HOW I DO IT

Endoscopic anterior cruciate ligament reconstruction using a four strand hamstring tendon construct

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Disruption of the anterior cruciate ligament (ACL) may result in recurrent episodes of giving way of the knee with the risk of concomitant damage to the menisci and chondral surfaces. Surgical reconstruction for ACL ligament deficiency is aimed at restoring normal knee kinematics, thereby, allowing for return to pre-injury function. Endoscopic reconstruction of the ACL using a four-strand tendon autograft is a well documented, prospectively evaluated methodology. This article outlines the authors' technique and identifies key points of the surgical procedure.

Key words: endoscopic, anterior cruciate ligament, hamstring tendon autograft, rehabilitation

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BACKGROUND

Anatomy

The anterior cruciate ligament (ACL) originates in a broad area lying immediately anterior to the intercondylar eminence of the tibia. It inserts into the most posteromedial aspect of the lateral femoral condyle. It is approximately 33 mm in length and 11 mm in diameter. It receives a blood supply from the middle geniculate artery. It is believed to function as two separate bundles. The anteromedial component is tight in flexion and the posterolateral bundle is tight in extension.

Function

The anterior cruciate ligament has both proprioceptive and mechanical roles. It acts to prevent anterior translation of the tibia upon the femur and works, in conjunction with other ligamentous structures, to control anterolateral rotation of the tibia upon the femur.

Histological examination has identified the presence of proprioceptive nerve endings.[1] Further work is ongoing to delineate the relevance of such nervous innervation.

Mechanism of Injury

The anterior cruciate ligament is most frequently injured as a result of a valgus, external rotation movement in a weight bearing joint. A variety of other injurious mechanisms have also been reported including a valgus directed force in a free-standing limb. There is frequently an immediate effusion secondary to a haemarthrosis and the patient is often unable to continue with the sporting activity. An audible snap is often heard. The patient may be unable to achieve full extension if the knee locks due to an inverted distal ACL stump, displaced bucket handle tear of a meniscus or osteochondral loose fragment.

Incidence

It is estimated that 50,000 knees undergo surgical reconstruction of the ACL in the United States annually.[2] The incidence of acute ACL injury does vary according to the local population. It has been reported to be 38 per 100,000 of population per year with, the highest incidence in the 10-19 year old group.[3] Analysis of injury-related activity has found basketball, netball, soccer and skiing to be the most risk-prone sporting activities. Despite increasing interest in knee injuries, there remains a high incidence of missed lesions. In the UK, the time from injury to diagnosis can be as much as 21 months.[4] Greater clinical awareness and emphasis on appropriate referral of acute knee injuries to specialist units should minimise this potentially deleterious delay.

Natural History

Recurrent episodes of giving way result in abnormal movement of the femur against the tibia. This may lead to injury to the meniscal and chondral structures. With each episode of giving way an effusion may develop. A meniscal lesion may propagate to produce a bucket handle tear with the

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development of a locked knee. In the absence of reconstruction and restoration of knee stability, the patient will learn to modify his behaviour so as to avoid activity, which would be likely to precipitate such injury. Thus, a history of altered or reduced sporting activity is often recorded. Occasionally, the knee becomes so unstable as to impact upon activities of daily living. The long-term result of an ACL deficient knee is a higher than normal association with medial compartment degenerative change. The relative contribution of medial meniscal injury or its removal and arthrotomy/arthoscopy remains unquantifed. Furthermore, the impact of early restoration of knee stability and normal kinematics through surgical intervention and possible preservation of meniscal architecture upon minimisation of such degenerative change is the subject of ongoing study.[5]

PATIENT SELECTION FOR SURGERY

Not all patients with an ACL deficient knee require reconstruction. Surgical reconstruction should be offered to those patients considered at high risk for symptomatic giving way, ideally before injury to the meniscal architecture. Typically, such patients are young and participate in many hours of sport involving pivoting. The anterior cruciate ligament is critical to facilitate correct knee motion during pivoting and sidestepping manoeuvres. Hence, it is required for sports such as tennis, soccer, squash, badminton or other activities where pivoting on a weight bearing limb is required. Despite this, many patients find that even with activities of daily living, the knee remains unstable and these patients will experience recurrent episodes of giving way with concomitant risk of meniscal and chondral injury, in the absence of surgical reconstruction. The principal indication for surgical reconstruction is to allow for restoration of a stable knee. This permits return to a pre-injury level of function. Restoration of normal knee kinematics should minimise the risk of subsequent meniscal injury. The influence of pre-existent knee osteoarthritis upon the decision to proceed to knee reconstruction remains controversial. Reconstruction may further constrain such a knee and generate greater shear force with the inadvertent acceleration of degenerative change.

PATIENT COUNSELLING

Patient Information

A detailed explanation of the rationale for the conservative and operative measures available for the treatment of an ACL-deficient knee should be given. Such a discussion must take place in a relaxed environment allowing the patient opportunity to query particular aspects of proposed care. To assist a fuller comprehension of such information, we provide all patients with a Patient Information Booklet on ACL rupture. This has been approved by the Hospital Trust Ethics committee. It details the mechanism of injury, the immediate post-injury course, the natural history of an ACL-deficient knee and the conservative and operative measures available. A full list of the principal risks of surgery and the expected post-operative course is given.

Timing of surgery

Surgical reconstruction is ideally an elective procedure. Surgery should be deferred until the effusion has resolved, there is full extension and a quadriceps training programme has been commenced. Surgery performed prior to this has been associated with an unacceptably high level of arthrofibrosis. We tend to defer surgery until at least four weeks from the date of initial injury. Rupture of the ACL may be found in association with a locked knee secondary to a displaced bucket handle tear of the medial meniscus. Controversy remains over whether one should proceed with surgical reconstruction of the ACL in the presence of an acutely locked knee. It is not unreasonable to perform meniscal surgery and defer reconstruction until the haemarthrosis has resolved and full extension has returned.

SURGICAL PROCEDURE

Patient Set-up

The patient should be positioned supine lying adjacent to the operated side edge of the table. The tourniquet is placed safely as high in the thigh as possible (Figure 1). It is isolated by means of Sleek (Smith & Nephew) and a U-drape. The limb is supported laterally with a side support and at the ankle with an adapted bolster. This allows for the limb to lie at a lazy 90° of flexion. An esmarch bandage is used to exsanguinate the limb. The area 10 cm above and below the knee is shaven.

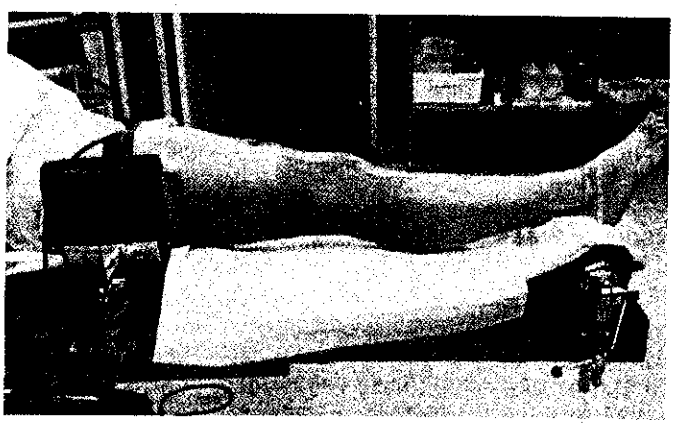

Figure 1: Position of leg with side and foot supports

Clean Air Theatre

All surgery, ideally, should be performed in a dedicated clean air orthopaedic theatre.

Radiographs / MRI on Screen

The patient's most recent index knee radiographs and magnetic resonance imaging (MRI), if available, should be displayed in the theatre upon the imaging screen.

General Anaesthetic

A general anaesthetic is usually given. We tend not to use local anaesthetic blocks. A single rectal dose of a non-steroidal analgesic is given at the end of the procedure. A dose of 1.5 g intravenous cefuroxime is given at least 20 minutes prior to inflation of a high thigh tourniquet. The tourniquet is applied so that the thigh is soft, full knee flexion is possible and there is adequate distal exposure for tendon harvesting.

Examination Under Anaesthesia

The range of movement, the Lachmann test and pivot shift manoeuvre are performed and the results recorded prior to surgery.

Skin Preparation

The leg is prepped from thigh to ankle first using betadine solution and then chlorhexidine preparation. The knee is always prepared first.

Pre-Operative Wash

A pre-operative wash or shower is not recommended. The patient is warned that the presence of a cut/skin lesion or abrasion adjacent to the operative site substantially increases the risk of infection and surgery would be deferred until such lesions are fully healed.

Draping of Limb

An occlusive impermeable stockingette is applied to the lower limb encompassing the foot and distal tibia and enclosed with a crepe bandage. An arthroscopic drape is then applied. This allows for containment and directed drainage of extraneous infusion fluid.

Iodoban for Proximal Tibia

An iodoban adhesive strip, circa 10 cm in diameter, is applied circumferentially around the proximal tibia just below the joint line. This prevents contact between the exposed tendons and overlying skin, thus, minimising the risk of graft contamination.

Arthroscopy

Arthroscopic examination of the knee is performed using high anterolateral and low anteromedial portals (Figure 2).

Route to Follow

Inspection of the joint commences at the suprapatellar pouch. The arthroscope is retracted to lie on the femoral trochlea and rotated so as to fully visualise the retro-patellar surface. It is then gently moved to sweep down into the lateral gutter. The popliteus tendon and lateral edge of the lateral meniscus are inspected. The arthroscope is moved back up the lateral gutter and across into the medial side. It is introduced into the

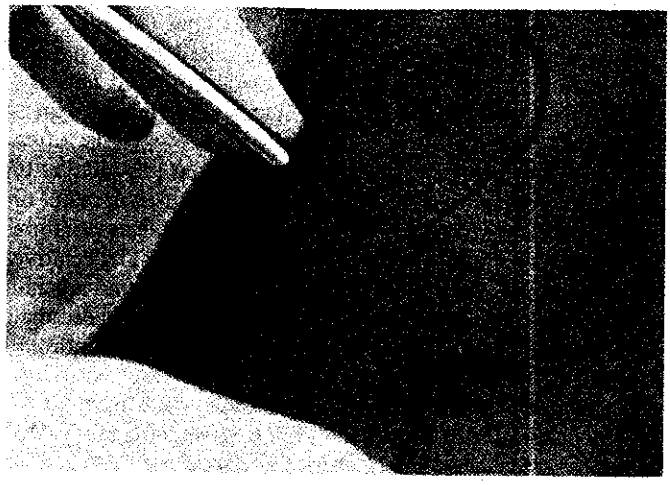

Figure 2: Portal placement

medial compartment and the medial meniscus, medial femoral condyle, tibial plateau and intercondylar notch are viewed. The low anteromedial portal is made after confirming correct placement with the aid of a 16 gauge needle. Sufficient exposure of this portal is made to allow for subsequent atraumatic introduction of the instruments. Surgical treatment of meniscal abnormalities may be performed at this stage. It is common to find a tear of the posterior third of the posterior horn of the lateral meniscus. It has been shown that such non-displaceable lesions may be left alone when the knee is reconstructed.

Achieving a Field of View

Step 1 is to divide the ligamentum mucosum and, hence, allow the fat pad to fall anteriorly. This creates a better field of view. The site of rupture of the anterior cruciate ligament is recorded. The residual tissue is removed with the aid of chompers. It is critical to commence the notchplasty at the most inferior, anterior aspect of the notch adjacent to the articular surface. A curved, upward sweeping movement allows for the removal of adherent fibrous tissue from the wall in a 'Peel-Pak' fashion. The frond of tissue often overhanging the central intercondylar notch is thus removed, again markedly improving vision. The densely adherent posterior remnant attachment of the proximal origin of the ACL is removed with the currette. The wall is smoothed off with a 5.5 mm full radius power shaver (Dyonics, Smith & Nephew, Andover). We have found the use of a window lock facility useful. This prevents inadvertent suction of intra-articular tissue. At this stage, the distal base of the ACL is removed with the aide of the power shaver. This will allow for later accurate placement of the tibial jig.

Identification of Posterior Margin

The posterior border of the femoral intercondylar notch is confirmed visually with an arthroscopic probe. It is critical to avoid mistakenly identifying the resident's ridge. A spike is then used to indent a point 5 mm anterior to the posterior margin and this should lie at 11 o'clock (right knee) or at 1

o'clock (left knee). The line of the shaft of the spike assists in visual confirmation of such a position.

Full Flexion of Knee

The knee is fully flexed. Under direct vision, a 4.5mm drill is introduced and laid to rest on the previously made osseous divot. The drill is directed 30° off the longitudinal axis of the limb, and dropped 10° off the horizontal. The drill is then passed through the femur and exits the anterolateral femoral cortex. The drill is withdrawn; the knee brought out to 90° of flexion and the tunnel inspected to confirm correct placement. This procedure can be performed in a stepwise manner with the aid of a femoral offset jig, wire and cannulated 4.5 mm drill, again with the knee in full flexion.

Graft Harvesting

We use the gracilis and semitendinosus as material to fashion a four-strand tendon construct. The relative merits and long-term results of reconstructive surgery with either the hamstring tendon or patellar tendon autografts have recently been prospectively evaluated.[6] A 3 cm longitudinal incision medial to the tibial tuberosity is made (Figure 3). This should be centred over the distal insertion of the pes anserinus. Care is taken to diathermy the constant venous plexus lying at the distal end of the wound. Using a small swab attached to an artery clip, dissection deep to the fat is carried out both medially and superiorly. A curved retractor is inserted and a curved incision, 1 cm in length, is made along the superior margin of the pes into the sartorius. Care is taken to avoid damage to the saphenous nerve. Through this incision, Mackenrodt scissors are introduced and opened so as to split and create a window within the superior border of the sartorius allowing for access to the tendons of gracilis and semitendinosus.

Identification of Gracilis / Semitendinosus

The gracilis tendon lies the more superior of the two. It is retrieved with the aid of a curved Moynihan clip. The tendon is brought into the wound and using an arthroscopic probe more proximal vincular attachents are identified and used to achieve distal traction upon the tendon. There is rarely more than one weak vincular attachment to the gastrocnemius muscle belly.[7] Only after confirmation of the absence of such obstruction to the passage of a tendon strip is it used. The surgical assistant places his/her hand upon the calf and by applying traction longitudinally, exclude the presence of remaining tendinous attachments by the absence of calf tethering. A similar technique is used for the semitendinosus tendon. This tendon traces a path more transversely at first and often has substantial distal accessory attachments, which again must be removed prior to use of the tendon stripper. The Linvatec (Linvatec, Largo, Florida) tendon harvester is used and this allows for a defined length of tendon to be retrieved (Figure 4).

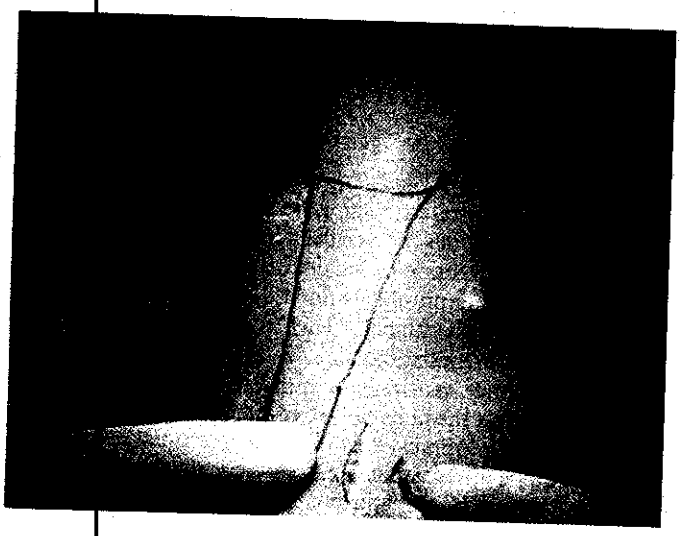

Figure 3: Graft harvest incision

Figure 4: Graft harvest with tendon stripped

Removal of Accessory Attachments

Both tendons should now lie free outwith the wound. The Mackenrodt scissors are opened out. The inner side of one limb of these scissors is used to remove excess muscle. The sartorius tendon is laid upon the semitendinosus and folded over so as to allow for tubularisation of the distal construct. The 22 cm combined tendons are folded over two 5 ethibond (Ethicon, Edinburgh) sutures, thereby, creating a four-strand hamstring tendon graft 11 cm in length. The end closest to the tibia is first sutured together using 1/0 vicryl. The construct is pulled taut and the 2.5 cm of tendon construct, adjacent to the leading sutures, is similarly sutured with 1/0 vicryl (Figure 5). The diameters of both the proximal and distal ends of the four-strand hamstring graft are determined using a standard block with orifices of pre-determined diameter (Figure 6). This allows for selection of the appropriate reamers for the femoral and tibial tunnels. It is critical to allow adequate room for passage of the graft but not to oversize the tunnels, thereby, minimising the compressive influence of the interference screws. A point 30 mm from the free end of the graft is marked with a pen to allow for confirmation of final docking of the graft within the femoral tunnel. The graft

remains attached to the distal periosteal area and folded into the tibial wound, thereby, minimising the potential for falling onto the floor or other contamination.

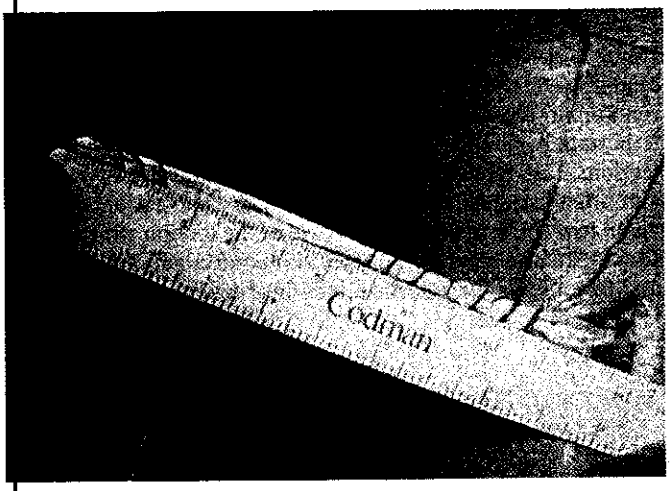

Figure 5: Folded tendons with completion of whip stitches

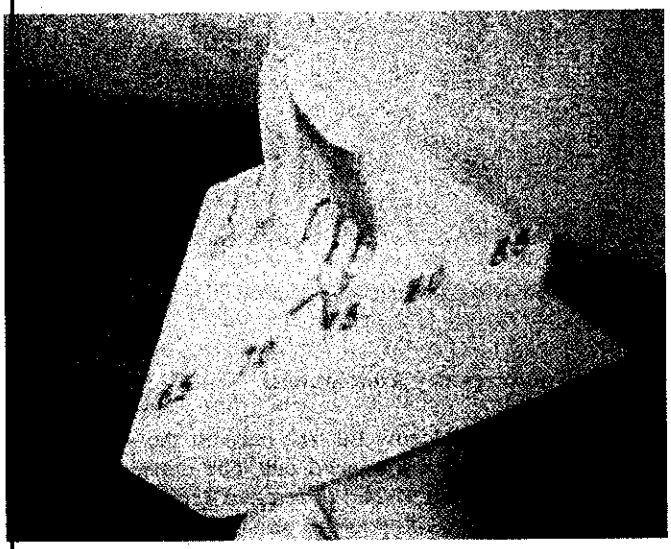

Figure 6: Graft diameter determination

Femoral Tunnel Positioning

The arthroscope is reintroduced into the knee. The intercondylar area is cleared of clotted blood with the shaver. The previously fashioned 4.5 mm femoral tunnel is found and the knee fully flexed. A Beath pin is introduced through the anteromedial portal and inserted into the femoral tunnel (Figure 7). It should exit outside the superolateral thigh skin. With the knee in full flexion, a cannulated RCI femoral router of the appropriate diameter is fed over the pin and passed through the anteromedial portal. The router creates a femoral tunnel 30 mm in depth and of the appropriate diameter. Care must be taken to avoid damage to the posterior cruciate ligament during this part of the procedure. With the knee held flexed, the router is removed and a doubled nylon suture is partially introduced into the eye of the Beath pin. By pulling the pin out through the anterior thigh proximally, the nylon suture is introduced into the anteromedial portal, through the femoral tunnel and out through the anterior thigh. This will subsequently be used to pull the leading sutures. It is folded upon itself and held with a clip over the anterior thigh.

Figure 7: Full flexion of knee with guide wire in femoral tunnel in preparation for RCI femoral router

Tibial Tunnel Positioning

The knee is then brought out to its resting flexed position and the residual distal anterior stump is removed with the power shaver. The leading limb of an Acufex tibial jig is introduced through the anteromedial portal. The pointer arm is positioned so as to rest at a point which lies 2/3 back along an imaginary line drawn between the anterior horn of the lateral meniscus and the medial tibial eminence. The guiding arm is advanced within the ratchet and the length of the tibial tunnel is read off the guide. The angle of the jig should be set at 45°. Care must be taken to avoid impinging upon the pes anserinus during the preparation of the tibial tunnel. A Beath pin is then introduced under power into the joint. It should exit at the point of the jig lead arm and should not touch the posterior cruciate ligament. A 4.5mm cannulated drill is passed over this wire and it should not encounter any significant resistance. The intra-articular portion of the wire must be visualised at all times within the joint. This should prevent inadvertent misdirection of the drill. The drill is removed and a RCI router of the pre-determined diameter is used to form an impacted tibial tunnel. This reamer acts to impact cancellous bone against the side walls of the tibial tunnel. It may be necessary, particularly in hard bone, to remove the reamer and clean the ends before re-passing it over the guide pin. Again, the wire must be seen within the joint at all times. The guide pin and reamer are removed. A power shaver is introduced from below and enables removal of extraneous debris and smoothing of the intra-articular aperture of the tibial tunnel. An 8 mm stopper is plugged into the lower end

of the tunnel allowing for fluid distension of the joint. The power shaver is then introduced into the joint through the anteromedial portal and the base of the ACL stump at the aperture of the tibial tunnel is again smoothed off. This should minimise the risk of late development of a cyclops lesion or graft capture during passage. The nylon loop is released from the anterior thigh. A pair of grasping forceps is passed into the joint along the tibial tunnel and the nylon loop retrieved and retracted distally. This nylon loop should pass along the tibial tunnel, into the joint, into the femoral tunnel and come to lie on the anterolateral thigh.

Passage of the Graft

The first 6 cm of the four strands of the free vicryl leading sutures from the graft are passed within the nylon loop. The assistant pulls the nylon suture proximally along the line of the femoral tunnel in a controlled but brisk manner (Figure 8). The four strands of vicryl should now lie free on the thigh and the nylon suture can be discarded. The graft is pulled into the joint and into the femoral tunnel under direct vision. Gentle distal traction is maintained on the graft so as to prevent bunching up. The knee is fully flexed and full docking of the graft within the tunnel is confirmed by the alignment of the 30 mm mark on the graft lying adjacent to the intra-articular femoral aperture.

Femoral Graft Fixation

Figure 8: Looping of the leading end pull-through sutures into the nylon loop

The knee is held fully flexed. A blunt ended guide pin is passed from the anteromedial portal to lie anterior to the graft. It should pass easily between the wall of the femoral tunnel and the graft. Resistance may be possible due to the pin inadvertently coming to lie between the whip stitches and the graft. This would tend to prevent proper passage of the interference screw. In this case, the pin should be removed and repassed. Only with the knee in full flexion, proximal and distal traction applied on the graft and confirmation that 30 mm of graft lie within the femoral tunnel, can the cannulated screw be introduced through the anteromedial portal. We use a standard 7x25 mm RCI interference screw for the left knee and a reverse thread screw for the right knee (Figure 9). The rotating action of these screws will act to push the graft to the back of the femoral tunnel thereby recreating an anatomical position. The screw head should be buried up to the internal aperture of the tunnel (Figures 10, 11 & 12).

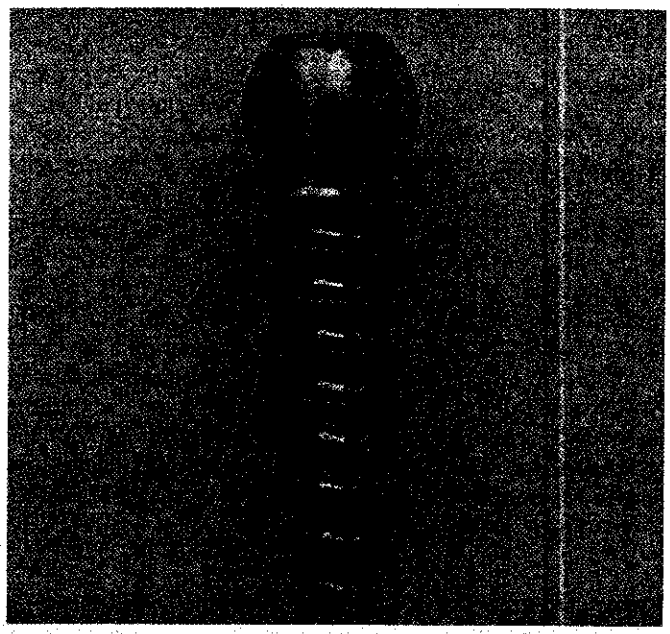

Figure 9: Interference screw

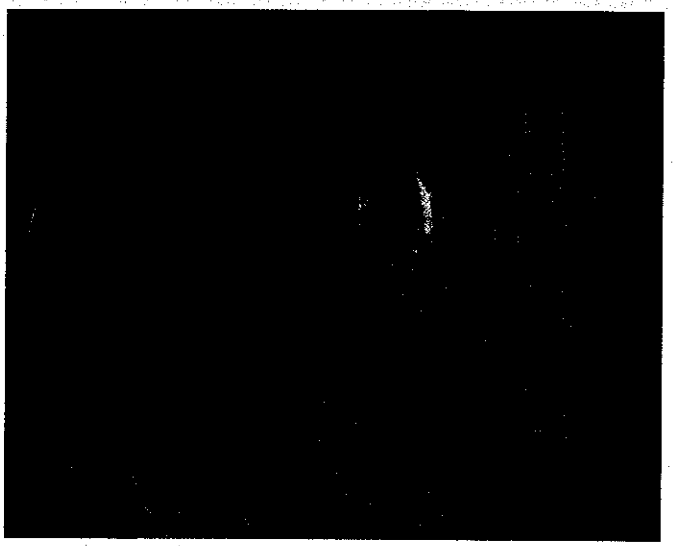

Figure 10: Docking of the interference screw into the femoral tunnel placing the graft posteriorly

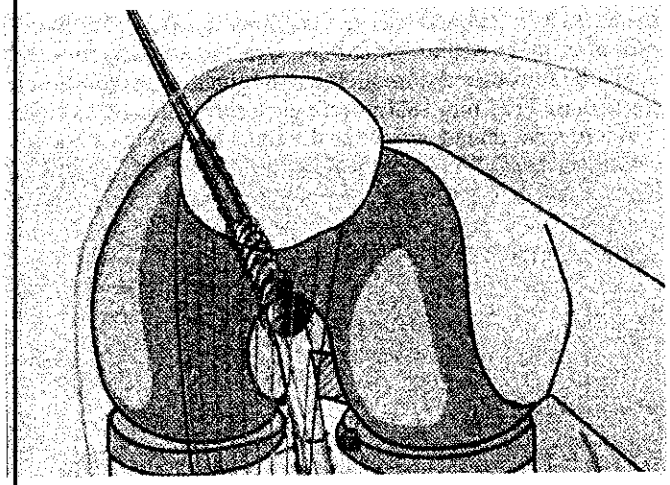

Figure 11: Schematic illustration of graft fixation

Tibial Fixation

The knee is returned to 90° of flexion. Distal traction is maintained on the graft by means of a surgical clip. The tendon is then wound tightly round the clip and held. A guide pin is introduced along the tibial tunnel posterior to the graft. A standard RCI interference screw is passed until a firm grip is obtained. Once the screw has engaged the tibial tunnel, whilst maintaining full tension, the knee is extended and the screw fully inserted to sit in the bony tunnel (Figure 12). This eliminates the risk of capturing the joint. Use of an accessory staple has not been found, in our hands, to increase stability even in poor quality bone.[8]

Figure 12: Tibial fixation

Final Steps

The knee is copiously lavaged with saline ensuring that all compartments are irrigated. The wounds are infiltrated with a solution of 0.5% marcaine and 1% adrenaline. The tibial wound is closed using subcuticular vicryl and steristrips are used for the portals. A drain is not used in either the knee or the graft donor site. Mepore dressings are applied. A temporary loose fitting wool and crepe bandage is applied and the leg maintained straight with a Raymed splint. A cold compression cryocuff is used in the first 2 hours after surgery to control pain and minimise swelling. A further intravenous dose of antibiotics is given at six hours after surgery. Patients are allowed home with full instructions when able to straight leg raise, flex comfortably to 90° and have confidence using crutches.

TECHNICAL TIPS

Transection of the Tendon

Every effort should be made to obtain an adequate length and diameter of tissue from the gracilis and semitendinosus tendons. Distal transection may occur as a result of incomplete release of the vincular attachments and diversion of the stripper into the tendon and premature division. The tendon stripper should be advanced in a controlled manner without the use of excess force. Confirmation of the absence of retained vincular attachments may be made by distal traction upon the tendon and palpating the medial gastrocnemius belly. Free movement of the tendon will be associated with no traction in the gastrocnemius muscle. Insufficient tendon tissue is an indication for harvesting of the patellar tendon as a graft structure.

Femoral Tunnel Blow-out

Prevention is better than cure. Certain authors have advocated the use of a femoral 5 or 6 mm offset jig. This is often difficult to introduce through the medial portal. Nonetheless, femoral posterior wall blow out must be recognised prior to attempting femoral fixation. Reconfirmation of correct siting

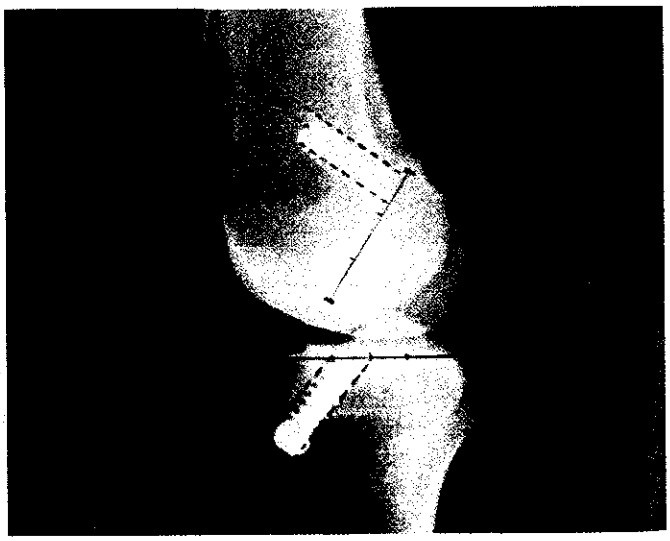

Figure 13: Post-operative lateral knee radiograph identifying screw placement

of the femoral tunnel is important. If correct, one can convert to endobutton proximal fixation.

Poor Visualisation of the Femoral Tunnel

This is often due to incomplete removal of the tissue at the anterior aspect of the lateral intercondylar notch. One must return to this area and clear the notch with the aide of the arthroscopic shaver and currette.

Cyclops Lesion

The tibial origin of the ACL should be removed so as to minimise the risk of late development of a cyclops lesion.[9] The aperture of the intra-articular component of the tibial tunnel must be cleared of tissue. This can be achieved with the insertion of the arthroscopic shaver both within the tibial tunnel from below and through the medial portal. After fixation of the graft, the knee should be fully extended and the intercondylar area fully visualised so as to confirm the absence of impingement.

REHABILITATION

Early Rehabilitation

The patient is returned to the ward. A cold compressive unit is applied over the knee. The patient should be safe with crutches. Anteroposterior and lateral radiographs of the index knee are performed prior to discharge. Full instructions on how to obtain help if needed and safe knee movements are provided. Outpatient physiotherapy is arranged for the immediate post-operative period.

Goals of Physiotherapy

The principal goals of physiotherapy are to progressively and safely achieve the following: diminish post-operative pain and swelling, restore a full range of motion; maximise muscle tone and strength, maintain and develop aerobic conditioning; proprioceptive retraining, thus allowing a safe return to work and to sporting activity as soon as possible. Early return of controlled movement of the knee is critical to a good outcome. This has been validated in experimental studies.[10] Close supervision of the patient's progress should allow for the correct direction of such instruction. The pace of progress will depend on many variables. These include the age of the patient, co-existent morbidity, associated knee pathology, chronicity of the injury and the requirement for pre-operative brace support for medial collateral ligament injury.

Principles of Physiotherapy

- The key principles of physiotherapy must be applied during the rehabilitative phase. And include the following:
- Early mobilisation enhances articular cartilage nutrition, retention of bone mineralisation and reduces the risk of arthrofibrosis.
- Progressive controlled loading of the graft provides a stimulus for collagen healing and regeneration. It is very difficult to inadvertently overload a graft placed in an isometric and anatomic position.
- Weight bearing should progress as rapidly as pain permits.
- Graft fixation allows for immediate aggressive mobilisation.
- Open chain exercises may cause significantly more anterior tibial displacement (and thus force upon the graft), compared with closed chain activities.

FOLLOW-UP

Physiotherapy is commenced upon return to the ward. An radiograph of the knee is carried out in the early post-operative period (Figure 13). Prior to discharge, the patient is given a follow up appointment for further physiotherapy. Urgent medical contact details are provided in the event of an emergency. Wound inspection is performed about 14 days after surgery. Further clinical review at made at six weeks and six months after surgery. Final review is at one year after reconstruction. Patients are allowed to return to full competitive sport after six months, upon confirmation that the knee is stable. The use of scoring systems and KT1000 instrumented measurements are reserved for those patients entered into a trial.[11] Such information is collected independently by knee physiotherapists.

KEY POINTS

Patient selection is critical

Surgery should be performed by an appropriately trained surgeon

Endoscopic surgery minimises soft tissue dissection potentially allowing for earlier rehabilitation

The use of a four-strand hamstring tendon autograft is an acceptable alternative to the patella-tendon graft and minimises the risk of extensor mechanism dysfunction.

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