Rationale for the preference of bone-patellar tendon-bone ACL grafts

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Abstract

ACL reconstruction is most commonly performed with bone-patellar-tendon bone or hamstring autograft. We present the argument in favour of the BTB graft and describe the operative technique used.

We believe the BTB graft offers the most stable knee post reconstruction and this therefore is most appealing in the elite athlete and the general population.

Donor site morbidity can be minimized with simple techniques such as double incision graft harvest and bone grafting of the patellar and tuberosity defect

Function, Mechanism of Failure and Anatomy

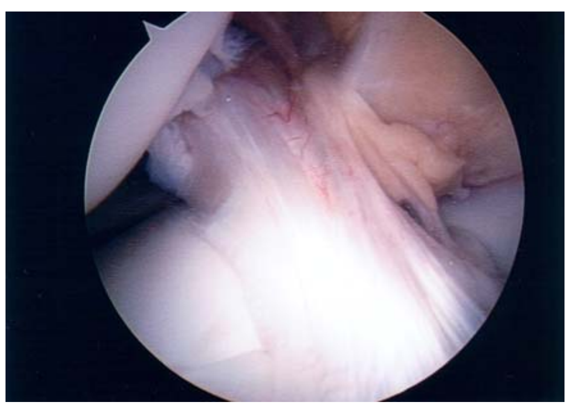
The primary role of the ACL is to control the “screw home” mechanism of the knee, by which the tibia rotates on the femur during terminal extension to ‘slot in’ to the fully extended position of the knee. The secondary functions of the ACL are control of AP glide at 90 degrees flexion and prevention of hyperextension. Failure of any of these three mechanisms results in ACL rupture. Failure of the screw home mechanism occurs between 0 – 25 degrees when the knee gives way on rotation. Thus the most common cause of ACL rupture is internal rotation of the tibia during the side-stepping or cutting maneuver with the knee between 0 and 25 degrees. This mechanism also occurs when one lands from a jump with a simultaneous rotatory landing force. Hyperextension or contact forces are uncommon mechanisms of injury, though it is possible to rupture the ACL with an over-reaction of the quadriceps particularly when the knee is at 90 degrees. Many authors believe that ACL lesions occur when there is lack of co-contraction of the hamstring/quadriceps muscular sleeve, increasing the forces through the static stabilizers of the knee.

Knee flexed internally rotated at 0 - 25 degrees

On field Lachman Test…Ruptured ACL

Direct injuries to the lateral aspect of the knee where there is rupture of the medial collateral ligament, avulsion of medial meniscus and rupture of the ACL often with a radial tear of the lateral meniscus is the “unhappy triad” originally described by Dr O’Donohue. Importantly the meniscus is avulsed, not torn and can always be preserved in this mechanism of injury.

The ACL attachments are a large footprint on the intercondylar eminence of the tibia and stretch proximally to the posterior juxta-articular area on the lateral femoral condyle.
Due to the posterior offset of the femoral condyles the attachment of the ACL is the most posterior structure in the normal anatomical position and arthroscopically is at “1:30 o’clock” in the intercondylar notch of the right knee and at “11:30 o’clock” in the left knee. It is important to note these anatomical attachments so as to avoid a common mistake in ACL reconstruction often made when the femoral attachment is performed at “12 o’clock”. This is approximately 10-12mm anterior to the true attachment of the ACL and can lead to failure of reconstruction.



Proximal attachment ACL: Posterior at 1:30 ’o’clock

Good Tunnel and Screw Position

Vertical Tunnel Position

Treatment of Anterior Cruciate Ligament Rupture

Treatment can be divided into acute repair, acute repair with augmentation and reconstruction of the ACL. In very few cases the ACL can be avulsed from the lateral femoral condyle or from the tibia with a bone fragment. In these cases successful acute repair can be performed. It is also possible to reinforce the avulsion or the tear of the ACL with an augmentation with the semitendinosus and gracilis tendons and this is the preferred method of treatment in the pre-pubescent children. In both these cases repair must occur before the ACL dissolves and thus is a matter of relative urgency in order for a successful result to be achieved.

The four types of ACL reconstruction are:

1. bone-patella-bone reconstruction
2. quadruple hamstring reconstruction
3. quadriceps tendon reconstruction
4. allograft reconstruction: BTB, hamstrings, Achilles tendon, quadriceps.

Of the above, allograft reconstruction is rarely performed in Australia while quadriceps tendon reconstruction is not an accepted method of treatment. Allografts obviously remove the problem of donor morbidity, but at the cost of potential infection, rejection and failure of integration; the use of allografts is more common in the US and UK particularly in the multi-ligament or revision setting.

Thus the debate is centered on the advantages and disadvantages of bone-patella-bone reconstruction and the quadruple hamstring reconstruction with multiple surveys in Australia and overseas showing no consensus yet as to the graft of choice. [3]

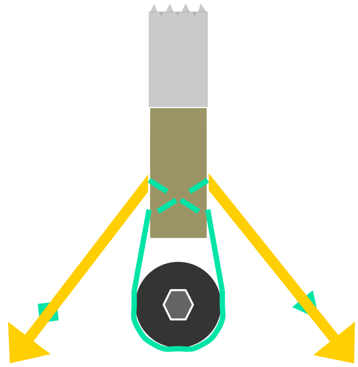
The arguments for Bone-Patellar Tendon-Bone graft

1. Superior fixation

The main advantages of BTB reconstruction arise due to it being the most physiological reconstruction. The native tendon is already connected to the bone blocks and bone-to-bone (block-to-tunnel) union occurs within six weeks. While Hamstring tendon connection is an indirect one, made between the tendon and newly woven bone by connective tissue called Sharpey's fibres. There is also strong evidence from animal studies to suggest that due to a variety of biochemical and biomechanical insults hamstring healing of tendon graft in the bone tunnel is delayed and weaker. [5] Fixation of the hamstring graft within the femoral tunnel with a screw can also compress and squash the tendon fibres; it does not always guarantee the formation of Sharpey's fibres and tendon healing in all cases. Proponents of hamstring grafts have realized this and have developed reverse thread screws to attempt to solve this problem.

In the BTB graft, the bone plug in the femoral tunnel can be fixed such that the tendon is flush with the outlet and does not suffer the "windscreen wiper" affect that occurs when the hamstring tendon rubs over the rim of the outlet of the tunnel.

The other advantage is that it is possible to put more tension on the bone-patella-bone graft by using the "block and tackle" technique on the tibial bone plug. This rigid fixation means there is no intra-tunnel loss of tissue or possible slippage/non union of tissue.



"Block and Tackle" Technique: allows rigid fixation of tibial bone plug to tibial post screw

The most conceptually secure way to fix a quadruple hamstring is with a Transfix bar into the femur as you do not get the effect of damage to the tendon with an interference screw. However, you do have the disadvantage of the "windscreen wiper" effect as well as increased tunnel size which is more common in hamstrings than in patella tendon reconstructions. [1, 6, 12] This increased tunnel expansion may be indicative of non-healing of the tendon in the tunnel and excessive movement.

Fixation distally of hamstrings is still often performed with staples, however, if you attempt to use an interference screw fixation in the tibia there is a tendency to push the graft towards the joint as the screw is inserted despite simultaneous pulling on the tendon. The other disadvantage of interference screw fixation in the tibia is that there is soft tibial bone and the screw can migrate in this soft tibial bone. For this reason sole use of interference screw fixation is not recommended in the tibia for BTB reconstruction as the screw can migrate and the graft bone block can be pushed proximally to the joint.

Screw Migration

Interestingly if the interference screw is a satisfactory method of fixation why does there seem to be a continuing scientific search for new methods of hamstring fixation?

2. Less stretching

It has been demonstrated in numerous RCT's and meta analysis that there is increased laxity on both clinical examination and arthrometer testing in those patients that have had a hamstring reconstruction compared to those that have had a patella tendon reconstruction. [6, 7, 10] These studies all show less absolute AP movement with the BTB graft, but within the power of these studies there is no statistically significant difference compared to the Hamstring grafts. Feller et al demonstrated high rates of failure of bone filling-in of the graft tunnels in the hamstring groups which did not occur in the BTB group. [6] More recently, Bizzini et al showed hamstring reconstructions to have significantly greater knee joint laxity on arthrometer testing when compared to BTB reconstruction. [4]

This may be attributed to a tendency for hamstring tendons to stretch and that it is not possible to achieve tight fixation as with the block and tackle method mentioned above. There is also a practice of tightening the hamstring graft at 30 degrees flexion with the prediction that the graft will stretch, therefore the question must then be asked why use a graft where stretch and laxity is an expected outcome?

The basic physical properties of stretch mean that the shorter the tendon the less stretch that can occur. This is one of the disadvantages of using the Endobutton because any slight stretch per unit length will be amplified with a longer graft construct resulting in greatly increased laxity.

3. Reduced re-ruptures

Though RCT's have not shown the difference in re-rupture rates to be statistically significant, it is our experience, particularly in elite athletes that hamstring grafts more commonly result in re-tears. The major cause of re-rupture is of course graft independent and is due to mal-positioning of the bone tunnels.

Due to the increased joint laxity and a rate of ACL rupture in female athletes 2-8 times that of males [2] some studies have advised caution with the use of hamstring reconstruction in females. [4] It is our belief that there should not be a distinction based on sex or level of activity; if the patella tendon is the best reconstruction for the elite athlete then it should be offered to all patients.

4. Morbidity.

It is widely accepted that patella tendonopathy, disturbance of sensation over anterior knee and kneeling pain are more common after BTB grafts [1, 7 ,8 ,9, 10] though this rarely affects return to sport or activity that does not involve kneeling.

It is our practice and studies suggest that by taking cored cancellous bone blocks from core reamers and grafting the patella and tibial tuberosity donor sites, anterior knee pain is reduced. [11] Also by using a two incision technique when harvesting the patella tendon graft, preservation of the infrapatellar branch of the saphenous nerve may contribute to the prevention of anterior knee sensory disturbance [11]

It is worth remembering that chronic hamstring pain occurring after semitendinosus and gracilis harvest whilst rare can be disabling. By removing two hamstrings the H:Q ratio will also decrease which may lead to further instability.

5. Late onset arthrosis.

It has recently been suggested that following ACL reconstruction there is an increased risk of radiological degenerative joint disease with BTB rather than Hamstring grafts at 7 years post surgery. [9] This raises the question as to why should the hamstring graft have chondro-protective properties? One suggestion may be that the increased laxity of the hamstring graft may be beneficial in preventing the onset of osteoarthritic change. Importantly, though not statistically significant, there was an increased incidence of graft rupture in the hamstring group compared to BTB group (4 vs 9 $p=0.15$). Interestingly there was also an increased rate of contralateral rupture of the native ACL in those patients who had received the BTB graft. [9] It is our belief that this suggests patients receiving hamstrings are less likely to return to full activity and therefore the hamstring reconstruction is not functioning sufficiently for the subject to return to an injury-prone environment. This means they are not able to participate at a higher level of sport and hence function better. It also should be noted that this study was not an RCT and similar results have not been matched by other authors as yet.

Follow up of anterior cruciate reconstruction.

This patient population is highly mobile (often due to employment moves) and complete follow-up is extremely difficult. This has been attempted by the senior author (MC) on a number of occasions and even with due diligence, having access to many methods of tracing, we have only been able to contact approximately 75% of patients. These patients are usually active, in full time employment and often with young families; taking time to return questionnaires and return to clinic for clinical and radiological examination when their knees are functioning well is not in their interest.

The other difficulty with assessing anterior cruciate laxity is that maximal KT1000 has been found to be unreliable; it depends on the strength of the person doing the test. It is generally acknowledged that a totally independent person should be performing the jerk test or the lateral pivot shift which is the true indicator of anterior cruciate success rate in reconstruction. Accurate use of the lateral pivot shift or jerk test is dependant on significant experience of the examiner and of full cooperation of the patient.

The ultimate aim of reconstruction of the anterior cruciate ligament is to anatomically restore the function of that ligament to allow return to pre-morbid function and level of play. We believe this is best done with a graft associated with the lowest chance of future stretch.

Thus the true test of anterior cruciate reconstruction is the number of patients that return to their previous activity or level of play; this is particularly sensitive with the elite athlete.

In the amateur population, where all RCT's have been performed, it is impossible to account for voluntary drop-out of high risk sports at a future date. It is also impossible to properly assess how much graft function caused this drop out. In other words, if a patient is 5 years post-ACL reconstruction and no longer plays contact sports (but did for a year or two post surgery) was the reconstruction primarily responsible for the reduction in sporting activity or was it patient choice for whatever reason – e.g. patient older, less time from work, more family demands on time……etc.

The return rate and re-rupture rate in elite athletes (NRL players, AFL players, international rugby players, Olympians) is a better true guide to graft survival, as the drop out rate from professional sport (other than age-enforced retirement) is very low. Those that drop out prior to their predicted sporting lifespan are usually due to injury (e.g. graft failure). Graft choice for ACL reconstruction within the professional athlete population is more commonly a BTB than Hamstring graft[3].

The senior author (MC) has performed BTB reconstructions in over 60 International level athletes with only 2 known reconstruction failures in this group; this is a lower rate than other authors have reported even in the amateur population.

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<u>2006 Operative Protocol ACL reconstruction</u>

INDICATIONS

Tear of ACL diagnosed clinically +/- MRI diagnosis.

Instability, giving way, knee pain and inability to participate in sporting activities

PRE-OPERATIVE ASSESSMENT

Dynamic extension, Lachman + jerk tests

SET-UP

Supine position

Thigh tourniquet (inflated with knee flexed)

Lateral thigh support: vertical support at level of tourniquet

Foot support to maintain knee flexed 90°

Knee prepared + draped

Disposable full-length stockinette, pulled up to just below tibial tuberosity

Disposable ACL drape

2 saline inflows

INCISION

Two longitudinal incisions of 2cm for taking the graft

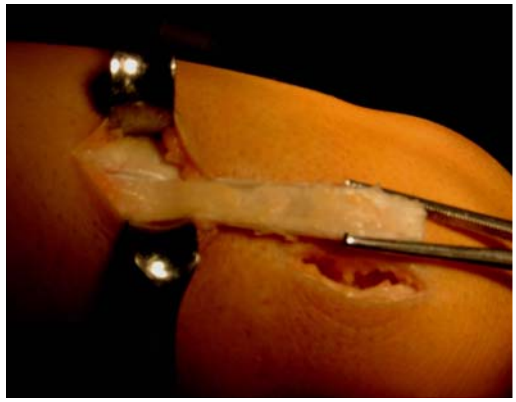
Upper incision placed at the distal aspect of the patella and the lower just medial to the tibial tubercle

Arthroscopy portals: high anterolateral, low anteromedial (close to tendon) + superolateral (2nd inflow); the lower patella tendon incision is also used.

PROCEDURE

HARVESTING OF GRAFT

The central one-third of the patellar tendon is identified (there is a constant blood vessel at the junction of the middle and lateral thirds)
Paratenon and bursal tissue is cleared off the anterior surface of the tendon
The bone blocks are marked out by incising the periosteum over the lower patella and tibial tubercle, using a No.15 blade
A trapezoidal-shaped bone block (approx. 20x10mm) depending on the size of the patient, is removed from the patella, using a combination of a micro-saw and osteotomes
The tidemark on the saw-blade is used to judge the depth of the saw-cuts (8-10mm)
Osteotomes are used longitudinally to create stress risers around the bone block
The patellar tendon is incised subcutaneously using a No.10 blade, ensuring that a constant width graft is harvested
The patellar block, held within Kocher forceps, is passed down under the skin bridge into the distal wound
The tibial bone block (approx. 25x10mm) is marked out by incising the periosteum down as far as the ‘blue’ area
A stress riser at the top of the tuberosity is made using an osteotome held transversely at an angle of 10-20° above horizontal
The bone block is removed using a combination of a micro-saw and osteotomes



Harvesting Graft

Remove all fat and excess soft tissue

The patellar and tibial bone blocks are then fashioned into appropriate bone plugs

Measure the dimensions of both plugs (diameter and length) and the overall graft length

The femoral lead (bone plug) must be of equal or smaller diameter (than the femoral tunnel) and is fashioned into a bullet shape at the leading edge in the direction of graft passage. The femoral lead is normally fashioned from the tibial bone block as this has a more well defined bone-tendon interface than the patellar end. The plugs should have any bony ridges nibbled away.

The intra-articular length of the graft should measure about 40mm

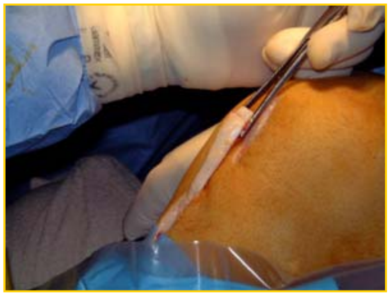
Two evenly-spaced AP drill holes are made in each plug

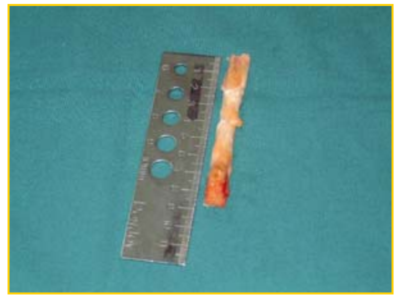
Femoral plug: proximal 5 Ticron (looped and loop snugged down) + distal 5 Ethibond (unlooped)

Tibial plug: proximal 5 Ethibond (looped) + distal 5 Ticron (looped) – the loops provide a block-and-tackle arrangement – see diagram – to allow for graft tensioning around the post screw.

i.e. blue Ticron through the holes nearer to the ends of the plugs and green Ethibond through the holes adjacent to the tendon

The prepared graft must be kept moist by being wrapped in a saline-soaked gauze swab

1. 

2. 

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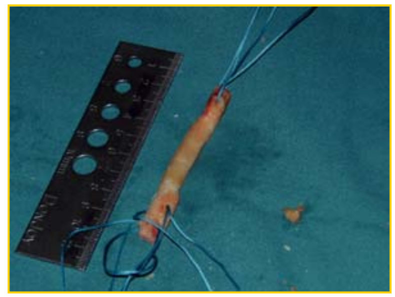
4 

5. 

Preparation of Graft

OPERATIVE ARTHROSCOPY

An arthroscopy is performed

Any meniscal or chondral lesions are dealt with accordingly

FEMORAL TUNNEL

The notch is cleared using the power shaver and the stump of the old ACL removed
A notchplasty is performed if necessary, with a narrow osteotome being inserted via the anteromedial portal to remove part of the anterolateral notch
The posterior aspect of the lateral wall of the notch is curetted

An arthroscope is then inserted through the patellar tendon defect (the proximal incision)
This gives a deeper view of the notch and allows placement of the femoral tunnel
Clearance of soft tissue from the notch gives a view of the position of the femoral tunnel 5 mm anterior to the true posterior capsular insertion and at the 10 o'clock (right) or 2 o'clock (left) position with respect to the apex of the notch
A bone awl (Steadman pick) is used to begin the femoral tunnel, aiming to create a tunnel that leaves a 2mm thick posterior wall
Fully flex the knee and, via the anteromedial portal, insert a drill guide that hooks over the back of the condyle
Start a drill hole using a 2.5mm AO drill, aimed approximately 30° lateral and 30° anterior to the femoral axis, check its position and if satisfactory then continue with a 3.2mm AO drill, passing all the way through the femur
A 2.4 mm Beath pin is placed in the drill hole followed by an appropriate-sized cannulated drill (typically 9-11mm) inserted to a depth just greater than the length of the femoral bone plug
The posterior wall of the femoral tunnel is tested with a probe
The Beath pin is withdrawn partly such that the tip protrudes out of the thigh and the threadable end lies just within the femoral tunnel

TIBIAL TUNNEL

The tibial tunnel is created using an Acufex drill guide, with the guide’s tip inserted through the anteromedial portal
The correct angle of the guide should be set to ensure a correct length of tibial tunnel:

Graft length > 90mm	60° from horizontal
Graft length 80-90mm	55°
Graft length <80mm	50°

The tip of the guide is placed within the remnants of the stump of the ACL at a position one-third of the distance from the medial end of a line joining the anterior horn of the lateral meniscus and the medial tibial spine (up against the PCL)
The drill guide is then pushed against the anteromedial cortex of the tibia (within the distal wound), making sure that it is below the lower extent of the tibial graft trough

A 3.2 mm drill hole is created into which a blunt pin is inserted
The intra-articular position of the pin is checked arthroscopically
A tunnel is then started using the appropriate-sized cannulated drill (usually 9/10 mm)
The blunt pin is replaced with the obturator of a bone corer and the tunnel is completed using the appropriate-sized bone corer
The bone core is kept for grafting into the patellar and tibial defects later in the procedure
The length of the tibial tunnel is usually 45 to 50 mm
Debris including any remaining stump of the ACL at the aperture of the tibial tunnel is removed to avoid impingement when the knee is fully extended ('a cyclops lesion').

GRAFT PASSAGE

The Beath pin within the femoral tunnel is passed back into the knee joint and pulled out through the anteromedial portal using pituitary rongeurs
The two ends of a nylon pull-through suture are inserted into the end of the pin
With a finger holding the loop of the nylon suture, the Beath pin is pulled back through the joint and out of the thigh, bringing the ends of the nylon suture with it
The nylon loop is pulled into the joint and then pulled out through the tibial tunnel using rongeur
The patellar tendon autograft is then unwrapped and the sutures of the femoral plug are passed through the nylon loop
By pulling the nylon loop through the knee and out of the thigh the femoral plug sutures are pulled out through the thigh
By pulling selectively on either just the lead suture (Ticron) or both sutures, the femoral bone plug is positioned in its tunnel – with the cancellous side facing anterosuperiorly
Make sure that the tibial plug is sufficiently inserted into its tunnel not to be placing tension on the graft – the cancellous side should be facing anterosuperiorly as well

A probe, rongeurs or awl may be needed to guide the plug around the PCL into the tunnel

A prominent PCL may prove less of an obstruction with the knee in the figure-of-4 position

A tight plug may need to be punched home

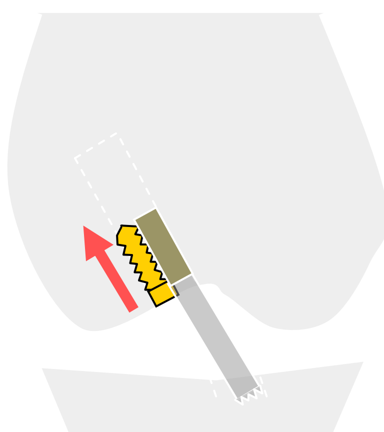
GRAFT FIXATION

Hold the tibial plug sutures firmly to prevent proximal migration of the femoral plug

With the knee fully flexed, insert a blunt pin via the anteromedial portal into the interface between the femoral tunnel and the cancellous area of the femoral bone plug to allow parallel placement of an interference screw with the bone plug

Start the screw hole using the cannulated screwdriver (or, if the bone is especially hard, use a chipper)

Insert a 7mm x 25mm interference screw, using a Bristow applied to the screwdriver to increase the torque when tightening the final few turns



Femoral screw pushes graft into tunnel.

Firm traction is then applied to the tibial bone plug while the knee is taken through a full range of movement to pretension the graft and to observe full extension without impingement

The knee is extended fully (lift foot when tightening sutures)

A 5mm x 25mm post screw is inserted into the anteromedial aspect of the proximal tibia, just below the tibial tunnel

When drilling the pilot hole, direct the drill slightly caudally

Position the loop of the proximal tibial plug suture (green Ethibond) around the post screw and tie this suture firmly, using the block-and-tackle effect

Repeat this using the distal suture (blue Ticron)

Tighten the post screw using “Block and Tackle” technique

An 8mm x 20mm interference screw is then inserted parallel and anterior to the tibial bone block

Stability is checked by performing a Lachman test intra-operatively

CLOSURE

Bone graft (including the bone core) is inserted into the patellar and tibial defects

The patellar tendon is then closed with 2/0 Vicryl

The wound is closed over a suction drain

10 ml of 0.25% Marcain is instilled into the joint and around the portals

Subcutaneous 2/0 Vicryl

Subcuticular Monocryl skin closure

Wool and crepe dressing

Hinged knee brace locked to allow flexion from 0° to 90°

POST-OPERATIVE REHABILITATION

Patients begin weight-bearing on crutches immediately

Simple analgesics for pain control.

Usual time in hospital is two nights.

A hinged brace is advised for approximately 2 weeks, but longer with generalized ligamentous laxity.

Daily physiotherapy to reduce postoperative swelling and to allow active exercises aiming for full extension by 14 days

Review at 10 to 14 days for wound inspection and suture removal

Further review at six weeks, six months and then yearly

Intensive rehabilitation programme including closed-chain exercises and an emphasis on proprioceptive re-training.

The Dr Cross protocol is available on request or online at www.kneeclinic.com.au for the treating physiotherapist and physician.

At six weeks, patients begin jogging in straight lines, swimming and using a bicycle

From 12 weeks general strengthening exercises are continued with agility work and sporting activities encouraged

Return to competitive sport involving jumping, pivoting or sidestepping is prohibited until six months after the reconstruction

COMPLICATIONS

Patella Fracture
Chronic patellofemoral pain – kneeling pain
Patella tendon rupture
Patella tendonopathy and calcification
Graft Fixation screws prominence
Graft Failure
Stiffness – and Cyclops lesions preventing full extension
Cysts of the ACL
General Complications; infection, DVT, haemarthrosis, nerve injury, complex regional pain syndrome (CRPS or RSD)

ACKNOWLEDGEMENTS

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