

A Historical Review of Anterior Cruciate Ligament Surgery

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INTRODUCTION

Reconstructions of the anterior cruciate ligament (ACL) are among the most frequently performed procedures in knee surgery nowadays. Looking at the history of ACL surgery since its advent in antiquity, it is amazing to see how long it took for some diagnostic and management techniques to establish themselves. However, since the early 20th century, there has been increasing awareness of, and interest in, the ligament & its lesions.

The treatment of ACL insufficiency continues to be a significant problem in orthopaedic practice. Although the current problems are well known and have been identified, many questions remain unanswered. Major procedural differences and the contradictory results attest to the fact that there is still no general consensus to the management of the knee with anterior instability. To fully appreciate the complexity of these problems, we must first understand and learn from the historical foundations laid down by our predecessors. A grasp of history is essential if we are to push new boundaries and explore new areas in ACL surgery. It is also only fitting that as we look towards the future, we acknowledge the work of these pioneers.

Ancient History

Claudius Galen¹⁸ of Pergamum and Rome is credited with first describing the anatomy and nature of the ACL ("genu cruciata") in the 2nd century. Before that, it was thought that the cruciate ligaments were part of the nervous system and had contractile properties. Galen developed the concept of these ligaments as static stabilizing structures that limit abnormal motion in diarthrotic joints. During the next 1600 years, little attention was given to the knee ligaments except in descriptions of dislocations and severe sprains.

19th Century and Early 1900s

As early as 1836, the **Weber brothers**⁶² described abnormal anterior-posterior movement of the tibia following transection of the ACL. They also noted the roll and glide mechanism of the knee and tension patterns of different bundles of the cruciate ligaments.

In 1845, **Amédée Bonnet**^{4,5}, wrote a book titled *Diseases of the Knee*. He described three essential signs indicative of acute ACL rupture: "In patients who have not suffered a fracture, a snapping noise, haemarthrosis, and loss of function are characteristic of ligamentous injury in the knee." His statement was based on his clinical experience, as well as on cadaver studies in which he

produced knee injuries and then dissected the knee to see what lesional pattern had occurred. Bonnet also noted that the ACL tore mostly at the femoral origin while the posterior cruciate ligament (PCL) tore mostly in the middle. He described the subluxation syndrome and recommended a two-hinge orthosis. Another important discovery of his was that immobilization resulted in "absorption of the cartilage", and he advocated mobilization as soon as possible. His recommended treatment for acute knee ligament injuries was a short period of immobilization with a removable splint so as to enable daily knee examination and the application of cold water locally to reduce inflammation.

In 1850, **Stark**⁶⁰ described rupture of the ACL in 2 cases. He treated the injury by immobilizing the knee in plaster and subsequently found only slight residual disability. In 1875, **Georges K. Noulis**⁴³, wrote a thesis entitled *Knee Sprains*. In it, he very accurately described the role of the ACL, and showed how the integrity of the ligament. He wrote, "fix the thigh with one hand; with the other hand hold the lower leg just below the knee with the thumb in front and the fingers in the back. Then try to shift the tibia forward and backward. When only the ACL is transected, this forward movement is seen, when the knee is barely flexed." The test proposed by Noulis was identical with the one now known and used as the Lachman test.

In 1876, **Dittel**¹⁴ confirmed Bonnet's work and described the mechanism of avulsion fractures of the anterior tibial spine.

In 1879, **Paul F. Segond**, wrote a paper entitled *Clinical and experimental research into bloody effusions of the knee joint in sprains*, which was published in *Progrès Médical*⁵⁷. For this study, Segond had repeated Bonnet's work, producing lesions in forced extension in 90 knees. He gave a detailed description of the signs and symptoms of rupture of the cruciate ligaments. He described severe pain, rapid joint effusion, a frequent audible "pop", and abnormal anterior-posterior movement of the knee. In the same paper, Segond also described an avulsion fracture of the anterolateral margin of the tibial plateau, which he had found to be routinely associated with ACL tears. This fracture now bears his name, and is considered as a pathognomonic feature of ACL tears.

In 1895, **A.W. Mayo Robson**⁴⁰ performed the first cruciate ligament repair in a 41-year-old miner who had been injured 3 years ago. The patient had weakness and instability of the right knee. The two torn cruciate ligaments were stitched in position at their femoral attachments. 6 years later, the patient was able to walk without a limp and run.

Astonishingly, since his discharge, he was able to return to working in the mine 8 hours a day, and had never been off work a day because of his knee. The patient had no wasting of the quadriceps, no abnormal mobility, and only had slight limitation of flexion with a fine crepitus on motion. The case was not reported in the literature until 1903. By then, in 1900, **W.H. Battle**³, had exhibited a case of repair of acutely torn ACL, of which he claimed that it was an all-time first.

In 1903, **F. Lange**³² of Munich performed the first ACL replacement, using braided silk attached to the semitendinosus as a ligament substitute. The procedure did not work, leading Lange's colleague **M. Herz**²³ to conclude that the use of silk had been a good idea, but was not possible.

In 1913, **Giertz**²⁰ published a case where he stabilized a flail knee with free fascia lata grafts.

In 1913, **Nicoletti**⁴² performed ACL reconstruction in dogs using both free and pedicled grafts of fascia, periosteum and tendons. He obtained the best results with periosteum.

In 1913, **Goetjes**²² performed studies in cadaveric knees and investigated the mechanism of ACL rupture in 37 cases. He recommended examination under anesthesia when the diagnosis was in doubt, and he advocated early surgical repair of acute ruptures.

In 1917, **Ernest W. Hey Groves**²⁴ performed ACL reconstruction using an iliotibial band (fascia lata) transplant. The approach was through a wide anterior horseshoe incision, and involved a tibial tubercle osteotomy, to give excellent exposure of the joint. The incision was extended laterally, to harvest a strip of iliotibial band. In the initial technique, the graft was detached from the tibia and routed through a femoral and a tibial canal. At its exit from the tibial tunnel, the graft was sutured to the periosteum and the fascia. The tibial tubercle was refixed with two ivory nails. The technique was subsequently modified²⁵ in 1919 as follows: the 20 cm x 8 cm graft was left attached to the tibia. The strip was passed, in a frame pattern, through a tunnel in the lateral condyle, through the joint, and into a tibial tunnel in the anterior part of the tibial spine, exiting at the anteromedial aspect of the tibia. From there, it was routed up the medial aspect of the medial femoral condyle, and attached to the condyle with an ivory nail. This was the first successful case of reconstruction of a torn ACL in a traumatically injured knee. The earlier successful cases were in paralytic knees. This technique by Hey Groves is thought to be the precursor of all modern intraarticular reconstructions.

In 1918, **Maj. S. Alwyn Smith**¹ of Cardiff published a paper reporting on 9 cases treated with Hey Groves' technique. He criticized the incomplete nature of the construct, which failed to strengthen the medial collateral ligament. He also described his instruments, and mentioned other techniques practiced at the time: plication, reefing, wire loops, and a ligament substitute made from silk. He modified the Hey Groves operation by pulling the graft medially through the medial femoral condyle to reinforce the medial collateral ligament, and by advancing the insertion of the sartorius muscle for extraarticular reinforcement. Unlike Hey Groves, Smith advocated

reconstruction for chronic ruptures of the ACL. He also attempted reconstruction of the ligament using only a silk band as prosthetic replacement. However, it failed. Jones & Smith, with their description of the "rocking knee" in 1913, provided early insight into the pathomechanics and diagnosis of ACL injuries. As quoted by Arnold et al. (1979), these authors also published the first description of the "pivot shift" phenomenon: "...placing the hands on the joints, the femur seemed to be suddenly displaced inward, just before extension was completed, constituting the slipping of which the patient complained."

In 1919, **Hey Groves**²⁵, in the *British Journal of Surgery*, reported his anatomical and physiological findings in the cruciate ligaments, and described their ruptures and repair. In particular, he noted the presence of forward displacement of the tibia, which the patient could induce by putting weight on one leg with the knee slightly flexed. He had found the tibia to slip forward with a jerk in some cases. His classic description of the "giving way" phenomenon is still used today. Hey Groves also used the anteroposterior instability in slight flexion observed in his patients as a clinical test. The paper dealt with his first 14 cases operated on since 1917. None of the patients had been made worse by the operation; 4 showed no benefit; 4 benefited to some degree; and 4 were cured, and able to return to their former activities. 2 were still undergoing rehabilitation at the time of publication of the paper.

In 1927, **Ludloff**³⁷ described a technique for ACL reconstruction in which he used a strip of fascia lata enveloped in a thick silk suture. This was certainly the earliest description of the LAD (ligament augmentation device) technique of Kennedy and may be the first augmented ACL reconstruction.

Pre-70s

Between 1919 & 1930, the procedures of arthroscopy & arthrography were introduced and technically refined. These procedures were to revolutionize the diagnosis and treatment of ACL injuries. The pioneers were Eugen Bircher from Switzerland & Kenji Takagi from Japan. Takagi was the first to examine the interior of the knee with a cystoscope in 1918. However, the 7.3mm caliber of the instrument made it too large for practical clinical use. In 1919, Bircher, working independently of Takagi, first experimented on cadaveric knees using the Jacobus laparoscope, and this was soon followed by endoscopic examinations in patients. In his publication, the first on knee arthroscopy in general, Bircher described 13 correct diagnoses in 18 arthroscopically examined knees. The 13 diagnoses were later confirmed by open arthrotomy. In 1922, he praised the value of this technique: "*Arthroscopy permits us to visualize the interior of the joint and evaluate pathologic changes, and thus to establish a diagnosis by visual observation. In this respect it is superior to all other methods of examination and, like endoscopy of the bladder, can be used to define certain indications for surgery. Also like cystoscopy, it will meet with resistance but undoubtedly will gain in popularity and develop until it becomes as indispensable as cystoscopy itself*" (quoted in Henche & Holder 1988, pg3). Bircher's prediction was followed in 1925 by the first English-language description of arthroscopy

by P.H. Kreuzer, & in 1930 by Bircher & Oberholzer's description of double-contrast arthrography. The triangulation technique of arthroscopic surgery was popularized by Takagi, Watanabe, Takeda, & Ikeuchi.

In 1936, **Willis C. Campbell**⁷, reported the first use of a tibia-based graft of the medial one-third of the patellar tendon, the prepatellar retinaculum, and a portion of the quadriceps tendon. The technique involved drilling two tunnels, one in the tibia and one in the femur. The graft was stitched to the periosteum at the femoral tunnel exit. The operation was followed by posterior-splint fixation for 3 weeks. The technique did not become widespread until MacIntosh reintroduced it, many years later. Campbell's paper was published in *Surgery, Gynecology and Obstetrics*. It dealt with 17 ACL reconstruction cases, most of whom were athletes. Nine patients had an excellent outcome, and were able to return to playing football from 6 to 10 months after operation. Campbell felt that, while the need for reconstruction was more urgent in athletes, restoration of the ruptured ligaments would materially improve the end-results in about 10 per cent of all traumatic knees, especially if the procedures employed could be carried out rapidly and without undue intra- and extra-articular reaction. Campbell described the first use of the patellar tendon to reconstruct the acutely ruptured ACL in 1936 and in 1939⁸. He also noted the relative frequency of associated tears of the medial meniscus & medial collateral ligament.

In 1936, **Bosworth & Bosworth** described the first extraarticular reconstruction of the ACL using strips of fascia lata placed on the medial and lateral sides of the joint.

In 1937, **Cubbins et al.** concluded that early surgical repair of the acutely torn ACL & reconstruction of a chronically deficient ligament would yield the best results. They also emphasized the importance and need of at least one year's postoperative rehabilitation following such a procedure.

In 1938, **Ivar Palmer**⁴⁷ published his thesis *On the Injuries to the Ligaments of the Knee Joint*. It was a detailed study of the anatomy, biomechanics, pathology, and treatment. He introduced several new ideas such as the pathophysiology and biomechanics of the subsequent changes in the joint and anticipated several concepts in the future treatment of ligamentous injuries.

In 1939, **Harry B. Macey**³⁸, described the first technique using the semitendinosus tendon. The tendon was left attached to the tibia, then passed through a tibial and a femoral tunnel, and sutured to the periosteum. The joint was approached via an anterior oblique parapatellar incision. (The same principle was used for posterior cruciate repair, with exposure of the popliteal space for accurate placing of the posterior tibial drill hole.) Only the tendinous portion of the semitendinosus was harvested, stopping short of the musculotendinous junction. The tunnels were 4.7 mm in diameter, and the graft was attached with the knee in full extension. A plaster of Paris cast was applied and worn for 4 weeks; full activity was permitted at the end of 8 weeks.

The period from 1940 to 1950 was the dearth of progress in ACL surgery probably because of World War II. The fast pace with which ACL surgery had developed before 1940

had given rise to the hope that further rapid progress would be made around the middle of the century. However, it was not to be. All that was achieved were techniques of active stabilization and collateral ligament retensioning, as reported by **Robert W. Augustine**² in 1956. Augustine's paper concerned a technique devised by the German **K. Lindemann**³⁴ (1950), who had used semitendinosus tendon detached from the tibia and re-routed, with the muscle belly, through the popliteal space. From this position, it was taken through the notch, and into an anterior tibial tunnel. The graft was attached using a wire suture tied around a "boat nail". Augustine also described how a slack collateral ligament could be retensioned by detaching its femoral origin, with a bone block, and reinserting it more proximally with a boat nail. For posterior cruciate ligament (PCL) lesions, he also proposed a dynamic stabilization technique which involved detaching one third of the patellar tendon from the tibial tubercle, passing it back into the joint, and out through a tunnel in the tibia.

In 1948, **Albert Trillat** taught that the knee should be examined in extension, and very accurately described the "give" felt as the tibia was moved slightly forwards and backwards. He considered this to be the most sensitive diagnostic sign in ACL injuries.

Start of the Modern Era

The modern era began in 1950, when **O'Donoghue**⁴⁶ published his results of treatment of major knee ligament injuries in athletes. Although his ideas were not new, his paper was the catalyst that set in motion in the United States the advances in the care of knee ligaments. With its careful documentation, his paper was instrumental in dismissing the notion that knee ligament injuries were career-ending. His successes with the treatment of many athletes also helped.

In 1960, **J. Ritchey**⁵³, a colonel in the US Armed Forces, gave a detailed description, in the *Armed Forces Medical Journal*, of a test of anterior knee instability in near extension. 16 years later, this diagnostic procedure came to be officially known as the Lachman test.

In 1963, **Kenneth G. Jones**^{29,30} revived the idea of using a central one-third of patellar tendon graft with an attached patellar bone block. However, the technique described in his paper differed from the one used nowadays. The tendon was left attached to the tibia; there was no tibial tunnel; and because of the shortness of the graft, the author had to drill the femoral tunnel from the anterior margin of the notch. The ligament was secured to the periosteum at the superolateral exit site on the femur. Jones reported on 11 cases that had been operated on successfully. In the discussion of the article, **Don H. O'Donoghue** made the point that the femoral tunnel was in the wrong place; however, the technique was simple and caused minimal operative trauma, which made it a distinct improvement.

In 1966, **Helmut Brückner**⁶ described a similar technique, using the medial one-third of the patellar tendon. The graft, harvested with a patellar bone block, was left attached to the tibia, then passed through a tibial tunnel, so as to obtain more length. After being passed through the joint, the graft was placed in a socket in the femur; the

sutures were then fastened to a button on the lateral aspect of the lateral femoral condyle.

In 1968, **Donald B. Slocum** and **Robert L. Larson**⁵⁸ introduced the concept of rotational instability of the knee, stressing the role of external tibial rotation in the anterior drawer at 90 degrees of flexion, in medial capsuloligamentous lesions. They also noted that the test was much more positive when the ACL was injured, and proposed ways in which to remedy the rotational instability.

In 1970, **Kurt Franke**¹⁵ pioneered the use of a **free bone-tendon-bone graft** consisting of one quarter of the patellar tendon and attached patellar and tibial bone blocks. The graft was fixed with a wedge-like piece of bone anchored in the tibial plate, and a shell-like piece implanted into the femoral condyle. The technique was derived from the procedures proposed by Brückner and by Jones. However, unlike them, Franke had the very novel idea of using a free graft. In 1976, he reported on nearly 100 cases of ACL repair, mainly in soccer players. One of his patients went on to take part in the Olympic Games, as a wrestler, 5 months after cruciate ligament replacement. Franke recommended that the procedure be performed as early as possible, before cartilage damage had occurred. He had found cartilage damage to be associated with postoperative pain on knee loading, in 10 per cent of his patients. Also, the procedure should not be used in patients over 50.

The 70s

In 1972, **D. L. MacIntosh**¹⁹, went back to the phenomenon described by Hey Groves back in 1920, calling it the pivot shift. To remedy the instability, he described a technique using a fascia lata graft pedicled on the tibia, then passed under the lateral collateral ligament, and attached to the intermuscular septum (MacIntosh 1 - the extra-articular MacIntosh). In a subsequent modification (MacIntosh 2), the graft was brought back intra-articularly (with its weakest portion traversing the joint) and passed into a tibial tunnel. However, the distinctive feature of the technique was the extra-articular routing of the graft.

In 1975, **M. Lemaire**³³ described his extra-articular ligament reconstruction techniques. Medially, gracilis was used for the management of the medial collateral ligament injuries; while laterally, fascia lata was employed for the reconstruction of the torn ACL. The ACL reconstruction was referred to as the Lateral Lemaire. The original technique had been published in 1967, as a procedure for "the control of the ill effects of ACL rupture." The author stated that the technique was "sound" and "offered a better prospect of return to sports activities than [did] muscle and fascia transplants." Several variants of the technique (Lemaire II, III, IV) were developed, each with a different way of routing the graft in relation to the lateral collateral ligament. Lemaire himself reported on 453 knees that he had operated on and followed up for 12 months, with particular attention to the patients' return to sports activities. In patients with isolated ACL tears, the rate of good results was 91 per cent. In his conclusions, Lemaire drew attention to the fact that any associated meniscal lesions tended to have an adverse effect on the outcome.

In 1976, the contribution of **John Lachman**, became known through one his students, **Joseph S. Torg**⁶¹, who described the test at the 1976 Annual Meeting of the LAOS at New Orleans, and called it the Lachman test, in honour of his teacher. However, the principle of the test had been described earlier, by Ritchey in 1960, Trillat in 1948, and, above all, by Noulis in 1875. Sadly, their contribution to the diagnosis of ACL tears went unrecognized.

In 1979, **D. L. MacIntosh** and **J. L. Marshall**³⁹ changed the nature of the graft material used, and decided to harvest the central one-third of the entire extensor mechanism, with a wider portion taken from the prepatellar aponeurotic tissue, which was tubed to give greater strength to what would otherwise have been a relatively thin area of the graft. The graft was routed "over the top" of the lateral femoral condyle, and attached with sutures or a staple. The final portion was taken back to be attached to Gerdy's tubercle. This procedure (the MacIntosh 3/Marshall-MacIntosh) still involved a tibially based graft, which meant that the strongest part of the graft would be in the tibial tunnel.

The 80s — The Age of Synthetic Ligaments and Arthroscopy

The techniques in use in the late 70s were aggressive to the soft tissues and did not produce consistently good results. This is why the new generation of surgeons in the 80s went back to earlier ideas of ACL reconstruction. As mentioned earlier, as far back as 1903, Lange, in Munich, had used silk to augment the semitendinosus, albeit without success. Corner, in 1914, had used silver wire. In 1975, **Rubin, Marshall, and Wang**⁵⁶ had developed an experimental model of a prosthetic ACL made of Dacron. In the early 80s, there was a first wave of carbon fibre-reinforced prostheses.

In 1981, **D. J. Dandy**^{12,13} was the first to implant a carbon fibre-reinforced ligament substitute, using an arthroscopic procedure. The results were rather poor. Carbon deposits were found in the synovial membrane and the liver, which put a stop to the further use of the technique.

As carbon fibre went out, surgeons seized on other synthetic materials like Dacron and Gore-Tex, as a means of performing ACL reconstructions quickly and effectively, with minimal trauma. However, towards the end of the 80s, there was an unacceptably high rate of synovitis and subsequent rupture of the neoligaments. As a result, this line of ACL reconstruction had to be abandoned as well. During those years, some surgeons had remained faithful to the concept of autografts, the only difference being that they were now increasingly performing these procedures arthroscopically. However, the autografting community was riven by two rival philosophies. On the one hand, there were the adherents of the principle of OUTSIDE-IN, routing the ligament into the joint through a femoral tunnel. On the other hand, there were the advocates of INSIDE-OUT, routing the ligament from inside the joint into a femoral socket. The main differences between the two surgical techniques were related to the positioning of the femoral tunnel. With the inside-out technique the femoral tunnel was significantly more vertical, both in the frontal and the sagittal planes.

1981: Clancy¹⁰ advocated the need for off-centre (relative to the normal attachments of the cruciate ligaments) placement of the tibial and femoral tunnels. This is necessary if the substitutes are to be under proper tension throughout the full range of motion of the knee, and ensures that the relatively flat patellar-tendon graft used in this study lies along the portion of the circumference of the tunnel that coincides with the anatomical centre of the normal anterior cruciate ligament. The patellar tendon was pulled through the tibial canal (using sutures through the holes in the piece of the cone removed from the patella) until this bone fragment was placed entirely within the femoral canal.

1983: Noyes⁴⁴ conducted a study validating the usefulness of an initial 8-point non-operative treatment program, including the need for close follow-up, determining the individual patient's goals and demands, and activity modification and counseling. He also concluded that arthroscopy should be indicated in certain knees to detect the true extent of joint deterioration and, in some patients, the necessity for early surgical intervention. In another paper in 1987⁴⁵, Noyes recommended early knee motion after open and arthroscopic ACL reconstruction.

1983: Gillquist²¹ did a comparison between arthroscopic reconstruction of the ACL and reconstruction through a miniarthrotomy. His conclusion was that there seemed to be no major benefit from arthroscopic reconstruction in terms of rehabilitation. However, there was decreased operation time with arthroscopic reconstruction. He preferred miniarthrotomy since the notch plasty is easier to perform adequately during it than during arthroscopy.

1988: Rosenberg⁵⁴ played a major role in the improvement in arthroscopic techniques. His work and the work of many others such as Drez, Dandy et al.¹³ and Clancy et al.¹¹, have made the now prevalent arthroscopic-assisted reconstruction of the ACL what it is today.

The 80s were a time when arthroscopy flourished, and surgeons obtained a better understanding of the ligament attachment sites. These facts appear to have played a major role in the good results obtained over that period.

The 90s — The Jones Procedure as the “Gold Standard”?

The Jones procedure appeared to establish itself as the superior procedure, and became very widely used, because of its simplicity and consistently good results. It involved the use of the free bone-tendon-bone graft of the central one-third of the patellar tendon. At the same time, metal interference screws were introduced into orthopaedic surgery.

In 1987, **M. Kurosaka**³¹ showed that the mechanically weak link of the reconstructed graft was its fixation. The research had been done in young human cadavers, and showed clearly that 9-mm diameter cancellous screws were much superior to other fixation systems. Within a few years, such screws came to be made of resorbable materials such as PLA (polylactic acid - France, 1992) or PGA (polyglycolic acid - US, 1990).

In the early 90s, the Jones procedure was backed up with a lateral reinforcement; towards the mid-90s, the procedure was used without this feature, with equally good results. There were, obviously, several reasons for the increased

rate of success, chief among them the earlier diagnosis and treatment of ACL injuries, which prevented the occurrence of associated lesions whose adverse effect on the eventual outcome was well recognized.

The Jones procedure did, however, have its weak points. It could leave the patient with some stiffness, and, above all, extensor mechanism (patellar and patellar tendon) problems. This is why, in 1982, **AB Lipscomb**³⁵ started using semitendinosus and gracilis tendons pedicled on the tibia, for ACL reconstruction. A similar procedure, using only the semitendinosus tendon, had been proposed previously, in 1975, by **K. O. Cho**⁹.

In 1988, **M. J. Friedman**¹⁶ pioneered the use of an arthroscopically assisted 4-stranded hamstring autograft technique. He was followed, in 1993 by **R. L. Larson, S. M. Howell**²⁶, **Tom Rosenberg**⁵⁵, and **Leo Pinczewski**⁴⁹⁻⁵², who used semitendinosus and gracilis tendons in 3 or 4 strands, with graft placement in a femoral socket. Pinczewski used an “all-inside” technique, with a special large (8 mm) round-headed interference screw, known as the RCI screw. Other groups started using hamstring tendons, with different means of fixation. Tom Rosenberg devised fixation with the so-called Endo-Button that locked itself against the lateral aspect of the femoral condyle. L. Paulos³⁴ used a polyethylene anchor; G. Barrett, a bone graft; S. Howell and E. Wolf, cross-pinning; A. Stahelin⁵⁹, biodegradable interference screws; L. Johnson²⁸, a staple; and others, screws and washers.

In the 90s, hamstring reconstruction with double and quadrupled semitendinosus and gracilis tendons gained popularity as a result of decreased graft harvesting morbidity and smaller incisions. It was also shown that biomechanically, double and quadrupled tendons have superior strength and stiffness compared with bone-patellar tendon-bone grafts and the native ACL.

Looking Forward to the 21st Century

There is every prospect of further progress being made in the field of ACL surgery. As suggested by J. C. Imbert²⁷, it is likely that ligament replacements will take the form of “bioimplants” produced with the aid of cell and tissue culture techniques. This gene therapy will involve transferring defined genes encoded for growth factors or antibiotics into a target ligament, cartilage, or bone. Thus, local cells at the injury site can highly and persistently produce therapeutic substances, leading to better graft insertion site healing as well as faster ingrowth of the graft.¹⁷ Research along these lines is currently being conducted at Pittsburgh, US (Freddie Fu).

Freddie Fu has also conducted studies on graft fixation techniques. In 2003, he concluded that the 10 o'clock femoral tunnel placement more effectively resists rotatory loads when compared with the 11 o'clock position as evidenced by smaller anterior tibial translation and higher in situ force in the graft.³⁶ In 2005, he concluded that although neither femoral tunnel position restores normal kinematics of the intact knee, a femoral tunnel position inside the anatomical footprint of the ACL results in knee kinematics closer to the intact knee than does a tunnel position located for best graft isometry.⁴¹ In addition, Freddie Fu has been a strong advocate of arthroscopic anatomic

double-bundle ACL reconstruction using two femoral and two tibial tunnels.

In recent years, allogenic grafts have become a viable alternative to autologous tendon grafts, as problems with procurement, secondary sterilization, tissue handling, and storage, were recognized and overcome. Allograft tendons have also gained acceptance because there are no problems with donor site morbidity. However, the cost and risk of

infection and disease transmission remain as concerns. There has been no shortage of ideas throughout the years, but only time will tell which of these designs are sound. The fascinating story of ACL surgery has many more chapters to go, and for those who have dedicated themselves to this branch of orthopaedics, there are great things still to come.

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