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Technical Evolution of Arthroscopic Knee Surgery

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Abstract

The widespread growth of arthroscopic techniques and their use has dramatically changed the practice of orthopaedic surgery. A high degree of clinical accuracy and minimally invasive procedure with a low surgical morbidity have encouraged the use of arthroscopy to assist in diagnosis, to determine prognosis and to provide treatment. In particular, the knee is the proper joint in which arthroscopy has its diagnostic and intraarticular surgical application. The rapid advancement of arthroscopic techniques has demonstrated a variety of surgical techniques in procedures such as meniscectomy, meniscal repair and cruciate ligament reconstruction during the last decade. This article reviews the past history of arthroscopy and technical evolution of arthroscopy in knee surgery in our department.

Key Words: Knee, arthroscopy, techniques

INTRODUCTION

The widespread growth of arthroscopic techniques and their use has significantly changed the practice of orthopaedic surgery. In the beginning, no one realized the potential of arthroscopy in the orthopaedic field. However, the many advantages of arthroscopy are expanding the areas of orthopaedic treatment previously thought to be impossible. It is likely that this growth will continue at an even faster pace in the future. This article reviews the past history of arthroscopy and the technical evolution of arthroscopy in knee surgery in our department.

THE BEGINNING

Professor Kenji Takagi (1888－1963) was the first orthopaedic surgeon who successfully applied the principles of endoscopy to a knee joint. In 1918, he reviewed the interior of a cadaver knee using a cystoscope. He developed the #1 Takagi scope in 1931 and illustrated his report with a black & white picture taken through the scope in 1932. He was successful in obtaining color pictures and a movie film 4 years later. After some quiescent period, Dr. Masaki Watanabe (1921－1994) developed the first modern arthroscope, Watanabe #21, in 1958. His first arthroscopic surgery was the removal of a xanthomatous giant cell tumor and the first meniscectomy under arthroscopic control was performed in 1962.[1] Therefore, he opened a new horizon on the technique of operative arthroscopy.

In Europe, Dr. Eugen Bircher (1882－1956) introduced the Jacobaeus laparoscope into a knee in 1921. The first U.S. article on arthroscopy appeared in 1925, when Dr. Phillip Kreuscher (1884－1943) published a plea for the use of arthroscopy in the early recognition and treatment of meniscal lesion. In 1930, Dr. Micheal Burman (1901－1975) in New York examined every large joint of the body using cadavers.

Dr. Robert Jackson visited Japan in 1964 to study tissue culture techniques. However, he also observed the arthroscopic procedures of Dr. Watanabe, and in 1968 he gave the first instructional course on the subject of arthroscopy at the annual meeting of the AAOS (American Academy of Orthopaedic Surgeons). Early pioneers in the U.S. (Drs. Ward Casscells, Jack McGinty, Lanny Johnson and Ken DeHaven) developed the operating arthroscope and the video arthroscope in 1974, and the motorized instrument and needle scope in 1976.

Increasing numbers of techniques and surgical procedures are being performed under arthroscopic

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controls. Where the revolution will end is unpredictable. The next generation might have the same delightful challenges in the field of arthroscopic surgery.

MENISCAL REPAIR

The menisci are C-shaped discs of fibrocartilage interposed between the condyles of the femur and tibia. Functions of the meniscus include load transmission across the tibiofemoral joint, shock absorption to protect the articular cartilage, secondary mechanical stability, and possible joint lubrication with distribution of joint fluid and nutrition. Tear of the meniscus is one of the most common knee injuries. For symptomatic torn menisci, many surgeons once advocated surgical excision. However, King found 2 important facts about the role of meniscus in the knee: a) not only did meniscectomy incite degenerative changes in the knee, but these changes were directly related to the amount of meniscus removed, and b) meniscal tear healed in the avascular portion of the menisci if the tears extended into the well-vascularized meniscosynovial junction.[2] In experimental study, removal of the medial meniscus caused a reduction in the contact area by 50% to 70%, and the absence of a meniscus increased the gradient considerably near the margins of the articular contact area.[3] Therefore, surgeons have since learned to excise as little as possible of a torn meniscus, and eventually learned how to repair the torn menisci.

Ikeuchi performed the first arthroscopic meniscal repair in 1969.[4] After that, a variety types of meniscal repair have been developed, including the three basic types of inside-out, outside-in, and all-inside technique (Fig. 1, A and B). Henning performed the first arthroscopic repair in the U.S. in 1983 with inside-out technique, which is good for the middle one-third of meniscal tear.[5] Outside-in technique was developed by Warren, using spinal needles to skewer the anterior meniscal rim and fragment.[6] Morgan reported an all-inside technique for repair of the posterior horns to avoid posterior neurovascular structures and peroneal nerve injuries.[7] However, viewing the posterior horn with a 70° arthroscope through the intercondylar notch, it is sometimes hard to visualize the posteromedial or posterolateral corner. The senior author (S. J. Kim) favors the all-inside technique of meniscal repair using a suture hook through the trans-septal portal. A trans-septal portal is made on the proximal half of the posterior vertical septum behind the posterior cruciate ligament. The posterior septum is perforated from the posterolateral portal to the high posteromedial portal using a switching stick. This portal provides lots of room for procedures without concern about neurovascular injuries.

Recently, many materials and techniques for meniscal repair have been developed.[8,9] T-fix is a self-anchoring suture consisting of a 3 mm polyacetyl

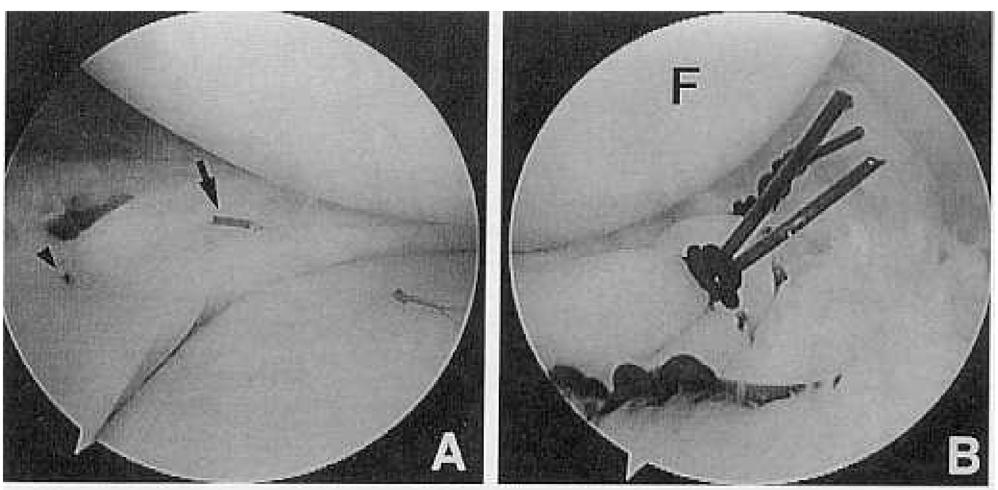

Fig. 1. (A) Arthroscopic repair of medial meniscus with inside-out (arrow head) and outside-in technique (arrow). (B) Arthroscopic repair of posterior horn in medial meniscus with all inside technique (arrow). F: femoral condyle.

non-absorbable bar and double #2-0 braided polyester suture.[8] It is ideal for a central posterior horn tear that is difficult using conventional techniques. Although the T-fix allows ease of suture placement for meniscus stability without the problems associated with ancillary incision, non-absorbable material remains permanently in the joint cavity. The meniscal arrow is a bioabsorbable self-reinforced polylactic-acid barbed shaft with a T-shaped head. Albrecht-Olsen et al. developed this material for meniscal fixation of a bucket-handle tear.[9] The main goal of this technique was to eliminate or at least reduce the risk of neurovascular injury during meniscal fixation and simplify the fixation procedures. However, its holding strength is known to be weak.

Because the techniques and materials for meniscal repair were confined to the vascular zone of the meniscus, many surgeons are concerned about healing enhancement and avascular repair.[10-14] In the past, synovial pedicle flaps have been grafted from the synovium and placed into a meniscal tear to enhance healing.[10] But this grafting would be difficult under arthroscopic control. Rasping of the perimeniscal synovium and tear site has been used to promote the neovascilarization.[11] However, this technique is not effective for tears in the avascular zone. Although injection of fibrin clot was another trial to heal avascular meniscal tears, it is unknown whether the healing strength is sufficient.[12] Trephination and suturing are indicated in longitudinal avascular tear of the meniscus.[13] Meniscal allograft reconstruction was developed to compromise the adverse effect of meniscectomy. Milachowski et al. first completed a meniscal allograft transplant after several animal studies in 1984 and they reported their results in a group of 15 patients in 1989.[14] Recently, arthroscopic-assisted meniscal allograft reconstruction has been performed as an elective out-patient procedure.

DISCOID MENISCUS

Discoid lateral meniscus in the knee is the most common type of anatomic variation of the meniscus. The incidence of discoid lateral meniscus is generally less than 5% in Caucasians.[15] However, discoid lateral meniscus is more common in Asians. Ikeuchi reported an incidence of 16.6% for Japanese and Kim et al. reported an incidence of 10.5% for Koreans.[16,17]

In the past, total meniscectomy was recommended as the proper treatment for a symptomatic discoid meniscus.[18] However, it causes progressive osteoarthritis and poor prognosis has been reported. Therefore, partial meniscectomy for the treatment of symptomatic discoid meniscus has been recommended to reduce progressive degeneration of the cartilage in the joint.[19,20] The goal of a partial meniscectomy is to remove the central portion of the discoid meniscus and to leave a stable, balanced rim. By doing so, the remaining portion performs the function of the meniscus. Many methods of partial meniscectomy have been introduced such as open excision, piecemeal arthroscopic excision, macellation excision and semiarthroscopic technique.[19-22] However, these methods are more time consuming, more aggressive and less safe. To minimize these disadvantages, the senior author developed and presented a simple one-piece technique in 1996.[23] Subsequently, Ogata presented a more delicate two-piece technique in 1997.[24]

Three unique portals are used in one-piece technique; lateral patellofemoral axillary portal, far anteromedial portal and low anterolateral portal. The lateral patellofemoral axillary portal is located in the corner formed by an anterolateral edge of the femoral condyle and inferolateral edge of the patella. An arthroscope is introduced through this portal and maintained throughout the entire procedure. The far anteromedial portal is located just anterior to the medial femoral condyle and 1.5 cm above the joint line. The low anterolateral portal is located 1 cm lateral to the patellar tendon and just above the joint line. To remove the central portion of the discoid meniscus in one piece, a straight scissor punch is inserted to reach the lateral compartment through the far anteromedial portal. The anterior side of the discoid meniscus is cut at a width 5 mm from the periphery of the meniscus. The anterior corner of the cut discoid meniscal fragment is pulled anteriorly through the low anterolateral portal. The posterior side of the discoid meniscus is cut 5 mm wide from the periphery. A grasper is moved into the far anteromedial portal and the inner edge of the central flap is pulled medially. A straight scissor punch is then inserted through the low anterolateral portal to cut the lateral attachment of the flap so that it's 5 mm wide of the remaining meniscus. The central portion of the discoid meniscus is detached and taken out of the joint in one piece. Reshaping is made with

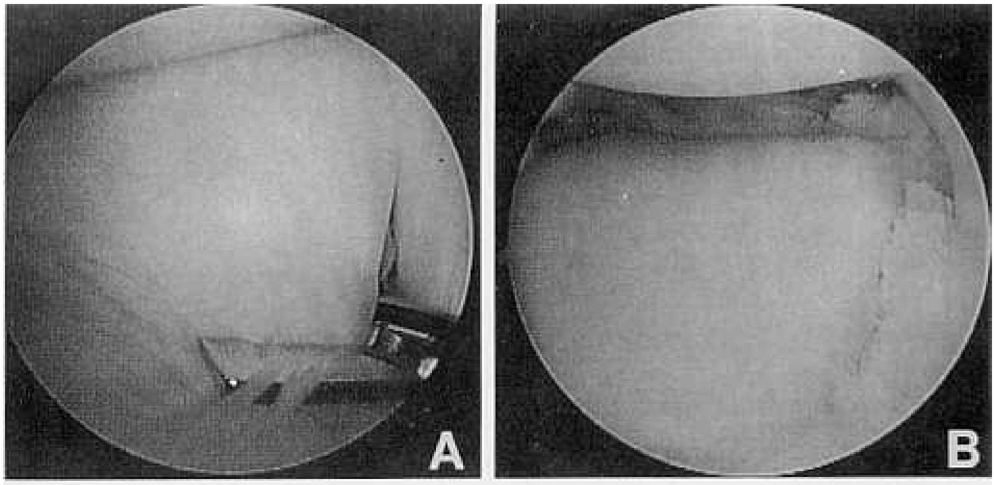

Fig. 2. (A) Discoid meniscus is removed from the anterior portion through far anteromedial portal in one piece. (B) After total meniscectomy of the discoid meniscus in one-piece technique.

a 90° rotary forcep, duck-bill and motorized shaver (Fig. 2, A and B).

Our experience indicated that this technique has several advantages compared with conventional surgical techniques. The one-piece technique in discoid meniscus is simple, less aggressive, less damaging to the cartilage, and there is less formation of loose bodies.

ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

The pathologic anatomy responsible for anterior cruciate insufficiency consists of loss of the primary restraint to anteroposterior translation of the tibia on the femur and laxity in the secondary restraints, especially those controlling rotary components of the instability. The common sources for replacement of anterior cruciate ligament (ACL) are the extensor mechanism (quadriceps tendon, patellar tendon), hamstring tendons and iliotibial track.[25-27] Since Clancy first used autogenous bone-patellar tendon-bone in 1982, reconstruction of the ACL with autogenous bone-patellar tendon-bone has been a popular procedure and is regarded as the standard method.[25] Many surgical techniques have been developed, such as open technique, arthroscopic two-incision technique and one-incision technique.[25,28-31]

However, the use of another graft is needed when patients have problems such as extensor mechanism maltracking, patellofemoral osteoarthritis, prior harvest of patellar tendon graft or poor skin condition in the anterior aspect of the knee. Furthermore, there are several disadvantages in harvesting the central one-third of the patellar tendon, including anterior knee pain, patellofemoral arthritis, limitation of knee extension, weakness of quadriceps muscle and kneeling difficulty. Hamstring tendons have been used frequently as an another graft material for the ACL-deficient knee.[26,32,33] Autogenous hamstring tendon can be obtained with minimal donor site morbidity comparable to the bone-patellar tendon-bone. Although a single strand of hamstring tendon is inferior to the central one-third of the patellar tendon in regard to the maximum tensile load and cross-sectional area, the combined double-looped gracilis and semitendinosus graft has proved to have 238% of the strength of the normal ACL.[34] Recently, therefore, multiple stranded autogenous hamstring tendon graft for ACL deficient knee has become popular. However, after proximal and distal fixation of the hamstring graft, Lachman test showed residual anterior laxity with soft-end point. This seems to be due to the long distance between fixation points on the tibia and femur, which caused micromotion of graft in the bone tunnel. Micromotion causes a "windbrush effect" and "bungee effect" to the bone tunnel followed by funnel-shaped widening of the bone tunnel, which is also caused by the stress shield at the articular side.[35]

The senior author has designed an arthroscopic technique for ACL reconstruction using quadraple autogeneous gracilis and semitendinosus tendons for increased graft tension.[36] And to reduce micromotion and tunnel widening, the authors have developed the technique of tendon graft without detachment of the tibial insertion of the hamstring and fixation with bioabsorbable interference screws. In our technique, without detachment of the tibial insertion, the whole gracilis and semitendinosus tendons are harvested with an open loop tendon stripper. The accessory insertions of the tendons are dissected carefully to obtain a longer graft. After debridement on the proximal portion of the graft, the ends of both tendons are sutured at about 4 to 5 cm in length using whipstitched #2 Ethibond sutures. A tibial tunnel and a 30 mm femoral tunnel are made as usual. This is followed by Endobutton tunneling on the femoral side. In this technique, a double-loop of Mersilene tape is tied through the central holes of the Endobutton at the calculated length, which is the length of the Endobutton tunnel plus 8 mm. Through the proximal hole and the distal hole of the Endobutton, #1 Ethibond suture and #2 nylon suture are placed respectively. The hamstring tendons are passed through the loop of Mersilene tape. After threading both sutures of the Endobutton through the eyelet of the passing pin, the pin is passed through the tibial and femoral tunnel and out of the anterolateral portion of the thigh. At first, a proximal Ethibond suture is pulled to pass the Endobutton out of the lateral femoral cortex. Then the distal nylon is pulled to rotate the Endobutton. The whipstitched sutures on the ends of the grafts are tied together and pulled distally to tighten the grafts with the handle of a Kelly clamp. The knee is cycled about 20 times to confirm the Endobutton locking at the femoral cortex and to give tension to the graft. Tibial fixation is done using 1 staple. Additional interference screw fixations are done at the femoral and tibial tunnel with absorbable bioscrews. Postoperative rehabilitation is the same as the accelerated protocol of ACL reconstruction with bone-patellar tendon-bone (Fig. 3).

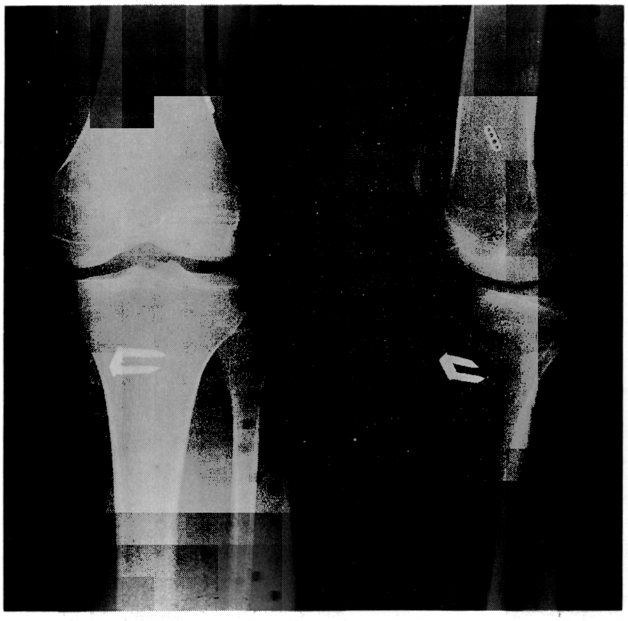

Fig. 3. Postoperative radiograph of ACL reconstruction using autogenous hamstring tendon graft without detachment of the tibial insertion.

The advantages of preservation of tibial insertion of hamstring are even tension for all 4 strands of the graft without stress shielding. In this technique, additional interference screw fixations are performed to allow firm fixation and to overcome widening of the bone tunnel.

POSTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

The posterior cruciate ligament (PCL) is one of the primary stabilizers of the knee. Research and knowledge about this important ligament, however, have lagged behind that of the ACL. Much controversy still exists concerning the natural history of injured PCL and the best treatment options.[37,38] In a recent survey, acute isolated injuries of more than grade 2 instability and chronic isolated injuries with symptomatic functional instability were considered as potential surgical lesions.[38-40]

The arthroscopic technique of PCL reconstruction is technically challenging. The technique described by Rosenberg et al. uses 2 incisions; one over the partellar tendon for harvesting the bone-patellar tendon-bone and the other over the medial femoral condyle for fixing the proximal bone peg of the graft.[41] However, this technique causes inadvertent damage to the extensor mechanism, difficulty in passing the proximal bone peg through the tibial tunnel and inadequate, weak proximal bone peg fixation due to the short length of the bone peg. In 1994, Kim and Min presented a new technique for

PCL reconstruction using one incision over the patellar tendon.[42] The femoral tunnel is made through the laterally-placed anterolateral portal without an incision over the medial femoral condyle. In 1996, Shino presented PCL reconstruction with hamstring tendon using one-incision technique.[43]

In one-incision technique, we routinely use a 30° arthroscope through 3 portals: parapatellar anteromedial, lateral anterolateral and proximal posteromedial portals. The parapatellar anteromedial portal is located just medial and adjacent to the junction of the medial margin of the patellar tendon and the patella and it is more than 2 cm above the joint line. The lateral anterolateral portal is located 2 cm lateral to the lateral margin of the patellar tendon and just above the joint line. The proximal posteromedail portal is situated 3 cm above the joint line. The proximal patellar bone plug is 2−2.5 cm long rather than 1−1.5 cm as suggested by Rosenberg et al.[41] The bone plug on the tibial side should be 4 to 5 cm long because the tibial tunnel for PCL reconstruction is much longer than the tibial tunnel for ACL reconstruction. For creating the tibial tunnel, the specially designed tip of the guide is placed on the posterior flat spot of the tibia 1.5 cm below the articular margin in contrast to 1.0 cm in the conventional method and just lateral to the midline because a blunter angle at the turning point from the proximal tibial tunnel is desirable. The drill guide is oriented 45° to the long axis of the tibia and introduced through the proximal anteromedial side or the distal end of the graft donor site. The desired femoral tunnel site of the PCL (anterolateral component) is believed to be 8 mm posterior to the articular junction at the 1 : 30 point on the right knee and the 10 : 30 mark on the left knee, which is different from the conventional method in which the femoral tunnel is located 10 mm posterior to the articular margin at the 1 : 00 and 11 : 00 points. Although nonisometric, this physiometric point places the graft in a more anterior-posterior orientation for tightening during flexion. Viewing through the proximal posteromedial portal, a tendon leader, which is connected to the suture of the proximal bone peg, is passed through the tibial tunnel and pulled out with a grasper through the intercondylar notch and the parapatellar anteromedial portal. For passage of the proximal bone peg, a specially-designed suture pusher is used. The specially-designed guide pin with a slotted eye in the distal end is passed through the cannula on the lateral anterolateral portal into the femoral tunnel. The leading suture is hooked into the eye of the guide pin and the guide pin is pulled out of the medial femoral condyle, bringing the suture end with it. After engaging the proximal and distal bone plugs into the bone tunnels, femoral and tibial fixations are achieved with the interference screw system (Fig. 4).

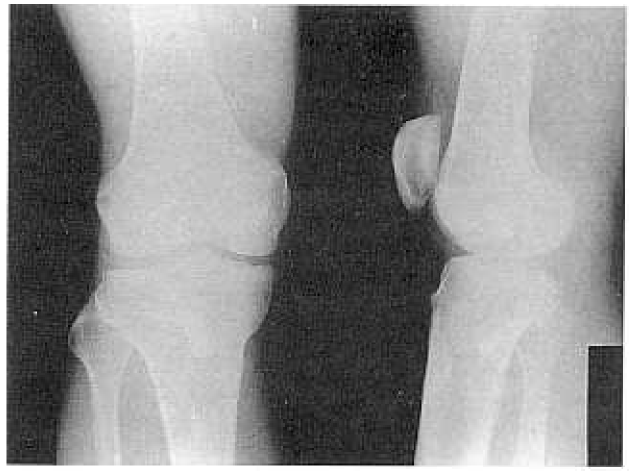

Fig. 4. Postoperative radiograph of PCL reconstruction using one-incision technique.

The arthroscopic one-incision technique for PCL reconstruction offers some advantages over the two-incision technique. The one-incision technique minimized injury to the extensor mechanism, especially the vastus medialis obliquus, and despite easy passage of the proximal bone plug, rigid fixation of the proximal bone plug allows early rehabilitation.

PATELLAR MALTRACKING

The surgical treatment of patellofemoral maltracking (dislocation, subluxation and malalignment) should be considered a last resort measure. Because the mechanism of the patellofemoral joint is highly complex, surgery must be carefully planned and acurately performed. Over 100 operations have been described for treatment of patellofemoral maltracking.[44,45] These procedures are categorized into lateral release, soft tissue proximal realignment, distal realignment, soft tissue with bony realignment and their combinations.[45-47]

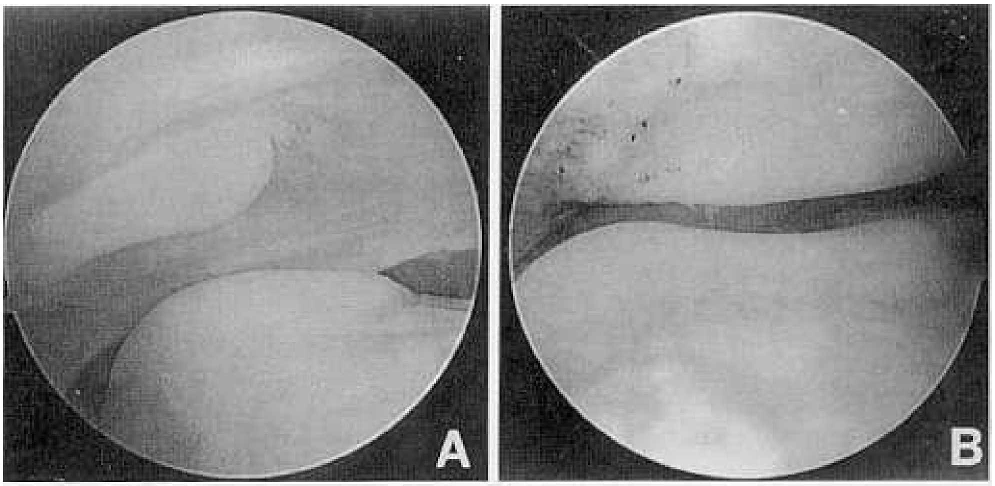

Fig. 5. (A) Patellar dislocation was found through the superolateral portal. (B) After arthroscopic lateral retinaculum release and medial reefing, the patella was accurately corrected and tracked along the femoral groove.

Arthroscopy is an important tool both diagnostically and therapeutically in patellofemoral maltracking. The arthroscopic examination can be used to confirm the clinical and radiographic examination with regard to the malalignment and the condition of the articular cartilage. Using superomedial and superolateral portals, arthroscopic lateral release of the patella with electrocautery was first reported in 1982.[48] A prime advantage of this technique over standard lateral release was the potential to minimize postoperative bleeding. At times, imbrication of the medial retinaculum may be advisable to balance the patellar in the trochlea, especially when the physes are open and tibial tubercle transfer must be avoided. The senior author has described the arthroscopic medial reefing without open incision.

Four long round needles are inserted into the knee joint transversely 3 cm medial to the medial margin of the patella, in which case the tips of these needles are then out of the joint just medial to the patellar margin. These 4 needles should be inserted from the level of the superior pole to that of the inferior pole of the patella. The capsule is cut longitudinally from the level of the superior pole to that of the inferior pole of the patella. The needles are pulled out of the knee joint. After that, the needle is reinserted conversely and then the needles are taken out of the knee joint. A small skin incision is made between the inlet and outlet sutures to avoid skin dimpling caused by soft tissue caught on sutures. Viewing through the superomedial portal, the sutures are pulled together medially through the incision and then tied under proper tension in order to balance the patella. In doing this, it is very important to avoid overcorrection (Fig. 5, A and B).

Although numerous operations for patella dislocation have been introduced, there have been no reports about the importance of precise patella tracking and tilting during surgery. The advantages of arthroscopic treatment of patellofemoral maltracking include realization of exact correction under the direct view of tracking while allowing knee motion, low surgical morbidity, cosmetic advantages and treatment of associated intra-articular pathology. Arthroscopic treatment offers an effective alternative to patella realignment procedures.

SUMMARY

Arthroscopic surgery has developed rapidly during the past decade. Progressive improvements in the lens systems of arthroscopes, fiberoptic systems and operative instruments have made possible advanced operative arthroscopic techniques for multiple joints in the body. A high degree of clinical accuracy and minimally invasive procedure with low surgical morbidity have encouraged the use of arthroscopy to assist in diagnosis, to determine prognosis and to provide treatment. For arthroscopy to be applied safely and effectively, however, the surgeon must possess a complete knowledge of knee anatomy and proficiency in the techniques of arthroscopic surgery, as well as the ability to integrate those techniques with other modalities.

In the near future, new energy sources such as lasers and robotics may be developed with arthroscopic applications. With further applications of high technology in arthroscopy, surgeons can treat patients more confidently and patients can recover more comfortably.

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