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Successful Knee Arthroscopy: Techniques

Chia-Liang Ang

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Abstract

Knee arthroscopy is one of the most common arthroscopic procedures required of an orthopedic surgeon. A successful case hinges primarily on adequate pre-operative planning, proper intra-operative set-up and thoughtful portal placement. This chapter will discuss in detail the necessary ingredients of a smooth and successful knee arthroscopy case. Advanced techniques to deal with intra-operative difficulties will be presented. Though uncommon, complications arising from knee arthroscopy will be presented and their management techniques described. Common procedures will be discussed, including simple knee arthroscopic debridement, arthroscopic cartilage reconstruction, anterior cruciate ligament reconstruction, and meniscus repair. Surgical steps for a safe and smooth case will be presented.

Keywords: knee arthroscopy, arthroscopic techniques, arthroscopic debridement, microfracture, anterior cruciate ligament reconstruction, meniscus repair, cartilage repair

1. Introduction

Knee arthroscopy is one of the most commonly performed orthopedic surgeries today. Its first reported use was by a Danish surgeon, Dr. Nordentoft, who made his own endoscope with a 5 mm trocar. He presented his work on knee endoscopy in 1912 at the 41st Congress of the German Society of Surgeons in Berlin [1]. Over the last century, technological advances in illumination and optical systems for viewing have facilitated the development of arthroscopic surgery, to the point where today, a large proportion of intra-articular pathology can be successfully treated with arthroscopic techniques. Arthroscopic surgeries involve much smaller incisions through skin, subcutaneous tissues, fascia and muscle, allowing rapid healing of these structures and early mobility of the patient, which is vital in reducing two key

complications that threaten the success of any knee surgery: wasting of the quadriceps and stiffness of the knee. Furthermore, arthroscopy allows access to the posterior parts of the knee joint much more effectively compared to open surgery, where accessing the posterior horn of the menisci requires a subluxation of the knee joint. Arthroscopy can also be an adjunct to fixation of peri-articular fractures, where a direct intra-articular view can help dictate fracture reduction [2]. However, one issue in such uses is the potential lack of a contained space where a constant stream of arthroscopic fluid provides a clear visualization. In such cases, the peri-articular fractures would have to be almost nearly reduced before a proper visualization can be obtained via arthroscopy to guide the final reduction.

Arthroscopy is a completely different skill set from performing open surgery. One of the key differences is that in open surgery, the surgeon's hand movements directly correlate with movements at the tip of the instruments, whereas in arthroscopy, the surgeon's hand movements are in opposite directions with movements of the tip of instruments due to the presence of a pivot point at the incision. This negative correlation with the surgeon's hands is the primary difficulty for any learning arthroscopist and is the main component of the learning curve. The second major difficulty with arthroscopy is the locations of the portals. The incisions will have to be precisely situated to create a cone of movement that allows the best access to intra-articular structures. The third difficulty is learning how to improve access to the posterior parts of the knee joint, in particular when repairing meniscal tears or meniscal roots. Also, to interpret the anatomy of intra-articular pathology, the arthroscopist should correlate what he views through the scope with a mental overview of normal knee anatomy. These will be discussed further in the chapter.

Notwithstanding the benefits of arthroscopic surgery, a successful clinical outcome depends almost as much on the surgical technique as on good post-operative rehabilitation. Self-exercises such as isometric quadriceps contraction and active ankle and toe movement should be started immediately post-operation. Weight bearing and knee range of movement would depend on the pathology treated and the surgeon's comfort level.

2. Basic set-up

2.1. Patient and OT positioning

The surgeon will stand on the side of the knee to be operated on (**Figure 1**). An assistant surgeon, if available, stands proximal to the surgeon, and the scrub nurse stands distal to the surgeon with her instrument trolley further distal to her. Across the operating table, the arthroscopic towers stand at the level of the opposite knee (**Figures 2 and 3**). Proximal to the tower is the Mayo stand which holds all the arthroscopic instruments. A separate table may be utilized adjacent to the scrub nurse instrument trolley for graft preparations. The operation bed and surgeon should be within the confines of the laminar flow ceiling.

The patient should be supine on the operation table. For a routine arthroscopy, a side support on the lateral side of the thigh and a sandbag or an attachable foot rest beneath the foot

should be placed (**Figure 4**). Placement of this side support must facilitate two functions: one, to allow the knee to be placed at a 90° angle, and two, to act as a post against which a valgus force can be applied to the knee to open the medial joint. For a right knee scope,

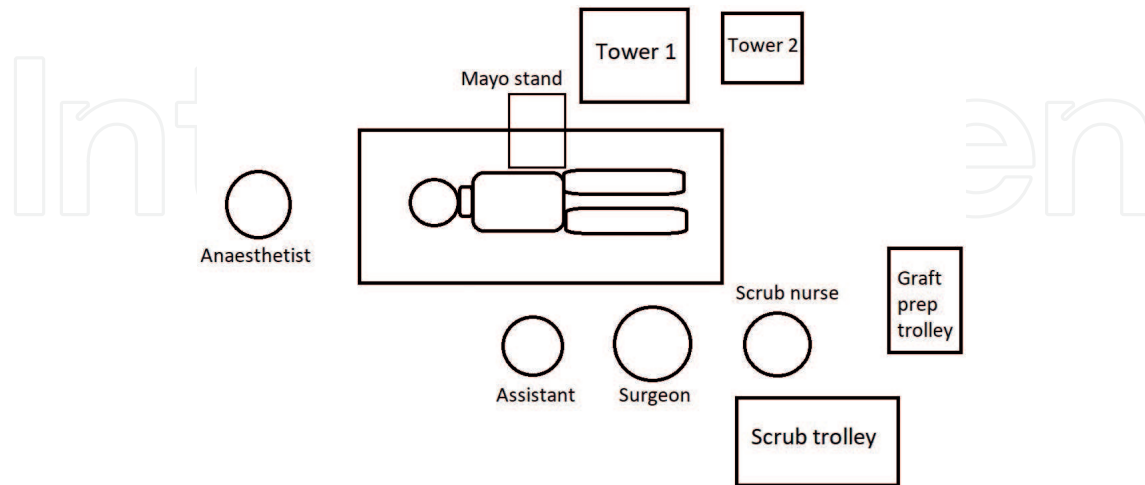


Figure 1. Operating theater set-up.



Figure 2. Arthroscopic tower 1. From top the bottom, the components are: screen, arthroscopic camera system, image management system, shaver console, arthroscopic light source, photo printer.



Figure 3. Arthroscopic tower 2. The top console is the fluid pump management system, and the bottom console is the radiofrequency ablation system.

the surgeon can place the patient's foot into his left hip and use his body to exert a valgus force with the patient's knee at 20–30° of flexion (**Figure 5**). The operation table may have to be lowered or the surgeon may place his left foot onto a stool. Therefore, the surgeon must check both positions before instructing the attendant to secure the side support in place. If a sandbag is used, it should be securely taped down to the table to prevent movement during the surgery.

A tourniquet is applied to the patient's proximal thigh. A properly applied tourniquet is a great aid to visualization during the surgery, especially during femoral drilling for Anterior Cruciate Ligament (ACL) reconstruction. A thick wad of cotton should be applied first to the thigh, and it is important that the width of the applied cotton is larger than the width of the tourniquet. This allows the even distribution of pressure from the tourniquet to the thigh. The tourniquet itself should be tightly applied over the cotton such that it will not admit even one finger. A crepe bandage is then secured over the lower half of the tourniquet and the lower edge is folded inwards beneath the lower edge of the tourniquet. For ACL reconstruction, an additional foot rest is applied to allow the knee to achieve maximum flexion during surgery (**Figure 6**). Positioning of this more proximal foot rest should be slightly less than full knee flexion. If the knee were fully flexed during positioning, the foot rest will not be able to hold the knee properly after draping adds bulk to the entire set-up.



Figure 4. Set-up for standard knee arthroscopy.



Figure 5. Placing the patient's foot in the surgeon's left groin, the surgeon can exert a valgus force on the knee.



Figure 6. Set-up allowing hyperflexion for ACL reconstruction.

2.2. Equipment

The arthroscopic lens used most commonly for knee arthroscopy is the 30° lens (**Figure 7**). This means that the line of visualization is at a 30° angle to the scope. When visualizing the posterior horn of the meniscus, this is important because the direction of the lens should be turned upside down to direct the angle of visualization towards the back (**Figure 8**). An upright image is maintained by adjusting the scope handle. In the author's experience, there has not been a need for a straight lens. The 70° lens can be used for the following situations: treating pathology behind the patella tendon, such as scar tissue; inspecting the superior portions of the medial and lateral gutters, and visualizing the posterior tibial step-off for Posterior Cruciate Ligament (PCL) reconstructions.

An arthroscopic debrider, commonly called a shaver, is used to debride damaged tissues. The author routinely uses a 4.5 mm shaver with serrated cutting edges for maximal debridement efficiency, especially for a torn ACL. When using this for cartilage or menisci, the shaver edge is first used to debride the damaged tissue, and the shaver gradually moved towards normal tissue with a controlled gradual movement to achieve a smooth tissue edge. When used carefully, there is no risk of accidentally debriding normal tissue.

The next important instrument is the radiofrequency ablation probe, or commonly called a wand. The wand delivers electrical energy to its tip, generating intense localized heat that coagulates tissues. There are two modes, cutting and coagulation. The cutting mode delivers a continuous high-frequency current, which heats the tissue so strongly that the cells are explosively destroyed, severing the tissue. The coagulation mode delivers high-frequency current in pulsed mode, delivering a lower energy such that the tissue dries out without being severed. The wand is a useful instrument for shrinking synovial tissue, smoothing out a rough meniscal edge or cartilage edge with fibrillations, and dissecting tissue off bone, for example when preparing the lateral femoral condyle in ACL surgery.

The most commonly used arthroscopic fluid is 0.9% Sodium Chloride, which is a physiological irrigation solution compatible with living tissues. For standard arthroscopy cases such as

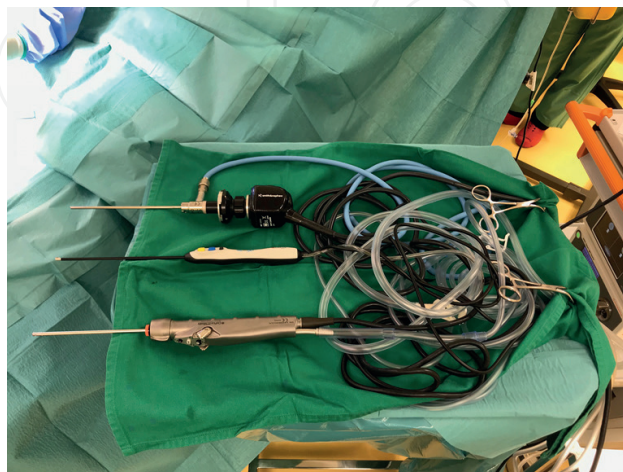


Figure 7. Arthroscopic instruments. From top to bottom, they are: arthroscopic viewing camera, radiofrequency ablation instrument (wand), arthroscopic debrider (shaver).

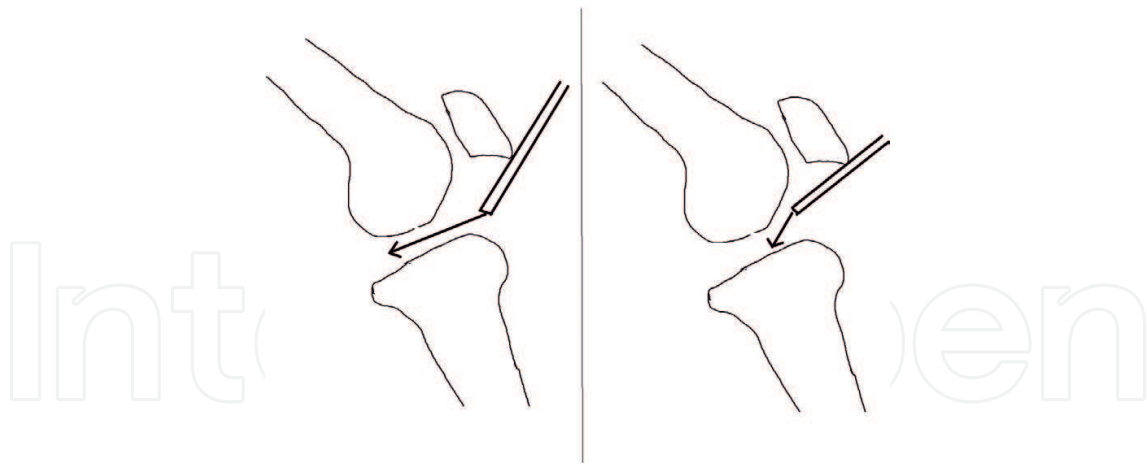


Figure 8. The diagram on the left illustrates the correct way of directing the angle of visualization to the posterior part of the knee. The diagram on the right is the wrong way.

cartilage or meniscal debridement and wash-out, a fluid management pump is not required. The author uses a fluid management pump for ACL surgeries, in particular for the drilling of the femoral tunnel. This is because hyperflexion of the knee for drilling of the femoral tunnel may decrease the tourniquet effectiveness due to the extreme positioning. At this stage, the irrigation pressure can be increased to 80 mmHg to maintain adequate visualization. At other times of the surgery, the fluid pressure can be at 50–60 mmHg to maintain just a clear view without excessive risk of fluid extravasation into tissues.

3. Standard knee arthroscopy

A standard knee arthroscopy starts with the positioning and set-up as detailed in the previous section. A dose of intravenous antibiotics as according to each surgeon's institution guidelines should be given at least 5 minutes before the inflation of the tourniquet. Following cleansing and draping of the knee, surface markings are drawn followed by inflation of the tourniquet and commencement of the procedure (**Figure 9**). The first portal to be established is the antero-lateral portal. This should be situated at the level of the inferior pole of the patella with the knee in 90°, and as close to the lateral edge of the patella tendon as possible. Correspondingly, the anteromedial portal is at the same level and situated as close to the medial edge of the patella tendon as possible. Taking in mind that the tibial plateaus are dish-shaped, the height of the portal at the inferior pole of the patella allows access to the posterior part of the tibio-femoral articulation. In the author's experience, portals established any lower to this height will have poorer access to the posterior of the knee.

The incision of the portal should be with a Size 11 surgical blade, made with the knee in 90°, and aimed towards the trochlear. In the author's experience, fluid injection into the knee before incision is not necessary. Furthermore, a wrong injection into synovium will cause marked synovial swelling that will severely obstruct visualization. Following incision, a straight arterial haemostat is inserted through the synovial tissue with a controlled force and the tip of the haemostat felt to touch the trochlear. A controlled insertion is important to avoid inadvertent



Figure 9. Standard incisions for ACL reconstruction.

damage to the trochlear cartilage. The haemostat is then opened to dilate the track. The scope trocar is inserted in the same direction, and similarly felt to contact the trochlear, before the knee is extended and the trocar driven beneath the patella into the suprapatellar pouch. The trocar is then removed, leaving the sheath, and the 30° lens inserted and locked into place. Following visual confirmation of placement in the suprapatellar pouch, fluid irrigation can be started. Where there is a lot of synovial debris, a washout of the suprapatellar pouch will first be performed using the irrigation.

A diagnostic arthroscopy starts with examination of the suprapatellar pouch with the knee in extension. Pathology that can be observed at this stage includes loose bodies, synovitis or plicae. The lens is directed upwards and the undersurface of the patella cartilage inspected. Following inspection of the suprapatellar pouch, the lens is taken over the medial side of the medial femoral condyle while the knee is allowed to flex over the side of the table. The medial gutter can be inspected at this juncture. The medial femoral condyle should be inspected in its entirety, followed by the anterior horn of the medial meniscus and the ACL. Frequently though, the fat pad posterior to the patellar tendon can interfere with visualization and it is at this point that a 21G hypodermic needle can be inserted through the surface marking of the anteromedial portal. The direction of the needle should be checked and confirmed to be able to give a direct line of access to the posterior horn of the medial meniscus. A stab incision is then made and the track dilated with a straight haemostat. The author routinely use a 4.5 mm incisor shaver to debride adhesions

and reduce the size of the fat pad and synovium just enough for visualization. There is often a rudimentary ligament at the anterior aspect of the tibiofemoral articulation which can be safely excised. The fat pad can also be downsized using the 90° wand, alternating between coagulation (for hemostasis of bleeding points) and cutting (for shrinking tissues). Adequate visualization is achieved when the anterior horn of both medial and lateral menisci are easily visualized together with the intermeniscal ligament. The ACL and PCL can be checked for laxity using a probe.

With the knee at different angles of flexion, the direction of the portal changes slightly due to the difference in position of the skin relative to the capsule and synovium. With experience, primarily through development of muscle memory, the surgeon is able to quickly locate the right direction of entry without forcefully creating another tract. Additional tracts through the capsule or synovium should be avoided as these are all potential sites for joint fluid extravasation and represents unnecessary additional tissue damage. To enhance easy insertion of instruments and changing of the scope through different portals, the track should be adequately dilated using the haemostat. With the scope in the anteromedial portal, the wand should be inserted through the anterolateral portal and used to shrink the synovium around the opening of the tract and vice versa.

To visualize the posterior horn of the medial meniscus, the knee is held at a 20–30° flexion with the patient's foot resting in the surgeons' hip. Putting the knee at 20–30° eliminates the ACL's contribution to stability, leaving only the medial collateral ligament (MCL) as a restraint against a valgus force. The patient's thigh is blocked by the side support, and the surgeon can exert a valgus force on the knee by moving his entire body outwards. Additionally, an assistant can help to apply more valgus force onto the knee (**Figure 10**). By slowly varying the angle of flexion using his hip, the surgeon will be able to find an angle of best access. Sometimes, this maneuver does not suffice to allow access to the posterior horn in muscular young adult male patients or patients with post-traumatic knee arthritis and joint stiffness. A method of improving access is by needling the MCL from within. An 18G spinal needle is inserted from the anterolateral portal. The spinal needle is directed towards the body of the medial meniscus, inferior to it. The curved tip is pointed inferiorly to avoid injury to the meniscus. The deep MCL and superficial MCL is then needled below the meniscus, with a gap of about 2–3 mm in between each penetration. This is done with the knee in 20–30° with a constant valgus force applied to gradually open up the medial compartment. It is important to apply a sustained gradual force and avoid sudden excessive valgus forces to avoid creating an iatrogenic MCL tear. This technique is sufficient to open up the medial compartment for visualization and instrument access. A similar method is needling the MCL from outside the skin and observing the needle penetrating the joint below the meniscus [3]. Both techniques work well but doing it from within avoids puncture marks on the skin and is more accurate in avoiding the meniscus.

To visualize just the posterior root of the medial meniscus, the scope can be inserted from the anterolateral portal and driven through the notch. This can easily be done in patients with a lax ACL and a wide notch. In patients with an intact ACL, a trans-patellar tendon portal is sometimes required in order for the scope to adopt the right direction to penetrate the notch. The direction of the scope should be medial to the ACL and inferior to the femoral insertion of the PCL.



Figure 10. Applying valgus force on the knee with an assistant's hand acting as a pivot.

To visualize the posterior horn of the lateral meniscus, the tip of the scope is first placed just lateral to the ACL with the knee at 90°. The leg is then brought over the other leg to adopt a 'figure of 4' position. A downward force on the knee is applied by an assistant and the scope can be inserted into the lateral tibiofemoral compartment (**Figure 11**). This position allows work to be done on the posterior horn of the lateral meniscus, with the scope inserted from the anteromedial compartment and the instruments inserted from the anterolateral compartment.

Following an arthroscopic inspection of the whole joint, the required work is then performed. Standard knee arthroscopies are often done as a debridement procedure in middle-aged patients with knee osteoarthritis. Worn-down or damaged cartilage is graded according to the Outerbridge or International Cartilage Repair Society (ICRS) classification. Menisci damage is classified according to the morphology (fraying, tear, horizontal cleavage) and location (within the white-white, white-red, or red-red zone). Routine debridement procedures involve



Figure 11. Applying downward force with the knee in a 'Figure-of-4' position opens up the lateral joint.

debriding damaged cartilage or menisci down to a stable and smooth rim with a combination of the shaver and wand. Degenerated menisci involving the white-white zone can be safely debrided. However, if the meniscal damage involves the red-red zone, an attempt should be made to repair the meniscus wherever possible and biologically feasible. Intra-articular loose bodies or prominent osteophytes, especially patellar osteophytes, can also be removed. Plicae, if present, are usually abnormal condensations of the capsule/retinaculum and can create pain when they abrade or impinge against the femoral condyles. They can be excised with a combination of the arthroscopic scissors and the shaver. Boggy synovial hypertrophy can be downsized as synovitis is also often an important contributor of pain. At the completion of the procedures, the knee is repeatedly washed out using the arthroscopic fluid to remove debris and inflammatory cytokines. The wounds are closed with non-absorbable sutures to achieve a water-tight closure, and generous local anesthetic can be infiltrated around the wounds. A bulky post-operative dressing is applied.

A lateral release is a commonly performed step of routine knee arthroscopy for patients who have tight lateral retinaculum causing a lateral patellar tilt. Patients will commonly have anterior knee pains after walking or running, and examination will show reduced medial translation of the patella and lateral patellar facet tenderness. This should be corroborated by a skyline x-ray view of the knee showing abnormal lateral patellar tilt. Patients with these findings will then do well with a simple lateral release. This step is usually performed at the end of the arthroscopy, because there will be fluid extravasation into the subcutaneous tissues once the lateral release is done. With the knee in extension, a small incision into the suprapatellar pouch is made about 1 cm proximal to the superolateral corner of the patella. A hook radiofrequency ablation tip is inserted through the incision and used to incise the retinaculum longitudinally about 1–1.5 cm from the lateral edge of the patella. The release of the retinaculum should be performed from 1 cm above the superior edge of the patella to 1 cm below the inferior edge of the patella. It is important that only the retinaculum be ablated and released, without ablating the more superficial subcutaneous layer. Another method of doing this is to insert the radiofrequency hook through the anterolateral portal. The patella should be checked for increased medial mobility and the knee taken through flexion to check for an adequate release.

In standard arthroscopy cases without meniscal or cartilage repair/reconstruction, the patient is allowed to weightbear fully after the surgery as pain allows. Static quadriceps contractions, straight leg raise, and active flexion of the knee is encouraged from immediately after surgery.

4. Arthroscopic cartilage repair/restoration

Cartilage repair or restoration is a group of surgical techniques of treating cartilage lesions in suitable cases [4]. Generally, these are middle-aged patients with fairly localized Outerbridge grade 3–4 degenerative cartilage wear, usually over the medial femoral condyle or beneath the patella facet. Patients with Outerbridge grade 1–2 cartilage wear can usually be satisfactorily treated with debridement. Young active patients with very localized cartilage lesions will benefit

from Autologous Cartilage Implantation (ACI), where the first stage involves arthroscopically harvesting cartilage from the anterior non-weightbearing surface of the medial or lateral trochlear. The cartilage chondrocytes are then cultivated in the laboratory. The second stage 4–6 weeks later involves an open procedure where a periosteal patch is first harvested from the proximal tibia, stitched in a water-tight fashion over the defect, and the chondrocytes injected beneath the periosteal patch. This procedure aims to regenerate 'hyaline-like' cartilage and has been shown in studies to have results comparable or superior to microfracture [5].

For most patients, the most basic method of treating cartilage lesions is microfracture, known as a marrow stimulation technique. The idea is to allow the release of mesenchymal stem cells from within the marrow into the cartilage defect, forming a blood clot. The blood clot then forms fibrocartilage over 3–6 months. This works well for Outerbridge grade 3–4 lesions about 1 cm × 1 cm in dimension and is more effective for the weight-bearing femoral condyles than for a patella lesion [6]. The area of damaged cartilage is first sized using the tip of the probe (which measures 5 mm), and the damaged cartilage debrided down to subchondral bone. It is important to create vertical wall edges wherever possible. This allows more effective trapping of the resultant blood clot within the defect. An arthroscopic awl is then used to create subchondral punctures in the bone to allow the escape of fat globules from within the marrow. The punctures should be spaced about 3 mm apart. Patients who had microfracture alone do not require protected weight-bearing after surgery. In fact, weight-bearing is beneficial because it compresses the femoral condyles against the tibia, closing off the cartilage defect and allowing formation of a contained blood clot.

Patients who have areas of cartilage damage larger than 1 cm × 1 cm will benefit from a cartilage reconstruction procedure using a commercially available hyaluronic acid scaffold. The scaffold traps the in-coming blood clot effectively, allowing the mesenchymal cells to differentiate and grow along the scaffold. This can come in the form of either a mesh (e.g. Hyalofast) or an injectable gel (e.g. Cartifill). The lesion should not be any larger than 3 cm × 3 cm, and should not have any associated subchondral bone defects. Disease processes such as OsteoChondritis Dissecans (OCD) or Spontaneous OsteoNecrosis of the Knee (SONK) with involvement of the subchondral bone will benefit from Osteochondral Autograft Transfer System (OATS).

Reconstruction using a hyaluronic acid scaffold can be done arthroscopically for lesions on the femoral condyles or tibial plateaus. Following debridement and microfracture of the defect, the surgical field must be adequately dried to prevent loosening of the scaffold during implantation. The fluid inflow is first turned off and remnant intra-articular fluid is drained. Small surgical patties can be used to dry the area around the defect. The knee can be infused with carbon dioxide which effectively dries the area and pushes surrounding synovium away. For lesions on the weightbearing surfaces of the femoral condyles, the knee is placed at 90°. Any flexion angle higher than this should be avoided because the anterior knee structures will begin to press downwards onto the condyles. The foot should be propped higher using towels while keeping the knee at 90°, thus flexing the hip. An assistant is vital to keep the leg in this position during implantation. The defect is thus made more horizontal, allowing easier implantation.

When using the scaffold mesh, it should be cut to the defect size or slightly larger, as the mesh will usually shrink when in contact with fluid. The mesh should be lightly dampened with saline to make it more firm and easier to manipulate. The superior point of the mesh is grasped with an arthroscopic grasper, and the mesh brought into the knee, laying the mesh first in the superior portion of the defect. An accessory anteromedial or anterolateral portal is essential to allow insertion of a probe to assist in seating the rest of the mesh. Following seating of the mesh, a fibrin sealant glue (such as Evicel or Tisseel) is laid over the edges of the mesh. It is important that synovium is kept far from the defect so that the glue will not inadvertently stick to the synovium. If it does so, the glue can be allowed to harden first before snipping the adhesion with an arthroscopic scissors. Two minutes is allowed to lapse for the hardening of the glue, and the knee is then ranged carefully to check for the stability of the mesh. It is imperative that throughout the implantation process, the area is kept dry.

For patella lesions, a mini-arthrotomy is often required as there is no conceivable way to implant the scaffold since the patella is downward-facing. With the knee extended, the incision can be done at the midpoint between the edge of the patella and the femoral condyle. Strong vicryl sutures are inserted into the deepest layer of the retinaculum and used to evert the patella, assisted by an assistant's finger on the outside of the patella as a pivot point. It is often possible to satisfactorily treat the lesion with the patella everted to just vertical. The cartilage defect is prepared and the microfracture performed, followed by implantation of the scaffold as described above (**Figures 12 and 13**).

Post-operative care for cartilage restoration includes bracing the knee in a hinged brace, allowing for 0–30° of movement as tolerated. Toe-touch weight bearing with two crutches is allowed. This is applicable for both femoral condyle and patella lesions. Isometric gentle quadriceps exercises and active ankle movement exercises can be started immediately after surgery. The allowable range of movement is gradually increased, and free range of movement can be allowed after 6 weeks.

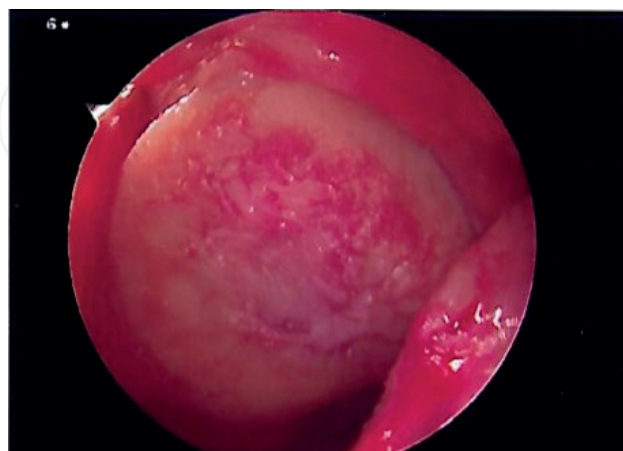


Figure 12. Open view of a 1.5cm x 1.8cm patella cartilage lesion through a mini-open arthrotomy.



Figure 13. Following debridement of damaged cartilage and microfracture, an injectable collagen scaffold has been injected into the lesion, filling up the cavity and forming a smooth surface contour.

5. Arthroscopic anterior cruciate ligament reconstruction

ACL reconstruction is one of the most common arthroscopic surgeries performed today. Different graft types (hamstring autograft, allograft, bone-patellar tendon-bone), different fixation methods (interference screw, suspensory, transfixion) and different techniques (single-bundle, double-bundle) exist and this chapter will not discuss the large amount of medical literature studying the pros and cons of each. The author performs ACL reconstructions primarily using single-bundle hamstring autografts. Allografts are used for example in revision cases, or if it is a combined ACL/PCL reconstruction. Double-bundle reconstructions are performed only for competitive athletes. The author's method is a trans-portal method that recreates the femoral attachment at the anatomical location. Transportal techniques have been shown to have better clinical outcome and knee laxity scores as compared to transtibial techniques [7]. The following technique describes a single-bundle hamstring autograft reconstruction using a femoral endobutton and a tibial interference screw.

The patient's own hamstrings can be harvested using a 3–4 cm oblique incision placed directly over the palpable 'speed-bumps' that insert into the anteromedial surface of the tibia. Where the speed-bumps are not well-felt, the lowest-most end of the incision should be 2 cm medial and 1 cm inferior to the tibial tubercle. The hamstrings consist of the sartorius, the gracilis, and the semitendinosus and the latter two are harvested. The hamstrings should be harvested with the knee in 90° flexion to allow the tendons to relax and allow for easy identification. Following incision and dissection through subcutaneous fat, the sartorius fascia will be encountered. An incision in line with the skin incision is made in the sartorius fascia and the fascia dissected and peeled away from the tendons. The sartorius fascia will be overlying the terminal tendons of the gracilis and the semitendinosus and will be effectively merged with the tendons at the insertion, so they cannot be properly identified at its insertion. Identification of the tendons should start at the proximal-most end of the incision, where the tendons are still separate. Glistening white tendons should be identified, and from the lowest semitendinosus up. This is because the sartorius may occasionally be mistaken for a

tendon on its own especially in large muscular adults, where the sartorius may be more round and tendinous at its insertion instead of spread out like a sheet. The sartorius should not be harvested because it has multiple attachments to the medial tibial surface and surrounding structures due to its sheet-like insertion. Once the semitendinosus and gracilis tendons are identified, the interval between them can be identified and then dissected distally to its insertion, thereby properly separating the tendons. The tendon insertions can then be incised, keeping in mind to preserve as much length as possible, the tendon end whipped-stitched, and surrounding adhesions dissected and cut before stripping the tendon. Before stripping the tendon, the ubiquitous band to the gastrocnemius should be cut. The entire length of the surgeon's index finger should be inserted into the wound and felt circumferentially around the tendon and the soft muscular portion of the hamstrings should be felt before proceeding to strip. A closed, blunt stripper is then inserted over the tendon and the tendon stripped from its muscle belly with sustained controlled force. The stripper tip should comfortably pass into the muscle belly before encountering much resistance. If there were resistance felt within the first few centimeters of inserting the stripper, it is likely that there are remnant adhesions. Failure to properly dissect off adhesions to the tendons may result in truncation of the tendons during stripping.

The saphenous nerve is in the vicinity during harvest of the hamstrings. The reported incidence of post-operative sensory disturbance is as high as 74–88% as reported in the literature [8, 9]. The infrapatellar branch of the saphenous nerve is also commonly damaged during hamstring harvest. While it is not possible to completely eliminate the risk every time due to anatomical variabilities, steps can be taken to minimize the risk. It has been found that an oblique incision carries a lower risk compared to a vertical incision [10]. After incising the sartorial fascia, dissecting the fascia separate from the tendons is done carefully and in a blunt manner. This is because the saphenous nerve can be closely apposed to the sartorial fascia at this level. Any obvious nervous structure should be preserved. Also, the nerve is also in close proximity with the distal portion of the gracilis tendon. Cutting of bands from the gracilis tendon must be done under direct visualization, and all sartorial and surrounding adhesions must be bluntly freed before stripping the tendon. During closure of the wound, stitching of the fascia must be done with only small needle bites, and the fascia is merely apposed but not bundled tightly together. Using these steps, the author finds a rate of less than 10% of patients reporting persistent post-operative numbness or sensory disturbance in the infrapatellar area of the knee, and perhaps 1–2% of patients reporting saphenous nerve sensory disturbances.

The graft is prepared on the back-table by first removing all remnant muscular attachments. For a quadrupled graft, both ends of the both tendons are whip-stitched and the folded quadrupled graft sized and then kept under tension. After drilling of the femoral tunnel and measurement of the tunnel length (usually femoral tunnel length will be about 40 mm), the appropriate endobutton will be opened and the graft threaded through the endobutton. The intra-articular portion of the quadrupled graft is then stitched together. If a particularly long graft is obtained (e.g. more than 24 cm), each graft can potentially be tripled to produce a sextupled graft. Generally at least 8–9 cm of graft will be a sufficient length for appropriate fixation in both femoral and tibial ends using a femoral endobutton and a tibial interference screw. If a sextupled graft is used, then the whip stitches will only be at one end of the graft.

Following threading of the graft through the endobutton, the graft is tripled, and the entire graft stitched together at the loop of the endobutton and throughout the entire graft, to prevent the graft from adjusting within the loop.

Standard positioning for ACL reconstruction is with 2 foot-rests. Following standard arthroscopic evaluation and debridement of remnant ACL tissue, the femoral tunnel is prepared first. Remnant tissue if available on the lateral femoral condyle can be used as a guide to the insertion point of the guide wire. Otherwise, the Resident's Ridge is a reliable landmark which is consistently present in nearly all knees. With the knee in anatomical position, the Ridge is a linear landmark that runs from superior-anterior to inferior-posterior across the lateral femoral condyle, more-or-less dividing the wall of the lateral femoral condyle into an anterior and posterior half. With the knee bent at 90°, the terminology can be confusing, so it is important to only refer to the landmarks based on anatomical terminology. The femoral insertion site of the ACL is in the posterior half of the lateral femoral condyle and slightly superior. Preparation of the wall of the lateral femoral condyle should show the Ridge and the entire wall inferior, posterior and superior to the Ridge. The anatomical landmark is at the halfway point between the Ridge and the posterior cartilage margin, and just slightly (1–2 mm) superior to the halfway point between the inferior and the superior cartilage margins. Proper visualization of the wall is through the anteromedial portal with a 30° lens. With the knee hyperflexed, the guidewire can be first inserted through the accessory anteromedial portal to judge its trajectory and position. The accessory anteromedial portal is more medial to the standard anteromedial portal and is as low as possible without injuring the medial meniscus. This ensures a trajectory of the guidewire exiting the anterolateral femoral cortex. With this method, there is no necessity to perform a notchplasty. The guidewire can be lightly tapped with a mallet to first engage the femoral condyle wall, before being advanced with the drill. With satisfactory guidewire positioning, the lateral cortex is then broken. The length of the tunnel can be measured at this point, following which the guidewire is re-inserted and the appropriate reamer used to create the femoral tunnel to a depth about 5 mm less than the length of the tunnel. For a standard 40 mm femoral tunnel, the 15 mm endobutton is used, giving a 25 mm length of tendon within the tunnel.

The tibial tunnel position should be centred at a point about 40% of the antero-posterior length of the tibial plateau from the anterior end backwards. Medio-laterally, it should be centred just slightly lateral to the medial tibial intercondylar tubercle. Arthroscopically, the centre of the tibial tunnel should be on the medio-lateral line just traversing the posterior part of the anterior horn of the lateral meniscus, and on the antero-posterior line just traversing slightly lateral to the highest point of the medial tibial intercondylar tubercle. This will ensure the entire graft is situated anterior to the line connecting the highest points of the medial and lateral tibial intercondylar tubercles and is medial enough. This is the anatomical position for a single-bundle reconstruction and will give the best results in terms of anterior drawer and rotational control. With the scope in the anterolateral portal, it is important to assess the tibial tunnel position from both an anterior view and from a lateral view to obtain an accurate judgment of the location. Sometimes, the 70° scope is used to assess the anatomy accurately. The tibial drill guide is inserted through the anteromedial portal and the guidewire inserted through the incision used for harvest of the hamstrings. The tunnel is then reamed and a shaver inserted through the tunnel to clear out debris and smooth the entry and exit edges of the tunnel.

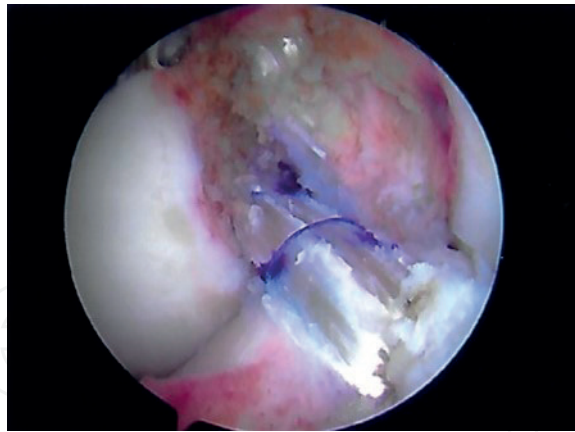


Figure 14. With the knee in 90°, the reconstructed ACL graft should appear as a low-lying graft passing from the anterior part of the medial tibial eminence to the lateral femoral condyle.

Following passage of the graft and flipping of the endobutton, the knee is cycled about 15–20 times while maintaining tension on the graft. This allows even distribution of tension throughout the diameter of the graft and allows stress relaxation. The tibial end is then fixed with an interference screw usually 0.5–1 mm larger than the diameter of the tunnel itself and with the knee in 20° of flexion and a posterior drawer on the tibia. A final check arthroscopy can then be done, assessing the final position of the new graft. The knee can also be brought to full extension and the graft arthroscopically checked to ensure no impingement on the femoral trochlear, though with anatomical positioning of the tunnels, there should be none (**Figure 14**). The wounds are closed in standard fashion followed by a generous subcutaneous infiltration of long-acting anesthetic.

The author's post-operative rehabilitation protocol consists of the following:

1. First 2 weeks: A hinged knee brace locked at 0–30°, worn all the time. Patient to perform static quadriceps and straight leg raise exercises.
2. Second 2 weeks: The brace can be removed while awake and not ambulating, but worn at night and if ambulating. The degree angle need not be adjusted as the patient can perform flexion exercises when the brace is not on. Patient can start to perform prone hang and passive flexion exercises.
3. Third 2 weeks: The brace can be removed at night, and worn only during ambulation. Again, the brace angle need not be adjusted. The locked brace will continue to protect the patient's ACL during activities such as ascending/descending stairs or getting in/out of a car. Closed-chain exercises can commence. The brace can be taken off after the third 2 weeks.

6. Arthroscopic meniscal repair

Meniscal repair methods include all-inside, inside-out, and outside-in techniques. However, with the advent of a range of commercially available products and instruments for all-inside

repair, this technique has become standard practice to treat all meniscal tears wherever possible. Meniscal tears are classified by their location and pattern of tear. Tears affecting the white-white zone, the edge of the meniscus, can be debrided to a stable and smooth edge since this zone is avascular and will not heal well with repair. Tears affecting the white-red zone or the peripheral red-red zone should be repaired wherever possible. An MRI is a prerequisite before surgery to repair the meniscus. It elucidates the location and the likely pattern of tear, but it should be noted that MRI is a static assessment of the meniscus with the knee in an extended position. Significant displacements that occur with the knee in a deep flexion position may not be seen on the MRI [11]. It is therefore important that arthroscopically, an assessment of the stability is made both with a probe and with the knee in varying degrees of flexion. One important pathology to look out for on the MRI is a root tear. The signs of a root tear on the MRI include the 'ghost' sign on the sagittal cut of the root (meniscus root appearing faintly and poorly defined), the truncation sign on the coronal cut (the posterior horn appears to be abruptly truncated and separated from its tibia attachment), and extrusion of the body of the meniscus on the coronal cut, indicating a lateral displacement of the entire meniscus [12]. Root tears should always be repaired as an unrepaired root is grossly unstable and will quickly lead to osteoarthritis.

All-inside fixation devices typically consist of a delivery needle that penetrates the meniscus and deploys fixation tabs behind the capsule. These come with a pre-tied, self-sliding knot that can be pushed downwards onto the meniscus after deployment of the fixation tabs, locking the meniscus in place. The delivery needles are usually curved slightly, giving the surgeon versatility in the direction of the penetration into the meniscus. Vertical mattress sutures have been shown to have higher fixation strength than horizontal mattress sutures. Importantly, these devices are only used for the posterior horn and body of the menisci. Anterior horn tears will need to be repaired with an outside-in technique usually. When using the all-inside devices, the needle itself can be used as a reduction device since there is usually little room to admit another instrument to hold the meniscus in place. For example, for a horizontal flap tear in the posterior horn of the meniscus, the needle can first be used to penetrate the upper flap, and used to bring the upper flap over the lower flap in a reduced position, then penetrated through the lower flap to deploy the first tab (**Figures 15 and 16**). For bucket-handle tears, it is often useful to provisionally reduce the meniscus by using a smooth suture passed through the body of the meniscus using an outside-in needle. The body of the meniscus can be held in place with a grasper while the needle penetrates the body. The suture is passed through the needle and retrieved outside either of the anterior portals. The needle is then passed one more time from outside-in either above or below the meniscal edge, and a lasso passed through and retrieved outside the same portal as the one with the end of the suture. This end of the suture can then be shuttled back outside the knee, and traction applied to provisionally reduce the body of the meniscus. The rest of the meniscus can then be fixed using all-inside fixation.

Repair of the meniscus will start with an assessment of the location and morphology of tear, in order to guide optimal suture placement. Fibrillated or torn edges in the white-white zone can be debrided to a stable rim. The remaining tear surfaces in the white-red or red-red zones are first abraded using an arthroscopic rasp to create bleeding vascular channels to optimize

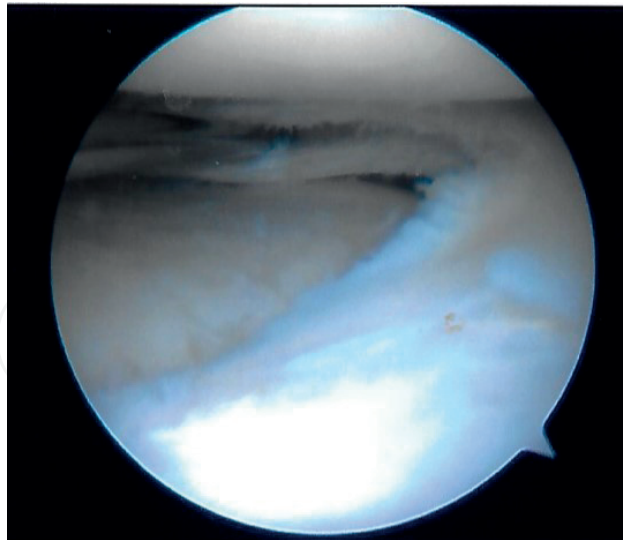


Figure 15. A cleavage tear of the posterior horn of the medial meniscus.

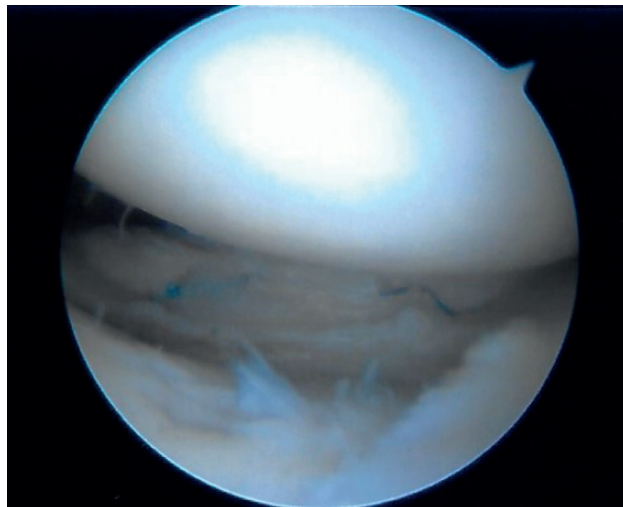


Figure 16. Following meniscal repair with all-inside fixation devices closing the cleavage and debridement of the frayed edges.

biological conditions for healing. Another described method is to use a needle to penetrate the tear surfaces, called trephination. When working with very unstable tears, it is useful to use a grasper to hold the meniscus in place while the rasp or needle is used. The grasper can be inserted from an accessory portal on the same side as the meniscus tear. Following abrasion or trephination, the meniscus can be repaired. Sometimes, instead of a tear in the meniscus itself, it is a separation of the meniscus from the capsule, called a menisco-capsular separation (also called a ramp lesion). This will result in abnormal increased mobility of the meniscus and should be repaired as well. Radial tears can be repaired using an arthroscopic suture-passer (for example Arthrex Knee Scorpion) or an all-fixation device (for example Smith & Nephew FastFix 360). The arthroscopic suture-passer is small enough and allows easy passage and retrieval of suture through the meniscus. The surgeon then ties arthroscopic knots to repair the meniscus.

Meniscal root tears, as mentioned above, should always be repaired [13]. The attachment site of the root on the tibial plateau should be freshened with a serrated curette or even a motorized burr to create a fresh bleeding surface. Using the ACL tibial drill guide aimer, a transtibial tunnel is created. The undersurface of the root should also be freshened with a rasp. There are different methods of repairing root tears, including using trans-tibial sutures to pull the root down or suture anchors inserted via an accessory posteromedial portal. There are also different ways of suture passage through the root. One commonly used method is cinching the suture, meaning passing the suture through its own loop. However, this often creates fixation only along the edge of the meniscus. The author's preferred method is to insert the suture in a cruciate manner in the root, creating an undersurface area of fixation rather than just an edge of fixation. The dimensions of the cruciate should be slightly larger than the width of the transtibial tunnel, which is usually about 4 mm to admit a suture lasso device to shuttle the root sutures through the tibial tunnel. The sutures can then be tied over a button on the surface of the proximal tibia.

7. Complications of arthroscopy

Even though uncommon, every surgeon should be aware of potential complications of arthroscopy and these should be fully discussed with the patient before a decision for surgery is made. Infection remains one of the most feared complication with an incidence rate of 0.1–0.4%, and the most likely period of presentation within the first month after surgery. Where there is a suspicion of an intra-articular infection, aspiration should be performed for an immediate diagnosis through Gram Stain and bacterial cultures. Proven intra-articular infection of the knee should be treated with an open arthrotomy, wash-out and synovectomy. In ACL reconstructions, if the presentation had been fairly acute and treatment fairly expeditious, the graft may be retained. However, for more insidious infections that typically present over a longer time-frame, the graft should be excised and the femoral and tibial tunnels curetted. Infection in ACL reconstructions carries a high risk of a poor outcome with eventual stiffness.

There are several nerves which may potentially be damaged during arthroscopic surgery. When harvesting the hamstrings for ACL reconstruction, the anatomical variation of the saphenous nerve and its infrapatellar branches means that there is a high risk of damage to some of these branches with a resultant numbness or sensory difference in the infrapatellar area. In the literature, sensory nerve damage is very common during hamstring harvest, but the resultant numbness can be minimized using careful dissection and harvesting techniques as described in Section 5 above.

When repairing the lateral meniscus around the body/posterior horn junction using all-inside fixation devices, a potential risk is overpenetration of the needle device, injuring the common peroneal nerve. To minimize this risk, it is important to carefully penetrate the needle device through the meniscus, and ensure the tip penetrates to just immediately outside the capsule. It is important to have a mental awareness of where the tip ends up even though it

will be out of our visualization once it penetrates the capsule. It is also important to use a trajectory that is away from the central popliteal neurovascular bundle, and to use a curved delivery device that allows the surgeon to direct it away from the area of danger. Also, the penetration depth should be adjusted depending on the size of the patient [14]. For average sized males, a penetration depth of 14 mm can be used quite safely, 16 mm being the distance from the point of penetration on the meniscus to the tip of the device. For slim females, the depth can be adjusted to 12 mm. Keep in mind that penetrating the meniscus and pushing the device through the meniscus will also compress the meniscus towards the capsule, so if the device is entirely pushed through to the pre-set depth limit, the tip of the device may end up even deeper than anticipated. If repairing the lateral meniscus using inside-out methods, a posterolateral incision should be made and the biceps femoris retracted posteriorly to protect the nerve. The common peroneal nerve branches off the sciatic nerve at the distal part of the thigh and runs in between the lateral head of the gastrocnemius and biceps femoris muscles. It follows the biceps muscle distally where it wraps around the fibular neck. Injury to the common peroneal nerve is a debilitating complication causing the patient to develop foot-drop. The prognosis of a neurapraxic injury of the nerve is moderate at best, with 50% achieving full recovery within 6–12 months and 50% never recovering fully. Treatment is essentially supportive with an ankle-foot orthosis.

When performing PCL reconstructions, the proximity of the popliteal neurovascular bundle to the PCL mandates a posteromedial incision with the dissection just along the posterior capsule of the knee. The knee should be at 90° of flexion. The medial head of the gastrocnemius muscle is lifted posteriorly and a blunt trocar used to create a track along the posterior edge of the tibial plateau. When performing this step, the surgeon should maintain intra-articular visualization using the scope and observe the trocar come into view. The PCL is intra-articular at the femoral end and extra-articular at the tibial end, and so debriding the torn PCL will open the posterior capsule already, allowing the trocar to come into the posterior part of the knee. Seeing the trocar come into view indicates the correct placement of the trocar in the posterior part of the knee anterior to the popliteal bundle. This tract can then be dilated and the posterior tissues lifted off with the trocar during PCL tibial tunnel guide-wire drilling. When reaming the tibial tunnel, the terminal reaming of the posterior cortex should be strictly done by hand.

Deep vein thrombosis after a knee arthroscopic surgery remains very uncommon, and it is not routine to anticoagulate patients unless they have predispositions for deep vein thrombosis, such as inherited clotting tendencies, or combinations of factors such as poor mobility, cancer or smoking. The post-tourniquet syndrome is a commoner complication, consisting of numbness of the leg and weakness of the quadriceps following a prolonged period of tourniquet inflation, causing a neurapraxia of the femoral nerve. Neurapraxia of the sciatic nerve with resultant foot-drop is rare. This syndrome is treated symptomatically and is expected to recover fully. It is recommended that the tourniquet should be temporarily let down after about 100 – 120 min of inflation to prevent this complication. Death by pulmonary embolism is very rare but may be a reason for litigation, as are unfortunate situations such as wrong-sided surgery or retained instruments [15].

8. Conclusion

Knee arthroscopy is a vital skill for all orthopedic surgeons to have. This chapter describes the essential techniques required of an arthroscopist. The keys to technical success are appropriate pre-operative planning and thoughtful execution. To interpret the anatomy of intra-articular pathology, the arthroscopist should correlate what he views through the scope with a mental overview of normal knee anatomy.

Conflict of interest

The author has no conflicts of interest associated with any of the medical devices mentioned in this chapter.

Author details

Chia-Liang Ang^{1,2,3*}

*Address all correspondence to: med80199@yahoo.com

1 Royal College of Surgeons, Edinburgh, UK

2 American College of Surgeons, USA

3 Island Orthopaedic Consultants Pte Ltd, Singapore

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