Review Article

ANTERIOR CRUCIATE LIGAMENT INJURY: A REVIEW

Abstract

Anterior Cruciate Ligament (ACL) injury is now the most debatable ligamentous injury. It has been widely researched over the last 25 years all over the world. Over the last few decades, ACL repair surgery has advanced significantly. Anterior cruciate ligament reconstruction (ACLR) is a well-accepted and well-established surgical treatment for ACL injuries that are becoming more popular worldwide. The timing of restoration and rehabilitation is critical for a successful outcome. Because each type of transplant has distinct benefits and drawbacks, it is critical to carefully pick the graft for each patient. Ultimately, the surgical procedure should adhere to the fundamental principles of ACL biomechanics and anatomy to ensure proper graft location and a positive clinical result. The present review of literature provides the comprehensive search (various databases such as PubMed, PubMed central, google, google scholar, Scopus, science-direct, etc.) ranging from its history, mechanism, clinical examination, and reconstruction of ACL to its latest development.

Keywords: *ACLR, Anterior Cruciate Ligament, surgery, reconstruction*

Introduction

An ACL injury is now the most debatable ligamentous injury and has been widely researched over the last 25 years all over the world. Since the Anterior Cruciate Ligament is the weakest of the 2 cruciate ligaments, it is more prone to tearing than the Posterior Cruciate Ligament. Anterior knee instability caused by ACL rupture is a serious clinical issue. The ACL has a low capacity and a low intrinsic healing rate [1,2]. Thus, patients with knee problems caused by ACL insufficiency may seek ligament restoration to stabilize the tibiofemoral joint and restore normal knee joint function. Numerous publications [3,4] have documented effective ACL repair using donor autograft (patellar, quadriceps tendon, or hamstring) and allograft (patellar, Achilles, hamstring, or tibialis anterior) tendons. ACLR has previously been tried utilizing silver wire [5, 6], Fascia lata [6], and Iliotibial band [7].

ACL repair was historically accompanied by poor outcomes [8,9]. However, there is currently growing interested in re-exploring this avenue. ACLR has remained to be the "gold standard treatment" for young and physically active patients with symptoms of instability attributed to the ACL injury, patients with multiple knee ligament injuries as well as those who remain symptomatic after a course of non-surgical treatment [10]. Therefore, the current review was designed to analyze the postoperative outcome of arthroscopic ACLR when reconstruction fixed with quadrupled semitendinosus tendon autograft fixed in the femoral tunnel using an undo button and in the tibial tunnel using interference screws or Suture disc.

There are no gender or age biases; nevertheless, it has been claimed that females are at a higher risk of ACL damage due to a variety of reasons. According to some research, women may have relatively weak hamstrings and preferentially use the quadriceps muscle group during decelerating. Because the quadriceps muscles are less efficient than the hamstring muscles at limiting anterior tibial translation, activating the quadriceps musculature while slowing down exerts a significantly elevated load on the ACL. A second factor that may increase the risk of ACL damage is increased valgus angulation of the knee [11,12]. When changing directions quickly, female athletes are more prone to position their knees in greater valgus angulations, which increases the stress on the ACL ligament, according to one research that used video analysis. Finally, it has been proposed that estrogenic effects on the flexibility and strength of tissues like ligaments may have a role in predisposing women to injury; nevertheless, this is debatable and has yet to be demonstrated.

ACL injuries in athletes are frequently repaired surgically. ACL repair surgery generally comprises removing the torn ligament and replacing it with a tendon graft, which is commonly obtained from another portion of the patient's knee. This injury is also treated using nonsurgical (conservative) treatments. This is often accomplished through a progressive rehabilitation program that includes exercises to enhance strength and balance [13]. Therefore, surgery is the key area of research in ACLR and it is one of the most common orthopedic operations performed globally. The present review of literature provides the comprehensive search (various databases such as PubMed, PubMed central, google, google scholar, Scopus, science-direct, etc.) ranging from its history, mechanism, clinical examination, and reconstruction of ACL to its latest development.

HISTORY

Since 3000 BC anatomy of ACL and posterior cruciate ligament (PCL) was known in old Egypt. It was then described by the popular Smith Papyrus. Later (460–370 BC) Hippocrates also stated: “the subluxation of the knee joint due to some ligament pathology involvement”. The cruciate was considered to be a part of the neurological system rather than the musculoskeletal system. Claudius Galen, a physician for gladiators in Rome, was the first to explain the real structure of the ACL and to see its traumatic injury in knee instability around 150 A.D. [14]. Galen included concepts from Hippocrates, Plato, and Aristotle into his model of the body since he had both intellectual and medical training. His thorough anatomic dissections revealed that the cruciate ligament is a supporting component to the knee that prevents aberrant mobility [14,15]. The Weber brothers of Goettingen, Germany, were the first to report the anterior-posterior displacement of the tibia following ACL transection in 1836. They also detailed the knee's roll and glide mechanism as well as the tension distribution of the various cruciate ligament bundles [14].

Amedee Bonnet of the Lyon school authored a dissertation on joint diseases generating bloody effusions in 1845, in which he examined knee injuries. The author reported three key symptoms of an 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” [16]. Georges K. Noulis (1849-1919) properly characterized the role and function of the ACL in 1875 and demonstrated how the ligament's integrity should be evaluated with the knee in extension. The 7-test developed by Noulis was recognized as the Lachman test, which is currently widely utilized [14].

A. Mayo Robson (Leeds, UK) conducted "the first cruciate (or, as it was still known, critical) ligament repair in a 41-year-old miner who had been wounded in an earth fall 36 months before" in 1895. [17]. At their femoral attachments, the two torn critical ligaments were repaired in place. 6 years later, the patient characterized his knee as "totally strong," and he was able to walk without a limp and run; he had never missed a day of work since his knee repair [15,17].

F. Lange of Munich was the first to execute the first ACL replacement in 1903, utilizing braided silk connected to the semitendinosus as a ligament substitute [18]. The method did not succeed, prompting Lange's compatriot M. Herz to accomplish that while the usage of silk was a fine try, the effort to emulate nature had been unsuccessful. Ernest W Hey Groves of Bristol was the only one to disclose the treatment surgically for ACL rupture in 1917. The first procedure was the use of an iliotibial band transplant on an unstable knee that had been damaged by a horse kick [18,19].

Willis C. Campbell of Memphis, Tennessee, described "the first application of a tibia-based graft of the medial one-third of the patellar tendon, the patellar retinaculum, and a part of the quadriceps tendon" in 1935. Drilling two tunnels, one in the femur and one in the tibia, was required for the method. At the femoral tunnel exit, the graft was sewn to the periosteum. The procedure was followed by three weeks of posterior splint fixation. [20].

IVAR PALMER addressed the lack of spontaneous recovery of a full ACL rupture in 1938 [21] and the consequent significance of reconstruction. Harry B. Macey of Rochester, Minnesota, reported the 1st method involving the semitendinosus tendon in 1939. The tendon was left connected to the tibia before being sutured to the periosteum after passing via a tibial and a femoral tunnel.

D.H. O'DONOGHUE described his ACL reconstruction procedure in 1950, which included a suture weave through the tibial stump and its transit via a tunnel in the femur, as well as its use in postoperative immobility for four weeks with the knee maintained at 30° [22]. He performed research on ACL repair in dogs in the 1960s and It was revealed that even after a suture repair of the ligament, the repaired ACL only attained 10% of its normal strength after four weeks [23].

D. L. MacIntosh of Toronto developed a method in 1972 that included predicting a fascia lata graft on the tibia, passing it beneath the lateral collateral ligament, and attaching it to the intramuscular septum (MacIntosh 1 – the extra-articular MacIntosh). In a later revision (MacIntosh 2), the graft was resurrected intra-articularly (with its weakest part spanning the joint) and went via a tibial tube. The technique's most notable aspect, however, was the graft's extra-articular routing. [24].

M. Lemaire presented his proprietary extra-articular ligament repair procedures in 1975. In the middle, gracilis was utilized to treat medial collateral ligament damage, whereas fascia lata has been used on the outside to repair torn ACLs. The success rate for patients with isolated ACL injuries was 91 percent. Lemaire indicated in his conclusions that any concomitant meniscal lesions had a bad prognosis [24].

D. J. Dandy was the 1st to use an arthroscopic technique to implant a ligament replacement strengthened with carbon fiber in 1981. His findings were dismal [25,26]. Since the carbon particles were accumulated in the liver and synovial membrane, this method was not used. Subsequently, dacron and Gore-Tex were utilized as viable options for doing ACLR with minimum harm. By the end of the 1980s, there was a very high rate of synovitis, as well as no ligament rupture. As a result, this ACLR method was abandoned.

Clancy and colleagues [27] described a series of eighty ACL repairs in 1982 utilizing the medial 3rd section of the patellar tendon and extending the harvesting of the proximal portion of the graft with a block of patellar bone. Clancy later improved his method by removing the graft's distal end from the tibial tubercle [28]. In the 1990s, this Bone-Patellar tendon-bone autograft was considered the gold standard technique. [29].

Later on, several mechanisms and techniques has been discovered and developed which are discussed under the following heading.

MECHANISM AND RISK FACTOR OF INJURY

Competitive and recreational participation in sports is increasing. Concurrently, the number of injuries, particularly anterior cruciate ligament rupture, has increased. As a result, there has been a surge in interest in and study of ACL injury prevention. Understanding the injury mechanism and the risk factors that predispose to the damage are the first stages in injury prevention [30].

ACL injuries can be devastating in the nearby period because of the loss of athletic activity, break from work, and economic expenditures accompanying therapy [31]. Furthermore, ACL injuries can have lasting effects on the afflicted knee, as well as changes in knee kinematics, related meniscal and cartilage degradation, and, eventually, osteoarthritis of the knee [32]. Injuries of this type are believed to happen at a rate of more than 200,000 per year in the US alone. [33]. A large number of ACL ruptures (about 75%) occur with little or no impact at the time of injury [34]. The latest evidence employing a variety of modalities, such as computer modelling, video analysis, cadaveric investigations, and epidemiologic data, has all contributed to our knowledge of the mechanism of damage for the ACL tears.

The three primary causes of ACL damage are direct contact, indirect contact, and noncontact damage[34-36]. When an individual or item impacts the knee directly, a direct contact injury occurs. Indirect contact injuries happen when an individual or object impacts a portion of the body besides the knee, triggering extreme forces to be transmitted via the knee (for example, a direct hit to the thigh that causes the femur to move posteriorly in respect to the tibia) and leading in ACL failure. Noncontact injuries occur when a slowing down or changes in direction (pivot) force is given to the knee, but they frequently include an erroneous neuromuscular firing of tissues all around the knee, resulting in translation of the tibia on the femur and ACL collapse [34-36]. Non-contact mechanisms seem to be responsible for 60–70 percent of ACL injuries.

Furthermore, to understand the mechanics of damage, it is critical to comprehend the potential risk factors for ACL injuries. There are risk factors that are modifiable and non-modifiable that should be considered. Risk variables may also be divided into three categories: biomechanical, anatomic, and neuromuscular; all the modifiable risk factors in every one of those classes should be recognized to assist reduce injury risk [30].

According to Alentorn-Geli et al. (2014), "a variety of anatomical risk factors such as higher generalized joint laxity, quadriceps angle (Q-angle), anterior pelvic tilt, femoral anteversion, subtalar pronation, and body mass index" (BMI). Other anatomical risk factors are specific to the inherent knee architecture, such as a narrow notch width, reduced ACL size and strength, and greater posterior tibial slope" [37].

Beighton et al. 1973 published their findings that the Beighton criteria for generalized joint laxity [38] specify knee hyperextension beyond 10^0. At least one research, conducted by Söderman et al 2001, reported a higher relative risk of ACL damage in females with widespread joint laxity and knee hyperextension on assessment [39]. Increases in valgus-varus motion and external-internal knee rotation have been associated with knee joint laxity [40]. This increased mobility around the knee may place athletes at the hazard of landing in the provoking position most frequently accompanied with ACL damage, according to Boden et al 2009 [41]**.** Uhorchak et al 2003 found in an army cadet population that hyperextension of the knee put patients at higher risk for ACL damage [42]. In that cohort, approximately eighty percent of individuals with ACL injuries exhibited knee joint hyperextension on the exam, but less than 40 percent of healthy individuals had knee joint laxity. Söderman et colleagues demonstrated in a population of females that genu recurvatum placed athletes at risk of reduced limbs injury [39].

CLINICAL EXAMINATION OF ACL INJURY

This includes inspecting, palpating, measuring, and moving the knee joint. Then testing for cruciate ligaments, collateral ligaments, and menisci are performed to aid in diagnosis and treatment planning.

The different tests done [43,44] for ACL insufficiency are the Anterior Drawer test, Lachman test, Jerk test, Pivot shift test, Flexion rotation drawer test, McMurray's Test, Apley's Grind Test, and Slocum Anterior Rotatory Drawer test (Figure 1).

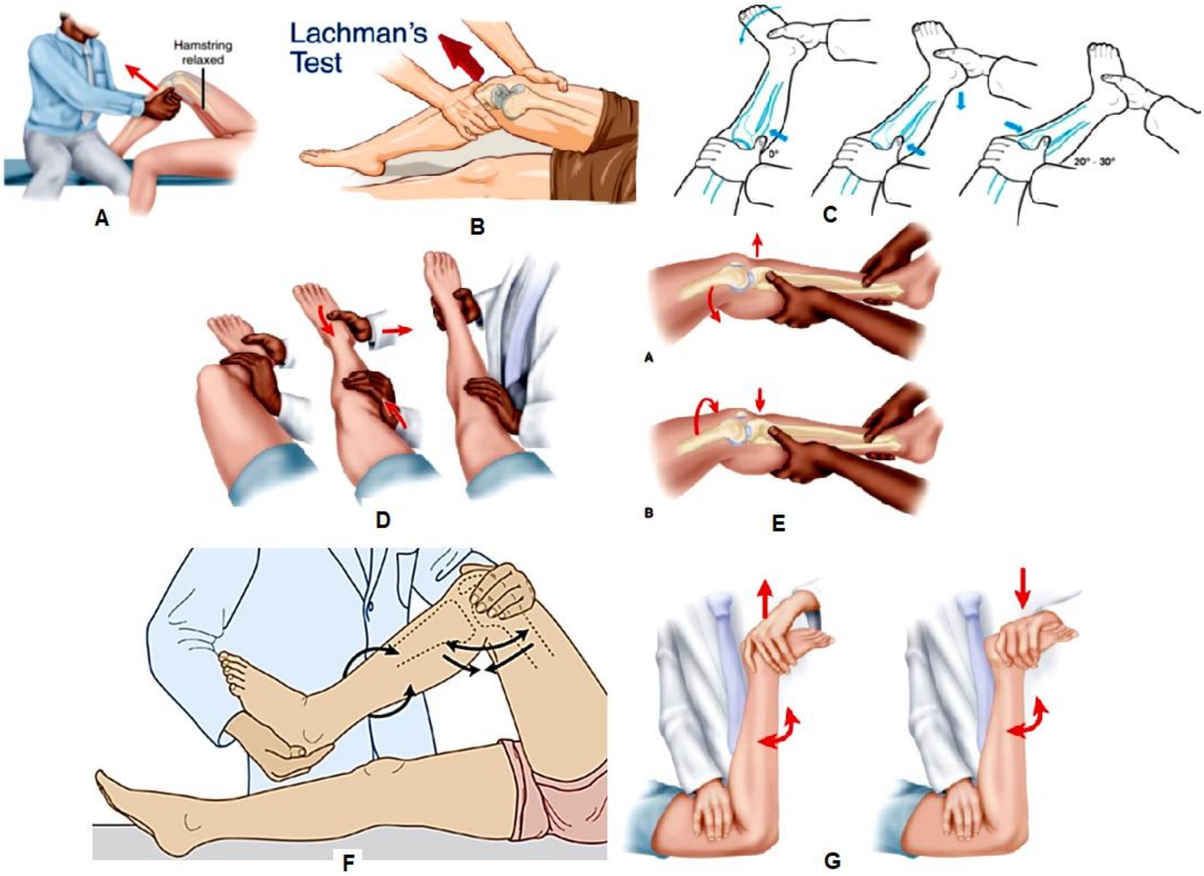

Figure 1: Clinical examination of ACL injury by different test (A: Anterior Drawer test, B: Lachman test, C: Pivot shift test, D: Jerk test, E: Flexion rotation drawer test, F: McMurray's Test, G: Apley's Grind Test**)**

ACL RECONSTRUCTION TECHNIQUES

Over the last few decades, ACL repair surgery has advanced significantly. ACLR is a well-established and well-accepted surgical procedure for ACL injuries that are increasingly being used across the world [45]. Open surgery, which may need the release of the vatus lateralis muscle and lateral dislocation of the patella, is now considered outdated, having been surpassed by arthroscopy. The arthroscopic approach is the best of all since the graft is collected without opening the joint, and bone drilling and rebuilding are accomplished deprived of opening the joint. It offers the advantages of precise bone tunnel insertion, aesthetic scars, and minimal morbidity. Graft materials for ACL repair include autografts, allografts, and synthetic materials. The patellar tendon, quadriceps tendon, semitendinosus-gracilis tendon, semitendinosus tendon, iliotibial band, and plantaris tendon are the autograft possibilities. The patellar tendon was the most commonly utilized and was thought to be the gold standard. According to numerous researches, the morbidity of the donor site is the most serious disadvantage of this procedure, and it is enormously problematic, if not impossible, to cure [46].

Arthroscopy is regarded as one of the most significant advances in the diagnosis and treatment of orthopedic patients throughout the 20th century [47]. The term "arthroscopy" is derived from the Greek words "arthro" (joint) and "scope" (to observe).

Masaki Watanabe used an arthroscope for the first time for therapeutic reasons in 1955, when he performed arthroscopic excision of a xanthomatous tumor from the superior recess of the knee [48]. In 1962, he was the first to conduct an arthroscopic partial meniscectomy. He is rightfully known as the "Father of Modern Arthroscopy." He created the No. 21 arthroscope, which served as a manufacturing model.

AUTOGRAFT

Autologous fascia lata graft

It is believed that the 1st effort of an anatomical reconstruction of the ACL was carried out by **Grekov in 1914** [49]. He operated on a 40-year-old man with knee dislocation following a fall from the third floor. With allegedly good results, he employed a free fascia graft that ran through drill holes in the femur and was sewn to the ligament remains on the tibia.

In **1917, Hey Groves** published the first properly documented ACLR surgery [50]. The author cut a strip of fascia lata from its insertion in Gerdy's tubercle, guided it through a tunnel in the tibia and femur, and sewed it to the tibial periosteum [50]. Hey, Groves reasoned that by leaving the tendon connected to the muscle belly, the tendon's blood supply and nourishment would be retained. He reported 14 more cases two years after, in which he changed his method by leaving the graft connected to the tibia and removing it at the higher end. The author also emphasized the significance of oblique graft placement to increase the stability of rotation, a concept that took more than eighty years to become broadly accepted. Furthermore, Hey-Groves discovered anterolateral tibial subluxation, a condition that was later used by Galway et al. (1972) to design the pivot-shift test, which is commonly used to detect ACL insufficiency. [51].

Mirouse et al. (2016) performed retrospective research on 30 athletes to assess return to sports and functional outcomes following revision ACL repair using a fascia lata graft. The functional outcomes of revision ACL repair using fascia lata graft were good, with comparable return-to-sports rates as with previous procedures. In revision ACL surgery, fascia lata offers a dependable graft. [52].

Bone Patellar tendon-bone (BPTB) graft

Ernst Gold described a case of a 27-year-old woman with the instability of knee who had ruptured her ACL skiing two years previous in 1928 [53]. He inserted a distal strip of extensor retinaculum and the medial border of the patellar tendon into the joint via a tibial tunnel. With interrupted locking sutures, this extensor retinaculum strip was subsequently anchored to the anterior–superior portion of the PCL.

Campbell described the first usage of a tibia-based graft of the medial 3rd of the patellar tendon, the prepatellar retinaculum, and a piece of the quadriceps tendon in 1936 [20].

Campbell's method involved drilling two tunnels, one in the tibia and one in the femur. At the proximal end of the femoral tunnel, the graft was sutured to the periosteum. The technique did not quickly gain widespread acceptance [20]. It was revived some years later by MacIntosh.

Abbott reported in 1944 that, in the absence of a fracture, examination of the knee joint was all too frequently shallow and hasty, with numerous ligamentous damage patterns lumped together as “internal derangements of the knee” and treated poorly. [54]. He proposed that "much higher accuracy in diagnosis and therapy is a must in a joint of such diverse complexity" to avoid the ultimate development of a painful, unstable joint with recurring effusions, subsequent arthritic changes, and the consequent irreversible impairment.

JONES developed a novel surgical technique for the repair of an irreversibly injured ACL (Bone-Patellar Tendon-Bone Grafts) in 1963. [55] The procedure was criticized since the graft was so small that the femoral tunnel had to be drilled at the anterior border of the notch rather than at the insertion of the original ACL. Although the procedure was basic, it resulted in minimum surgical stress and so acquired broad popularity. BRÜCKNER later demonstrated a similar technique utilizing the medial one-third of the patellar tendon in 1966 [56]. By 1969, FRANKE had improved on the approaches provided by Jones and Bruckner. Franke was the first to employ a free bone-patellar tendon-bone graft, which consisted of one-quarter of the patellar tendon with bone blocks taken from the patella and proximal tibia at opposite ends of the graft. [57]. MARSHALL et al. (1979) utilized the center third of the patellar tendon but left it distally connected and added a strip of quadriceps tendon for length, which was fastened in the over-the-top position to the lateral condyle [58]. By the 1990s, the "Gold Standard of therapy" was a free bone-patellar tendon-bone graft obtained from the central one-third of the patella. This approach was dubbed the "JONES PROCEDURE" in honor of Kenneth Jones’ pioneering work in the 1960s [55].

Kabir and colleagues 2020 [59] have examined the functional success of Arthroscopic ACLR utilizing Bone-Patellar tendon-bone autograft on 25 patients with persistent ACL deficiency. ACLR with a BPTB graft can stabilize the knee without causing loss of motion by closely replicating the original ACL with no risks or problems. It is beneficial in high-demand patients and a cost-effective alternative with a high patient satisfaction rate for ACL repair.

Hamstring graft

In 1934, **RICCARDO GALEAZZI**, an Italian orthopedic surgeon, demonstrated a method for ACLR utilizing the semitendinosus tendon technique. Along with it, he kept his patient in a cast for four weeks and partially weight-bearing for six weeks. An operated patient in the year 1932, who had a follow-up of 18 months, finally showed a stable knee with full extension and only a mild reduction of flexion. Riccardo was the 1st person to ever publish the use of hamstrings tendon autograft in ACLR [60].

MACEY later utilized the semitendinosus tendon for ACL repair in 1939 [61]. The semitendinosus muscle's tendinous part was extracted alone. During harvesting, he stopped just short of the musculotendinous junction and connected the graft to a knee held in full extension.

Following that, in 1950, LINDEMANN utilized the semitendinosus tendon as a dynamic stabilizer of ACL deficient knees [62]. Augustine [63] described the same technique. MCMASTER et al. [64] utilized the gracilis tendon alone in 1974. He left the gracilis tendon connected distally and dragged it through the femoral and tibial tunnels before stapling it to the lateral condyle. LIPSCOMB B published the first paper detailing a strategy that used both the semitendinosus and the gracilis in 1982 in addition to a plethora of suggested graft attachment techniques [65].

Lipscomb began utilizing pes anserinus (gracilis and semitendinosus) tendons pedicled to the tibia in 1982 to minimize harvest site morbidity accompanying with BPTB grafts [65]. Friedman initiated the usage of an arthroscopically aided 4 stranded hamstring transplant method in 1988 [66]. The hamstring tendons have been increasingly popular in recent years. Once harvested, the tendons are looped around to form a quadruple strand construction, which is then sutured together to form the last transplant. There is a misconception that hamstring grafts are linked with reduced donor site morbidity, however, studies have nevertheless found anterior knee pain and kneeling discomfort, albeit at a lower frequency than BPTB grafts [67-68]. Several studies [69,70] have suggested that the hamstring tendons can regenerate into a ‘tendon-like' structure, allowing complete hamstring function, and has also been employed in revision ACL repair.

Early rehabilitation, which is critical to the success of ACL repair graft attachment in the hamstring tendon, showed difficulty at first. Nevertheless, the fixation strength of soft tissue interference screws and endo-buttons is equivalent to that of BPTB grafts.

Recently **Rajadurai et al 2020** conducted an observational study on functional evaluation of arthroscopic ACLR using a single bundle of quadrupled hamstring graft fixed with endo button at the femoral side and with interference screw at the tibial side using transportal technique. There were 40 cases in the study. The period from injury to surgery varies from 1 week to one year with an average time of 3 months. Patients were followed up for a minimum period of one year and assessed with a Lysholm score. The maximum score achieved was 95 and the minimum score was 71. The study produced reproducible good functional results with minimum morbidity and helped patients get back to their previous job [71].

BPTB *vs* Hamstring Tendon Graft (HT)

The patellar tendon and hamstring tendon grafts are mostly utilized nowadays for ACLR surgery. Every kind of graft has its own benefits and drawback but meta-analysis studies show both grafts work very well concerning functional outcomes.

The HT graft was first criticized for its lack of stiffness and strength, but with amended methods, the quadruple-stranded grafts were equivalent to native ACL. Several research on the biomechanical features of ACL restoration with either HT or BPTB grafts have been reported in the literature. The majority of the investigations, however, employed incorrectly sized grafts or varied fixation methods. Using the identical fixation methods, Wilson et al. [72] discovered that the triple-stranded HT graft had a mean load failure of 2,422 N vs 1,784 N for the BPTB graft. The stiffness difference between the two grafts was not statistically significant.

Several controlled trials have been carried out since 2000 to compare the clinical outcomes of HT and BPTB grafts for ACL repair. It is worth noticing that the majority of the studies employed distinct fixation methods, patient outcome measures, and varying lengths of follow-up, necessitating an assessment of each study's quality. Eberhard et al. [73] published a prospective randomized trial comparing the BPTB to the HT graft for ACL repair. The surgery was carried out by a single surgeon, and both kinds of grafts were secured utilizing interference screws. The research comprised 71 patients, and the manual Lachmann's test and the KT 1000 arthrometer were utilized to measure stability. The result was further assessed using the Tegner activity level, Lysholm score, and International Knee Documentation Committee (IKDC) ratings. There was no significant difference in any outcome measure at the two-year follow-up, except that patients in the HT group could walk on the knee significantly better than patients in the BPTB group.

Laxdal et al. compared BPTB grafts to three-strand semitendinosus (ST) grafts and four-strand ST and gracilis grafts in a similarly structured prospective randomized trial [68]. 125 individuals were followed for a mean of two years. There was no statistically significant difference in clinical result measures, although patients in the ST-G and ST groups were considerably more able to walk on the knee than those in the BPTB group.

Holm et al. evaluated the clinical results and osteoarthritis prevalence in the HT and BPTB groups in a prospectively randomized trial [74]. At 10 years, 79 percent of patients who were entitled to the follow-up exhibited no significant difference in clinical results. The damaged knee had a considerably greater rate of osteoarthritis, although there was no statistical difference between the 2 groups.

Harilainen et al. found a variety for BPTB grafts repaired with intervention screws and HT grafts fixed proximally with a suspension fixation comparable to Endo-Button but managed to make by cutting an AO plate and connecting the graft to the plate with a Dacron loop and distally by tying it around a 4.5 mm cortical screw with a sling [75]. There was no significant difference in the IKDC score, Lysholm score, Kujala patellofemoral score, or Tegner activity levels between the 2 categories or between the two and five-year follow-up. In addition, there was no statistically significant difference between males and women. There was also no significant difference in the radiological assessment of the joint gap between 2 groups at the 2 and 5-year follow-ups.

Some researchers have found that the findings of the two groups are not comparable. Aune et al. showed that the HT tendon group had improved kneeling and single-leg hopping at six and twelve months in a prospective randomized controlled study of 72 patients [76]. The HT tendon category also exhibited higher isokinetic extension strength at six months, but there was no difference at twelve or twenty-four months. The isokinetic flexion strength of the HT tendon category was significantly lower than that of the BPTB group. At 3 years, Beynnon et al. found that the HT category employing two-strand semitendinosus tendons had lower knee flexion than the BPTB graft [77]. These data refute the hamstring tendon regeneration theory.

Following a review of numerous recent researches, it is obvious that the debate about the best autograft is far from finished. Various well-designed prospective randomized studies, albeit having a smaller sample size, reveal no meaningful difference between the 2 grafts aside from a reduced frequency of anterior knee discomfort in the HT category. There is still no convincing data to suggest that BPTB grafts are not the gold standard for ACL repair.

ALLOGRAFTS

The usage of allograft has gradually increased during the previous decade and is anticipated to continue. This is because allografts can eliminate the drawbacks accompanying morbidity of the donor site. In 1929, Eugene Bircher, well recognized for his revolutionary effort in arthroscopy, described his understanding using kangaroo tendon as an augment in addition to a single graft and was followed four years later by Micheli, who published his results [78,79]. Kangaroo grafts, like other xenografts, were used seldom, but the utilization of human tissues like the tibialis anterior tendon, calcaneal tendons, patellar, and Achilles tendons gained favor. [80]. Nevertheless, the allograft became controversial in the 1990s because of the increased risk of viral illness transmission (e.g. HIV, Hepatitis C). Sterilization techniques used at the time were known to affect the collagen structure and mechanical characteristics of the graft [81]. Nevertheless, because of the development of graft-friendly sterilizing methods, Allografts have regained some ground. Disease transmission through allografts is decreasing with adequate aseptic tissue procurement, sterilization, and donor screening. HIV transmission from a properly screened allograft occurs at a rate of around 1 in 1.5 million. The allografts can be sterilized in addition to being screened. [82]. Techniques not now utilized (ethylene glycol sterilization and high dose radiation) might have led to structurally weak graft tissue, resulting in unsatisfactory functional results. Some tissue banks now depend only on aseptic transplant procurement or sterilization using proprietary chemical solutions. As a result, while analyzing a research study, it is critical to understand the graft procurement and sterilizing procedure.

Other drawbacks of utilizing an allograft include the host's immunogenic reaction to the graft and delayed graft integration as compared to autografts. A historic examination of 9 allografts retrieved following postmortem at 2 years revealed inadequate vascularisation in the graft's center, which had remained acellular [83]. In contrast to earlier reports of excellent allograft integration after 18 months [84], our study indicates that incorporation may take 3 years or more. Despite the foregoing issues, allografts are still widely utilized, and it is critical to determine whether the data supports the use of allografts in ACL repair.

Ho Noh et al. has reported a randomized controlled experiment comparing free Achilles tendon allograft versus HT grafts in 65 patients over 2 years. Short-term results, including the Lachmann test, Lysholm score, IKDC score, and Tegner daily activities score, were shown to be equivalent to autogenous HT grafts**.** [85].

Foster and colleagues. recently carried out a comprehensive analysis of level I and II report to investigate the graft origins influencing functional results in ACL repair [86]. There was 27 research with 2,184 patients that looked at autograft reconstructions and only four studies with 137 patients that looked at allograft reconstructions out of the 31 that were included. They discovered a scarcity of prospective data comparing allograft with autograft, as well as trials with small populations. Despite this, there was no difference in outcomes between allografts and autografts in patients with up to 6 years of follow-up.

Surprisingly, in this research, the reduction in morbidity while utilizing an allograft was not supported. There is also a potential of disease transfer in allografts, albeit this is uncommon. Despite these concerns, several researchers remain optimistic about the potential of allografts in ACL repair.

SYNTHETICS

In the early 1990s, there was a surge of interest in synthetic grafts to solve the drawbacks of allografts while retaining the positives like the absence of donor site morbidity and simpler surgical procedures. Dandy et al. were the first to use an arthroscopic technique to implant a carbon fiber reinforced ACL replacement in 1982 [26]. However, despite promising first findings, there have been instances of early ruptures caused by inadequate resistance to twisting pressures, resulting in carbon accumulation in the liver and inflammatory synovitis in the knee.

Ligaments constructed from expanded polytetrafluoroethylene (PTFE) (Gore-Tex) grafts were authorized for use in failed autologous grafts in the United States in 1986. The ultimate tensile strength and stiffness of these synthetic ligaments were extremely high. They had very positive results at first, but later investigations revealed problems in 76 percent of patients, with up to 29 percent graft failure rate, tunnel osteolysis, and PTFE particle deposits in lymph nodes distal to the knee [87,88]. They were finally phased out of the market in 1993.

After being utilized in acromioclavicular joint injuries, the Dacron ligament was eventually used for ACL restoration. This ligament is composed of polyester and is intended to permanently replace the ACL. Despite early optimistic results [89], literature [89,90] showed a very high rupture rate extending from 29 to 60 percent. Whereas presenting the long-term results, the authors also observed that 83 percent of the patients had degenerative alterations in the knee joint, with just fourteen percent having acceptable stability and functional result [89]. This product was later taken off the market in 1994.

After all of the past disappointing outcomes from artificial ligaments used for ACL repair, there have been some hopeful findings of the usage of the Ligament Advanced Reinforcement System (LARS ligament). These ligaments are composed of polyethylene terephthalate and have a structure that permits tissue ingrowth in the intra-articular area. Lavoie et al. reported in their research of 47 patients with a follow-up period ranging from 8 to 45 months, with positive outcomes in subjective metrics and a satisfactory Tegner activity level. Further research from the same group compared the outcomes to BPTB autografts and discovered comparable outcomes with superior subjective and objective findings for LARS ligament in the early years. The LARS ligament findings are positive, but long-term effects are still expected.

Biocompatibility is the ultimate need for these materials, according to research in the field of artificial ligaments. Mechanical characteristics should be equivalent to those of natural ligaments. Despite several research, each material has been proven to have a disadvantage, and the hunt for the optimal synthetic graft continues.

Conclusion

The timing of restoration and rehabilitation is critical for a favorable result. Because each type of transplant has different benefits and drawbacks, it is critical to carefully pick the graft for each patient. Finally, the surgical procedure should adhere to the fundamental principles of ACL biomechanics and anatomy to ensure proper graft location and a positive clinical result.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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