Cruciate ligament reconstruction

Fares S Haddad, Sam IS Oussedik

Injuries to the cruciate ligaments of the knee can be disabling. Advances in treatment over recent years have made their early diagnosis imperative. Surgical reconstruction is not appropriate for all. Once surgical candidates have been identified a number of reconstructive options exist.

The anterior cruciate ligament (ACL) is the most commonly injured of the four main knee ligaments, with an incidence of 0.38 per 1000 per annum in North America. This accounts for 50 000 reconstructions undertaken annually in the United States (Miyasaka et al, 1991). This figure extrapolates to around 100 ruptures a year in an average UK district general hospital's catchment area (Allum, 2001a). Injuries to the posterior cruciate ligament (PCL), while less common, account for 15–20% of knee ligament injuries, and have proved more difficult to treat successfully (Swenson and Harner, 1995).

CRUCIATE ANATOMY AND FUNCTION

The ACL is a 3.5 cm long band of fibrous tissue which originates from the posteromedial lateral femoral condyle and inserts on the anterior tibial eminence. It is a primary stabilizer of anterior tibial translation, and a secondary restraint to varus or valgus forces and tibial rotation (Swenson and Harner, 1995).

Mechanisms of injury are those which oppose the stabilizing role of the ACL. These include:

- Deceleration injuries, such as those seen in footballers and basketballers who suddenly change direction, especially if the tibia is fixed in internal rotation
- Flexion, valgus or external rotation injuries, such as when a boot gets stuck in the turf, or a ski binding does not release
- Hyperextension, such as the sportsman who lands awkwardly (Patel and Haddad, 2002).

Direct blows to the knee or tibia can also lead to ACL disruption, often associated with damage to other structures (Patel and Haddad, 2002). Clinical examination will reveal an increase in the amount of anterior tibial translation in the injured knee compared with the other side. This can be assessed by means of the pivot shift test, anterior drawer and Lachman's test, this latter being the most sensitive to ACL injuries (Swenson and Harner, 1995). Magnetic resonance imaging (*Figure 1*) is not always necessary but is very helpful when clinical examination does not lead to a clear diagnosis. The integrity of structures which act as secondary restraints to anterior tibial translation (collateral ligaments, posterior horn of the medial meniscus, joint capsule) will influence the amount of pathological laxity demonstrated (Swenson and Harner, 1995).

While ACL injury is relatively common, it has been shown to be relatively poorly detected by clinicians. In experienced hands clinical examination has a 100% specificity and sensitivity for ACL injuries, but as recently as 1996 only 9.2% of injuries were being correctly diagnosed by referring clinicians, leading to an average 21-month delay in diagnosis (Bollen and Scott, 1996).

The PCL originates from the medial femoral condyle and inserts in a depression between the posterior aspect of the two tibial plateaus. It serves as the primary restraint for posterior tibial translation, and as a secondary restraint to varus

Figure 1. Magnetic resonance imaging scan showing ruptured anterior cruciate ligament.

Mr Fares S Haddad is Consultant Orthopaedic Surgeon and **Mr Sam IS Oussedik** is Clinical Fellow, University College London Hospitals, London W1N 8AA

Correspondence to: Mr FS Haddad

angulation and external tibial rotation in a 90° flexed knee (Swenson and Harner, 1995).

Common mechanisms of injury include hyperflexion, with a posteriorly directed force applied to the tibial tubercle, such as a dashboard injury, or a downward force imparted through the tibia; or hyperextension either with or without an associated varus or valgus force, this association increasing the likelihood of multiligamentous injuries (Swenson and Harner, 1995).

The most sensitive clinical test for PCL injuries is the posterior drawer performed with the knee in 90° flexion. The PCL-deficient knee may well sublux in this position, and it is therefore important to recreate the 8–10 mm anterior step-off between the medial tibial plateau and femoral condyle before applying the posterior drawer (Swenson and Harner, 1995).

ACL RECONSTRUCTION

Patient selection

Patient selection for reconstruction following ACL rupture depends on symptomatology, together with expectations of future activity level. The goal of therapy is to prevent further damage to knee-stabilizing structures and the progression to osteoarthritis (OA). An ACL-deficient knee relies more heavily on the secondary restraints to anterior tibial translation, in particular the medial meniscus, such that degenerative tears and the subsequent progression to OA are more common in this group if levels of sporting activities are not adjusted (Segawa et al, 2001). There remains no conclusive evidence linking ACL reconstruction to a decrease in the risk of future OA, although this would appear logical in those patients who continue at a pre-injury level of activity.

Factors to consider include: patient's age, level of activity, future expectations, ability to comply with physiotherapy, degree of laxity and associated injuries (Swenson and Harner, 1995). A survey of British surgeons revealed that the most important factors taken into account in patient selection are the patient's subjective reporting of 'giving way', a positive pivot-shift test and failure of conservative management (Francis et al, 2001).

The risk of requiring late surgery on either menisci or knee ligaments should also be considered. This has been shown to be strongly related to both knee instability, as measured by a KT-1000 (Medmetric, San Diego, USA) arthrometer, and level of sporting activity. Daniel and Fithian (1994) described three groups using these factors: those at low, medium or high risk of future surgery. Those in the latter two groups should be considered for reconstruction at an earlier stage.

Timing of surgery

Once a decision to reconstruct an acute ACL rupture has been taken, the timing of the procedure must be considered. It has been shown that operating during the acute post-injury phase, i.e. 3–4 weeks post-injury, results in a greater loss of range of motion than delayed surgery (Harner et al, 1992). Delaying the procedure until inflammation has resolved and a full range of motion is restored is currently favoured (Francis et al, 2001).

Graft choice

In addition to the ACL's mechanical functions, it also plays an important role in proprioception. The perfect graft would therefore reproduce the biomechanical functions of the ACL and provide the neuromuscular feedback the knee gains from the native ACL (Kaplan and Fu, 2002). Such a graft does not exist at present .

Three types of graft material are available for ACL reconstruction: synthetic ligaments, allografts and autografts. Synthetic ligaments have yet to prove their reliability and their use does not currently extend further than complex injuries and revision surgery, where the supply of autogenous material may be inadequate (Allum, 2001b).

Allografts from human donors avoid the donor site problems associated with autografts. However, the sterilization methods necessary to avoid the risk of disease transmission result in significant graft weakening, and again these are usually reserved for revision or complex procedures.

Autografts are therefore the most commonly used type (Francis et al, 2001). They provoke minimal host reaction and there are fewer concerns with infection. Drawbacks are mainly associated with harvest-site problems.

Autografts

Three sources of graft are commonly used today. The bone–patellar tendon–bone graft (B–PT–B) (*Figure 2*) has many attractive characteristics. It is harvested by removing a bone plug from the middle third of the patella together with the associated patellar tendon and a further bone plug from the tibial insertion.

The initial strength of this graft has been shown to be 172% of ACL (Cooper et al, 1993). The graft strength drops to 20% of this initial value by 6 weeks, although it then climbs to reach 80% of its original strength at 1 year. As the portion of tendon is bounded by bone plugs it is easier to achieve good fixation. However, problems exist with the donor site, with possible complications of patellar fracture, patellar tendon rupture, infrapatellar contracture and anterior knee pain. Reports differ as to the prevalence of anterior knee pain, with figures as high as 80% reported (Rosenberg et al, 1992). Despite these problems, the B–PT–B graft remains the gold standard to which all others must be compared.

Hamstring tendons offer the most common alternative to B–PT–B grafts. The four-strand semitendinosus–gracilis graft (*Figure 3*) has been shown in vitro to have strength equivalent to 270% that of ACL (Hamner et al, 1999). However, lacking the bony attachments of the B–PT–B graft, fixation presents more of a challenge. Concerns over hamstring strength following harvest have been shown to be unfounded (Beard et al, 2001). A number of prospective randomized control trials have been carried out comparing B–PT–B and hamstring grafts (Corry et al, 1999; Beard et al, 2001; Erikson et al, 2001; Beynnon et al, 2002). These have shown no difference in patient satisfaction between the two groups, although reduced extension has been seen in the B–PT–B group (Erikson et al, 2001) and reduced stability in the hamstring group (Beynnon et al, 2002).

The quadriceps tendon graft has recently gained favour. It has the advantage of a bony plug at one end, although there remain concerns over harvest and donor site problems. It remains useful in the revision and complex injury situation.

No significant difference in outcome has been found with the use of either B–PT–B or four-strand semitendinosus–gracilis grafts (Corry et al, 1999; Beard et al, 2001; Erikson et al, 2001; Beynnon et al, 2002). Autograft choice is therefore according to the surgeon's preference, although it may be sensible to avoid the use of B–PT–B grafts in those patients with a history of extensor mechanism problems, or those who will place a particular stress on the extensor mechanism, e.g. occupations which involve kneeling and jumping sports such as basketball. Likewise hamstring grafts should be avoided in sprinters, backward runners and patients with associated medial instability.

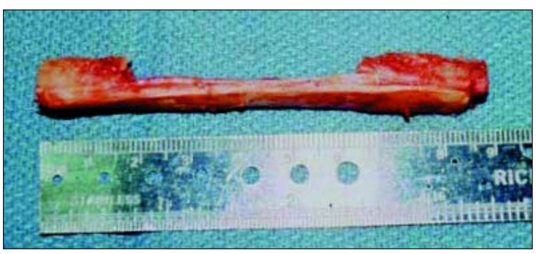


Figure 2. Bone–patellar tendon–bone graft.

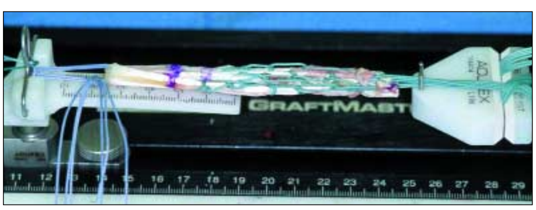


Figure 3. Four-strand hamstring graft using semitendinosus and gracilis.

Graft positioning

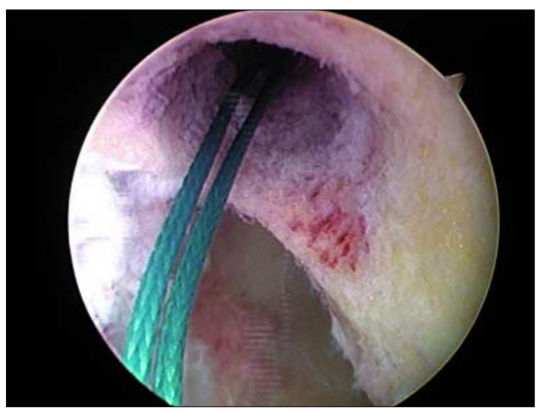
The intact ACL has broad attachment sites over the lateral intercondylar notch proximally and the anterior tibial plateau distally. This means that a number of positions are available for graft placement, all of which could be claimed to be anatomical. The situation is further complicated by the two-stranded structure of the intact ACL. It consists of anteromedial and posterolateral bundles, and stresses within these differ. It is currently accepted that placement at the central or posterior portion of the tibial insertion is favourable. This reproduces most closely the function of the intact ACL, and avoids the problem of graft impingement in knee extension (Amis and Jakob, 1998; Fu et al, 1999). On the femoral side, the over the top position is simulated by creating a tunnel as close as possible to the back of the lateral femoral condyle (*Figure 4*) at the 10.30 position for a left knee and the 1.30 position for a right knee.

The initial graft tension also governs the performance of the graft during knee motion. An initial tension of 44N has been suggested (Fu et al, 1999), although this lacks a scientific basis. Further studies are necessary to investigate this further.

Graft fixation

While the initial strength of autografts has been shown to be more than adequate for the task of ACL replacement, the strength of the neo-ligament construct also depends on the ability of the fixation device to withstand stress. Fixation can be achieved by suspensory or transfixion techniques. The B–PT–B graft allows rigid direct fixation within the bony tunnels, and healing is thought to be by a process similar to fracture healing (Fu et al, 1999). Several fixation devices are available, but the most popular continues to be the interference screw (Francis et al, 2001) (*Figures 5*

Figure 4. Arthroscopic view of the femoral tunnel with only a thin rim of bone behind it.



and *6*). Screw size, degree of divergence from the bone block and direction of insertion have all been shown to affect the ultimate tensile load (Fu et al, 1999). Bioabsorbable screws and staples are also available. Suspensory techniques include the use of devices such as the EndoButton (Acufex, Mansfield, Massachusetts, USA).

Fixation of soft tissue within a bony tunnel, as is the case when using a semitendinosus–gracilis graft, presents a greater challenge. Similar methods are available to those described above (Bickerstaff, 2001).

Comparative studies of graft fixation techniques have shown less stiffness in EndoButton fixation compared to interference screw fixation, although there remains no clinically detectable difference in outcome using either technique (Rowden et al, 1997; Brand et al, 2000; Ma et al, 2004).

Postoperative rehabilitation

Current trends are towards 'accelerated' rehabilitation, as described by Shelbourne and Nitz (1990). This encourages a more rapid return to a full range of motion, while avoiding those movements which place the graft under the most stress (Shelbourne and Nitz, 1990). Use of braces, continuous passive motion and cryotherapy have not been shown to benefit recovery significantly (Bollen, 2001). Despite the use of accelerated rehabilitation techniques, it is still at least 6 months before a return to full sporting activity can be expected.

PCL RECONSTRUCTION

Patient selection

The choice of appropriate treatment for PCL injuries is controversial. Outcomes for both non-operatively and surgically treated injuries have been disappointing (Amis and Jakob, 1998). Accepted indications for surgical reconstruction are (Swenson and Harner, 1995):

- Displaced bony avulsion (open reduction and internal fixation)
- Isolated grade III PCL tear in the young, active patient (reconstruction)
- Chronic symptomatic PCL deficiency (reconstruction)
- Combined ligament injury (reconstruction).

Surgical technique

The range of graft types on offer is similar to that available in ACL repair.

In common with the ACL, the PCL consists of two distinct bundles, anterolateral and posteromedial. The anterolateral bundle is thought to be the more significant of the two, and current techniques are designed to reconstruct this bundle (Swenson and Harner, 1995). However, studies of PCL biomechanics have shown that increased stability can be achieved by reconstructing both bundles (Harner et al, 2000). Such anatomical reconstructions have also achieved favourable results in vivo (Stannard et al, 2003).

Reconstruction can be performed using either the two tunnel or tibial inlay techniques. The former involves passing the graft through appropriately placed tunnels in both the tibia and femur. However, concerns about the amount of stress this was placing on the graft as it swept into the tibial tunnel at an acute angle led to the development of the tibial inlay technique (Berg, 1995). This involves placing the tibial end of the graft in a bony trough formed in the PCL tibial footprint, thus removing the need for an acute turn. Comparison of both techniques has shown no biomechanical difference (Oakes et al, 2002).

Rehabilitation

Current rehabilitation following PCL reconstruction is aimed at minimizing the stresses transmitted to the graft in the early phase of recovery. The knee is therefore immobilized in full extension, placing the graft under the least amount of tension. Unrestricted weight bearing is allowed with the brace locked in full extension, and supervised flexion can begin at 2–4 weeks, but

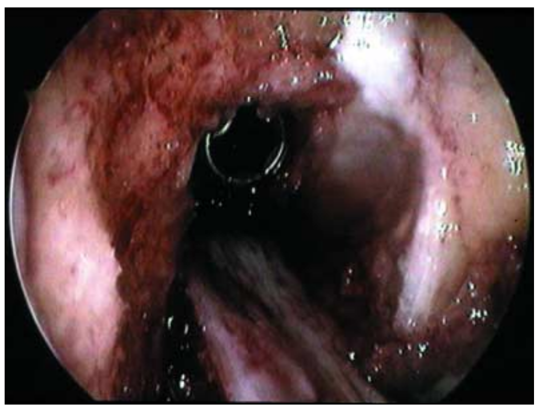


Figure 5. Arthroscopic view of screw fixation of an anterior cruciate ligament graft.

Figure 6. Lateral knee X-ray after anterior cruciate ligament reconstruction using interference screw fixation.

active flexion is delayed for 3 months (Swenson and Harner, 1995).

THE MULTIPLY INJURED KNEE

ACL and medial collateral ligament injuries

The medial collateral ligament (MCL) is a primary restraint to applied valgus stress, and a secondary restraint to anterior tibial translation (Swenson and Harner, 1995). This similarity in function to the ACL results in a common association in injuries to the two structures (Andersson and Gillquist, 1992). The MCL has a good healing potential, and as such responds well to non-operative management (Swenson and Harner, 1995). The current trend in such injuries is to reconstruct the ACL and treat the MCL injury non-operatively, although changes to the rehabilitation programme may be necessary (Andersson and Gillquist, 1992), with a period of bracing required to protect the healing MCL from valgus forces.

ACL and PCL injuries

Good results have been achieved for combined arthroscopically-assisted reconstruction of both ACL and PCL (Mariani et al, 2001; Fanelli and Edson, 2002). Following reconstruction knees regain an acceptable level of functional stability (Fanelli and Edson, 2002).

PCL and posterolateral corner injuries

Injuries to the PCL often involve the posterolateral corner (PLC). This is a complex group of structures which comprises the lateral collateral ligament, the popliteus tendon, the popliteofibular ligament, the fabellofibular ligament, the arcuate ligament, the short lateral ligament and the posterolateral joint capsule. Clinical signs of associated injury to the PLC include increased varus angulation, external tibial rotation and posterior translation at all angles of knee flexion. Tests such as external rotation recurvatum test, posterolateral drawer test and reversed pivot shift can be used for additional confirmation. Injury to both PLC and PCL results in an increase in knee instability, and work has focused on combined reconstructive procedures (Fanelli et al, 1996). This has shown that increased stability is achieved if direct repair of PLC structures is undertaken, together with PCL reconstruction (Fanelli et al, 1996) (*Figure 7*).

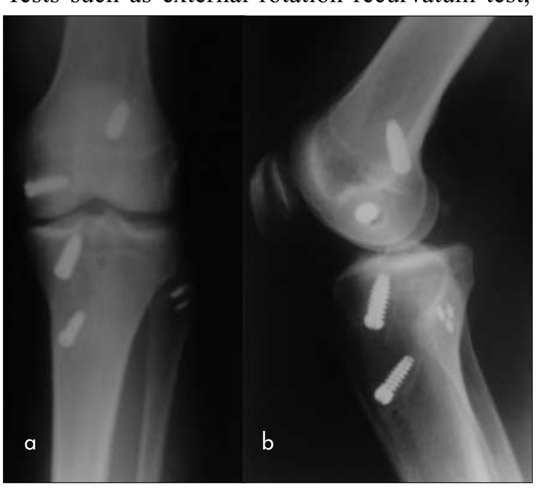


Figure 7. a. Anteroposterior and (b) lateral radiographs showing screw fixation after anterior and posterior cruciate ligament reconstruction and suture anchors in the fibular head from an acute repair of the posterolateral corner.

Meniscal injuries

Meniscal injuries are the commonest associated with ACL rupture, occurring in 40–70% of patients (Shelbourne and Nitz, 1990). The incidence of meniscal injuries increases with the time lapse between injury and reconstruction. A review of arthroscopic findings (Daniel and Fithian, 1994) shows that acute ACL injuries have a 17.8% association with repairable medial meniscal tears, and a 9.6% association with repairable lateral meniscal tears. In the chronic setting these figures change to 21.3% for medial tears and 2.4% for lateral tears. Chronic ACL deficiency has only a 25.5% association with an intact medial meniscus, illustrating the increased risk of meniscal injury in this group.

Perhaps unsurprisingly, those patients who have meniscal injuries requiring partial meniscectomy at ACL reconstruction have a poorer outcome than those with intact menisci (Kartus et al, 2002).

THE FUTURE

Management of knee ligament injuries is currently less than ideal. While most patients can expect a return to a reasonable level of function, treating the multiply injured knee in particular has proved difficult. This has stimulated a great deal of research.

It is postulated that a better understanding of the biomechanics of both the intact and reconstructed ACL will lead to advances in surgical technique and rehabilitation programmes (Fu et al, 1999).

Neuromuscular studies continue to shed new light on the role of knee ligaments in proprioception, balance and reflex control. This may well help to prevent injuries in the future through improved neuromuscular training, and lead towards improvements in graft design (Kaplan and Fu, 2002).

Advances in the field of robotics have lead to the use of computer guidance systems in tunnel placement, helping the surgeon achieve optimal results (Kaplan and Fu, 2002).

Research into biological factors affecting both ligament healing and graft maturation has yielded promising results. Gene therapy has been used to deliver specific growth factors to the injured ACL (Kaplan and Fu, 2002).

CONCLUSION

The treatment of cruciate injuries has evolved over the last decade, such that these injuries are no longer the disastrous events they once were. The success of ACL reconstruction is now well documented. The successful treatment of high profile sportsmen has led to an increased public awareness of this injury, and an associated increased level of expectation as to the outcome of treatment. This makes accurate and timely diagnosis all the more important if an optimal outcome is to be achieved. The multiply injured knee remains difficult to treat successfully, and continued research into this field is necessary. **HM**

Conflict of interest: none.

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KEY POINTS

- The treatment of cruciate injuries has evolved over the last decade, such that these injuries are no longer the disastrous events they once were.
- The success of anterior cruciate ligament reconstruction is now well documented.
- The successful treatment of high profile sportsmen has led to an increased public awareness of this injury, and an associated increased level of expectation as to the outcome of treatment.
- Posterior cruciate ligament reconstruction has fewer indications but can be successful in motivated patients.
- The multiply injured knee remains difficult to treat successfully, and continued research into this field is necessary.