible to achieve acceptable to good results by using the techniques just described. Early revision surgery has better results than late revision due to secondary arthritis.

Preventing ACL reconstruction failure is imperative. This can be achieved by improved surgical techniques such as correct tunnel placement, use of adequate grafts, and metal free graft fixation. It is critical to address secondary restraints at the time of the initial surgery.

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