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Contemporary Graft Options in Anterior Cruciate Ligament Reconstruction

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The optimal graft choice for anterior cruciate ligament (ACL) reconstruction remains controversial. Many factors must be considered to select the appropriate graft for each patient. Commonly used autografts include both hamstring tendon and bone-patellar tendon-bone, with long-term studies supporting either graft choice. There is also increasing support for quadriceps tendon autograft. The use of allograft is also increasing, with the benefit of less donor-site morbidity, although there is concern about slower graft incorporation time and disease transmission. Synthetic grafts are yet another option; however, further studies for an ideal synthetic ACL alternative are still underway. The goal of this article is to present the benefits and drawbacks of various ACL graft reconstruction choices so the surgeon can select the best graft for each patient.

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The anterior cruciate ligament (ACL) plays an important role in knee stability. The native ACL serves as the primary restraint to prevent anterior translation of the tibia relative to the femur and acts as a secondary restraint to tibial rotation and varus/valgus stress.[1,2] ACL reconstruction is indicated to prevent knee laxity and functional instability during activities of daily living and athletic activity. Reconstruction also serves to decrease the risk of meniscal injury and the eventual development of degenerative joint disease.[3]

Nevertheless, the optimal graft choice for ACL reconstruction remains controversial. Ideal properties of an ACL graft include structural and biomechanical properties that are similar to those of the native ACL, rapid biological remodeling and incorporation into host tissues, and minimal donor-site morbidity.[4] Appropriate graft selection for an ACL reconstruction requires a consideration of many factors, including a patient's age, activity level, and postoperative physical goals, as well as the availability of allograft and autograft tissue, any previous surgeries, medical comorbidities, and the experience and preference of the surgeon. Generally, graft choices can be divided into 3 categories: autografts, allografts, and synthetic grafts. Currently, the most common choices for autograft include ipsilateral or contralateral patellar tendon, hamstring tendon (HT, semitendinosus and gracilis tendons), and the quadriceps tendon (QT). Allograft choices include the previously mentioned autograft options in addition to the tibialis anterior (TA), tibialis posterior, and Achilles tendon (AT). Synthetic options include scaffolds, stents, and prostheses.

Comparisons between grafts can be performed on the basis of many criteria, including biomechanical properties, biology of healing, ease of graft harvest, fixation strength, graft-site morbidity, average graft size, and return-to-sport guidelines. The goal of this article is to review the graft options for ACL reconstruction and to present the risks and benefits of each graft choice to help the surgeon determine the best graft for each patient.

Autografts

Historically, most surgeons have preferred autografts to allografts; the 2 most common choices of autografts have been bone-patellar tendon-bone (BPTB) and HTs.[5] Autografts decrease the risk of disease transmission and offer the most biologically favorable option for incorporation, although often at the expense of donor-site morbidity. Nonetheless, ow-

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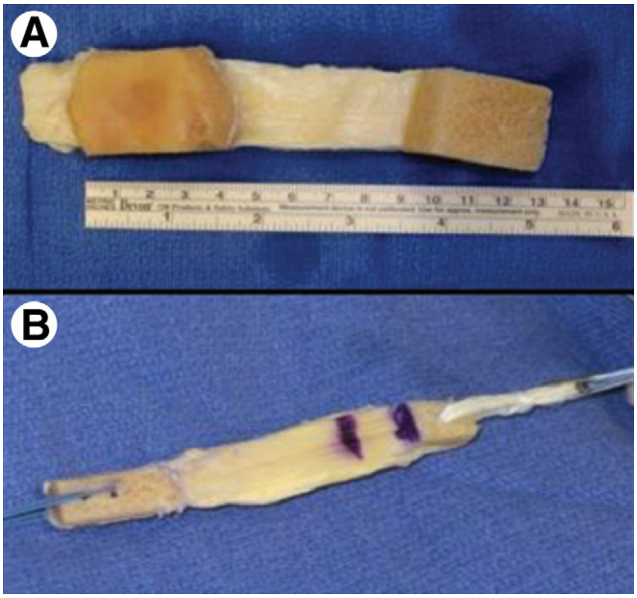

Figure 1 An example of bone-patellar tendon-bone allograft (A) after harvest from the patient and (B) after preparation for reconstruction. Reprinted with permission of Vyas et al.[10]

ing to their superior mechanical properties, autograft tendons are generally preferred to allograft tendons for ACL reconstruction, especially in younger more active patients.[6] Autografts also have the most evidence of success at long-term follow-up.[7-9]

Bone-Patellar Tendon-Bone

BPTB autograft is the most commonly used autograft in young and active patients. The graft is generally taken from the middle third of the patellar tendon, with bone plugs from the patella and tibial tubercle (Fig. 1). There are data verifying the long-term success of BPTB in ACL reconstruction, including faster incorporation and healing into bone tunnels when compared with soft-tissue grafts, making it a common choice for ACL reconstruction.[11] Furthermore, the biomechanical properties of BPTB are similar to those of native ACL (Table 1). While the native ACL has an ultimate tensile load of 2160 N with a stiffness of 242 N/mm and a cross-sectional area of 44 mm^2, BPTB autograft has an ultimate tensile load of 2977 N, a stiffness of 620 N/mm, and a cross-sectional area of 35 mm^2.[12]

One of the advantages of BPTB autograft is bone-to-bone healing and a more rapid incorporation and healing at the graft attachment site. The bone plugs are placed into the femoral and tibial tunnels and allow for healing by creeping substitution that is stronger and faster than soft-tissue-to-bone healing.[4] With bone-to-bone healing, the graft integrates into the host bone within 6 weeks, whereas soft-tissue grafts can take 8-12 weeks or longer to achieve healing at the tendon–bone interface.[4] Incorporation is a 4-stage process, including graft necrosis, cellular repopulation, revascularization, and collagen remodeling. Animal models have shown slower incorporation rates into bone tunnels with soft-tissue grafts compared with bone-plug grafts such as BPTB.[13] A recent rabbit model study showed that bone-to-bone healing was mature at 8 weeks, whereas tendon-to-bone healing was mature at 12 weeks.[14]

Historically, clinical results after ACL reconstruction have been most consistent with use of BPTB autograft. Reinhardt et al[15] performed a systematic review of level-I randomized control trials comparing BPTB with HT (semitendinosus and gracilis) autografts. Only 6 of 28 studies fit the inclusion criteria, which included a minimum of 80% follow-up at a minimum of 2 years. The studies comparing BPTB with 4-strand HT demonstrated an overall graft failure rate of 4.2% in the BPTB group and 10.9% in the HT groups. The authors also showed that in 5 of the 6 studies reviewed, there was an increased side-to-side difference in anterior laxity in the HT groups compared with the BPTB groups.[15] With re-

Table 1 Common ACL Grafts, Including Data from West and Harner[4]

Tissue	Ultimate Tensile Load (N)	Stiffness (N/mm)	Cross-Sectional Area (mm^2)	Advantages	Disadvantages
Intact ACL	2160	242	44		
Bone-patellar-tendon bone (10 mm)	2977	620	35	Bone-to-bone healing	Anterior knee pain, larger incision
Quadrupled hamstring	4090	776	53	Small incision, less anterior knee pain	Hamstring weakness, soft-tissue healing, bone tunnel widening
Quadriceps tendon (10 mm)	2352	463	62	Bone-to-bone healing, thick, can be made into 2 bundles	Anterior knee pain, larger incision, patella fracture if take bone plug, soft-tissue healing
Patellar tendon allograft	1403	224		Bone-to-bone healing	Longer incorporation
Achilles allograft	1189	741[3]	105		Longer incorporation, soft-tissue healing
Tibialis anterior allograft	3012	343			Longer incorporation, soft-tissue healing

gard to activity level after reconstruction, two studies demonstrated significant differences in activity level at final follow-up between patients with 4-strand HT and those with BPTB autografts, most notably that a significantly higher percentage of patients returned to their preinjury activity level after BPTB reconstruction compared with the HT cohort.[16]

Despite the purported benefits of BPTB autografts, a Cochrane review that compared outcomes between BPTB autograft and HT autograft in 19 trials composed of 1597 young middle-aged adults showed no statistically significant differences between the 2 graft choices for functional assessment, return to activity, Tegner and Lysholm scores, and subjective measures of outcome.[9] There was also no difference between 2 graft options with regards to rerupture or International Knee Documentation Committee (IKDC) scores. However, all tests (instrumental, Lachman, pivot shift, etc.) measuring static stability consistently showed that BPTB resulted in a more stable knee compared with HT reconstruction.

Other metrics such as cost-effectiveness have been studied as well, demonstrating that BPTB autograft is a cost-effective option when compared with BPTB allograft. One center demonstrated that after performing 160 BPTB ACL reconstructions (110 autograft, 50 allograft), the mean total expense difference between autograft and allograft was $1091.[17] In other words, the center saved nearly $1100 every time autograft was used instead of allograft during BPTB ACL reconstruction.

Although BPTB autograft has many benefits, there are also drawbacks that must be considered, including the risk of donor-site morbidity, an increased risk of patellar fracture, damage to the extensor mechanism, and graft–tunnel mismatch. The increased incidence of anterior knee pain is a commonly discussed disadvantage of BPTB autograft. Evidence has shown that there is a higher incidence of pain with kneeling and knee walking when comparing BPTB autograft with HT autograft.[15] Three other studies evaluating anterior knee pain after ACL reconstruction showed a higher incidence of pain in the patellar tendon autograft group (range: 25%-36%) compared with the HT autograft group (range: 7%-14%).[18-20] Furthermore, in a level-I randomized control trial with 8-year follow-up, the BPTB autograft group had statistically significant greater donor-site morbidity during kneeling and knee walking when compared with HT autograft.[21] In contrast, however, Shelton et al[12] showed no difference in anterior knee pain between patients after ACL reconstruction with either patellar tendon allograft or autograft. A surgeon should consider these factors when discussing ACL graft options with patients whose sport, occupation, or religion demands significant kneeling.

Another potential drawback of BPTB is postoperative quadriceps weakness. O'Neill[22] reported a decrease of at least 10% in quadriceps strength in 34% of patients who underwent reconstruction with BPTB, and in 13% of patients with reconstruction using HTs. It is possible that some degree of this is a result of routine weakness after reconstruction due to pain-related neuromuscular feedback and atrophy, although the 20% difference between the groups is not insignificant and discussion of this issue with patients before surgery may be appropriate to establish realistic postoperative expectations.

The issue of graft–tunnel mismatch must also be considered when using BPTB for ACL reconstruction. Whereas HT and QT have a variable length, BPTB has a relatively fixed length between bone plugs, which can be problematic if the length of the graft does not match the prepared tunnel lengths. Although the ideal length of the BPTB graft should fit the length of the drilled femoral tunnel plus the lengths of the drilled tibial tunnel and the intra-articular distance, anatomic variations such as patella alta or baja and surgical technique such as improper placement of the femoral and tibial tunnels may cause a graft to be either too long or too short. To compensate for mismatch, multiple solutions have been proposed, including recession of the femoral bone plug,[23] flipping of the tibial bone plug,[24] and the use of soft-tissue interference screws as well as rotation of the graft.[25] All surgeons must be prepared to implement a contingency plan to deal with bone–tunnel mismatch when using BPTB graft during ACL reconstruction.

Patellar fracture can also occur after harvest of the bone plug with BPTB autograft. To create bone plugs at the ends of the patellar tendon, the bony architecture of the patella is compromised.[26] Patellar fractures can occur because of a direct force, such as a fall onto the flexed knee, or an indirect force on the vulnerable patella (Fig. 2). Studies have attempted to explain various causes for indirect patellar fractures secondary to the stress riser created by the removal of

Figure 2 Lateral radiograph view of a displaced transverse fracture of the patella after an anterior cruciate ligament reconstruction. Reprinted with permission of Stein et al.[27]

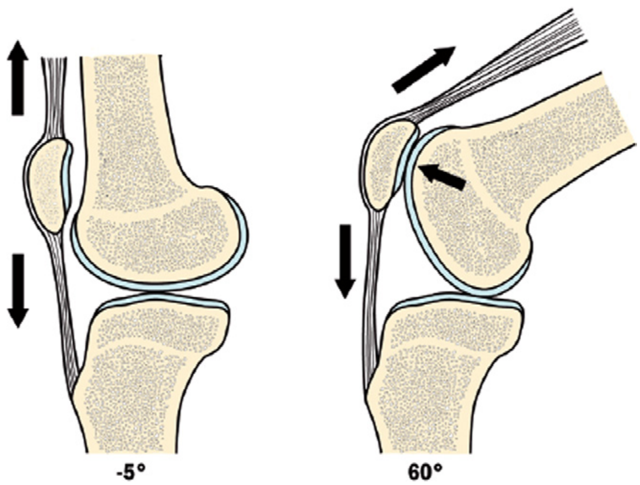

Figure 3 Sagittal view diagram demonstrating 3-point bending stress exerted on the patella with the knee in flexion. Reprinted with permission of Tay et al.[28]

the inferior portion of the patella.[28] In extension, the patella is subject to 2 opposing forces in a linear arrangement along the QT and patellar tendon. However, while in flexion, the patella is additionally subject to a third force when the posterior surface of the patella contacts the femur. This 3-point bending force acting on the vulnerable patella results in an indirect fracture when the knee is flexed (Fig. 3).[29] Stein et al[27] demonstrated that patellar fractures occurred, on average, 57 days after reconstruction with BPTB. In addition, because the bony patellar defect is replaced by fibrous tissue that has inferior mechanical properties and is less able to resist tensile forces, the patient may be at higher risk for a patellar tendon rupture.[30,31] Additionally, this fibrous tissue lacks the strength and resistance of normal anterior cortical patellar bone, which may predispose it to fracture.[30] As a result, many authors believe the patellar defect should be packed with cancellous bone graft.[26,32,33] Ferrari and Bach[26] followed 693 cases of ACL reconstruction with BPTB autografts in which the patellar defect was grafted and found no patellar fractures and less donor-site pain.

Finally, the prevalence of osteoarthritis (OA) after ACL reconstruction with BPTB has been of rising concern. Struewer et al[3] performed a study with a mean follow-up of 13.5 years on patients with ACLs that were reconstructed with BPTB after isolated injuries, and demonstrated that 73.8% developed grade I or II OA by the Kellgren and Lawrence classification, 17% of patients had symptomatic grade III OA, and 6% had symptomatic grade IV OA. It is evident that patients have an increased rate of OA when using BPTB.[3] Furthermore, Magnussen et al[8] performed a systematic review with minimum 5-year follow-up after ACL reconstruction with BPTB and HT groups; all 3 studies that allowed calculation of the rate of development of OA between the patella and femur and between the tibia and femur demonstrated a significantly increased rate in the patellar tendon group compared with the HT group.[8] However, Holm et al[34] compared HT and BPTB autografts 10 years after ACL reconstruction and demonstrated no difference in the rate of arthritis between the groups, but an increased rate of arthritis in both groups when compared with the contralateral knee. Their results indicated that graft type has a minimal influence on OA 10 years after ACL reconstruction. Further studies are necessary to separate the impact of the initial traumatic injury on the chondral surfaces and meniscal cartilage, surgical technique, and graft choice on the subsequent development of OA.

Hamstring Tendons

Quadruple-strand HT (semitendinosus-gracilis autograft) is increasing in popularity and has been documented to provide biomechanical characteristics equivalent to BPTB autograft.[35-41] Some surgeons have been trending toward increased use of HT for ACL reconstruction secondary to concerns of BPTB's possible deleterious effect on the knee extensor mechanism and donor-site morbidity, including anterior knee pain and increased risk for patellar fracture.[42] Thus, advocates for HT prefer this graft owing to its high biomechanical strength, its longevity, and decreased donor-site morbidity. For purposes of this review article, when discussing HT, we are referring to 4-strand semitendinosus-gracilis HT, unless otherwise specified.

The HT graft also has the biomechanical properties that allow it to be a suitable substitute for the ACL. The quadruple-strand hamstring graft has an ultimate tensile load of 4090 N, which is greater than both the native ACL and BPTB. It also has a stiffness of 776 N/mm and a cross-sectional area of 53 mm^2 (see Table 1 for comparisons). In addition to its biomechanical properties, long-term studies have shown that the HT graft is at least as successful as BPTB in return to activity level, patient satisfaction, and morbidity.[7-9] For example, Leys et al[7] performed a prospective cohort study comparing 90 patients who received an endoscopic ACL reconstruction with BPTB with 90 patients who received HT with identical surgical technique and assessed their progression at 2, 5, 7, 10, and 15 years.[7] They concluded that HT autograft showed superior results to BPTB autograft with respect to patient satisfaction, symptoms, function, activity level, and stability. The authors also demonstrated that 15 years postoperatively, the HT graft group had a lower rate of OA, as determined by radiographic analysis.[7] In addition, Wipfler et al[43] showed that HT was better than BPTB with respect to kneeling, knee walking, and single-leg hop test.

Although advocates of HT autograft believe that it is comparable with BPTB autograft for ACL reconstruction, several studies have shown that HT also has its own drawbacks, including weakness of the remaining hamstrings[44-47] and internal rotator musculature.[48] Lautamies et al[49] showed that peak isokinetic knee flexor torque was greater in the BPTB group compared with the HT group. Some surgeons believe that knee flexor strength impairments may contribute to functional limitations during high-speed athletic sprinting and directional change movements and thus recommend that knee flexor tendon autograft should not be performed in high-level athletes.[44]

Another disadvantage of HT grafts is the potential development of tunnel widening. Expanded bone tunnels can cause increased graft laxity, and several studies have shown that an increased number of patients with radiographic femoral tunnel widening were found in quadruple-strand HT autograft compared with BPTB autograft at 1-, 2-, and 3-year follow-up.[50,51] Similarly, radiographic tibial tunnel widening was greater in quadruple-strand HT compared with the BPTB autograft group at 1-, 2-, and 5-year follow-up.[52] Webster et al[51] also demonstrated that 32% of the BPTB graft group demonstrated complete obliteration of the femoral tunnel, whereas none of the HT group showed similar tunnel obliteration. However, Webster et al[51] did conclude that there was no relationship between tunnel enlargement and clinical measurements. Samuelsson et al[52] performed a systematic review of randomized controlled trials that showed femoral tunnel widening >25% in only 11% of patients reconstructed with a BPTB graft, in comparison with the presence of tunnel widening in 94% of patients with a 4-strand semitendinosus-gracilis graft.

There has also been growing concern about a greater level of knee laxity after use of HT for ACL reconstruction. Feller and Webster et al[50] illustrated that side-to-side differences at 134 N using the KT-1000 arthrometer were greater in the 4-strand HT graft group than in the BPTB graft group at all times from 8 months to 3 years.[51-52] Anderson et al[53] also showed that laxity evaluation with the KT-1000 arthrometer based on manual maximum side-to-side difference showed less laxity in the BPTB graft group than in the quadruple HT autograft group at a minimum of 2 years' follow-up. To the contrary, many studies have demonstrated no difference in laxity between BPTB and quadruple HT autograft.[37-39]

Quadriceps Tendon

Although HT and patellar tendon are the most commonly used ACL autografts, there is increasing popularity of QT autograft, both with and without a patellar bone block.[54] QT graft for ACL reconstruction preserves hamstring function and anatomy while also avoiding the complications of BPTB harvest, such as anterior knee pain and numbness.[55]

The QT can further reduce morbidity and provides other advantages for an ACL graft. When compared with BPTB, the QT has a decreased risk of patellar fracture.[55] In a short-term prospective study, Joseph et al[56] demonstrated that QT patients achieved earlier knee extension and required less pain medication in their postoperative course compared with their HT and BPTB counterparts. Geib et al[55] compared QT/QTB (with a bone plug) with BPTB in 191 patients with 4- to 5-year follow-up and demonstrated that QT/QTB elicited better results in terms of arthrometer measurements in the range of 0-3 mm and better extension. QT graft both with and without a bone plug also demonstrated a reduced incidence of anterior knee pain (4.6%) compared with BPTB patients (26.7%).[55] Finally, they found no significant benefit in harvesting a bone plug with the quadriceps graft.[55]

Disadvantages of QT graft include difficulty during graft harvest due to the dense cortical bone and curved proximal patellar surface, and close adherence to the suprapatellar pouch.[4] Additionally, the QT graft may be less advantageous owing to a decrease in the surface area of bone-to-bone healing. QT grafts have 1 bone plug compared with 2 bone plugs in BPTB grafts, resulting in healing of 1 bone-to-bone interface in QT compared with 2 bone-to-bone interfaces in BPTB. There are also concerns regarding effects to the extensor mechanism after graft harvest. It is difficult to make concrete conclusions regarding the long-term risks and benefits of QT autograft use in ACL reconstruction owing to the paucity of clinical data.

Allografts

Historically, most surgeons have preferred autografts to allografts.[57-59] However, using allograft could avoid donor-site complications such as patellar fracture, patellofemoral symptoms, muscle weakness, and anterior knee pain. Allograft options include BPTB, HT, QT, AT, TA, and tibialis posterior. Although eliminating the donor-site complications of autograft use, allografts also have disadvantages, such as delayed graft incorporation, disease transmission, potential immune reactions, and altered mechanical properties caused by sterilization. Evidence that favors the use of allograft over autograft is prevalent in the literature. There are multiple options for allograft use and multiple studies that support the use of each type of graft. A retrospective 5-year follow-up study performed by Mayr and colleagues[60] demonstrated no significant differences between BPTB autograft and BPTB allograft at a mean of 19.2 ± 5.8 months in anterior translation, manual examination of stability, IKDC 2000 findings, and Tegner and Lysholm scores in revision ACL reconstructions. However, there were extension deficits with the autograft at first follow-up.[60]

Achilles Tendon

AT allograft is an option owing to its favorable mechanical properties and ease of use. According to Chehab et al,[6] AT allograft is generally technically easier to use because the bone plug is more predictable than patellar tendon allografts, there is no concern for graft-tunnel length mismatch, the graft length allows for easier salvage if graft sutures are cut during insertion of tibial interference screw, and the graft diameter is more easily matched to the patient. AT is more cylindrical than a patellar tendon graft, thus for a given diameter, the AT graft has a greater cross-sectional area, which correlates with greater strength.[61] Chehab et al[6] performed 65 primary ACL reconstructions using AT allograft in patients aged 30 years or older and were able to restore 90% of the patients to normal or near normal based on IKDC score while limiting postoperative complications with a minimum of 2-year follow up. However, another study demonstrated a 21% failure rate (5/24) when using AT allograft.[62]

Tibialis Anterior

Reports have shown that TA allografts have similar strength in single-loop (2-strand) configurations as quadrupled hamstring autografts.[63,64] A study comparing knee flexion strength after ACL reconstruction with either HT autograft or TA allograft with a noninjured control group demonstrated that patients who were reconstructed with HT autograft had greater knee flexor strength impairments compared with the other 2 groups.[65] However, Singhal et al[66] demonstrated a 38% reoperation rate after primary ACL reconstruction with TA allograft, with a high percentage of failures occurring in patients <25 years of age.

Allografts undergo a similar process of incorporation as autografts; however, they have a slower rate of biological incorporation. It is technically difficult to study graft healing in humans, and as a result, most of our current understanding is derived from animal studies. In a goat model, Jackson et al[67] compared ACL reconstruction with BPTB autograft and allograft and demonstrated that at 6 months, the autograft group had better biomechanical properties, such as high ultimate failure load, increased density and number of small-diameter collagen fibrils (indicating progression of remodeling), and less anterior tibial displacement. In addition, a sheep model comparing the biological healing properties of fresh-frozen allograft with soft-tissue autograft showed a delay in recellularization and revascularization of allograft tissue at 6 and 12 weeks postoperatively.[68] Also, the mechanical properties of allograft tissue at the 52-week postoperative mark were significantly lower.

Allograft use also has the potential problem of disease transmission. Overall, this problem is rare owing to improvements in donor screening and testing procedures along with stricter guidelines at tissue banks. The literature has demonstrated that the risk of transmission of HIV is 1 in 1,667,000 properly screened patients.[69] There are no data regarding the numbers of hepatitis B or C transmissions that have occurred with allograft use, although it remains a concern considering there are more cases of hepatitis than HIV in the United States. With this in mind, tissue banks screen for antibodies to HIV-1, HIV-2, hepatitis B surface antigen, and hepatitis C, along with multiple other viral risks.[70] Although the risk of disease transmission is a common fear among patients with allograft, one study demonstrated that patients with a higher level of education show less aversion to allografts.[71]

Along with disease transmission, allograft use carries an increased risk for potential immunologic reactions. Clinical study of fresh-frozen allografts has demonstrated that these grafts can cause cytokine-induced inflammation and latent immunologic rejection.[72,73] Patients may present with local swelling, fever, erythema, and severe pain. The most common cause of this reaction is the most common symptom of immunologic rejection—acute synovitis.[74]

Altered mechanical properties caused by graft sterilization have proven to be an important issue that a surgeon must consider when using allografts. Ethylene oxide and gamma radiation have both been used for graft sterilization. Ethylene oxide has been shown to cause clinical failure by causing persistent synovitis, but it does not alter the mechanical properties of the graft.[75] Gamma irradiation effectively kills viruses, but high doses can have deleterious effects on graft strength. High-dose gamma irradiation (3 Mrad or more) should not be used owing to its detrimental effects on mechanical properties of the tissue. Irradiation (2-2.5 Mrad) has also been shown in several studies to cause unacceptable inferior clinical outcomes and high failure rates.[76,77] All surgeons should be familiar with their specific tissue bank, including the methods of graft procurement, processing, storage and sterilization, as these can vary widely throughout the industry.

Graft rupture rates in the literature have been reported in the range of 0%-14%.[78,79] Reinhardt et al[15] performed a systematic review comparing graft failure rates in autografts after ACL reconstruction. Four of the 6 studies they reviewed fit the inclusion criteria and compared BPTB autografts with quadruple-strand HT autografts. Only 4 graft failures were seen in 96 BPTB reconstructions (4.2%), whereas 12 graft failures occurred in 110 quadruple-strand HT reconstructions (10.9%).[15] On the contrary, a case series of 755 patients with a 15-year follow-up concluded that there was no difference in rupture rate between BPTB autograft and HT autograft.[80] Krych et al[81] performed a meta-analysis comparing graft rupture in BPTB allograft vs BPTB autograft in 444 patients (214 allograft, 230 autograft); the odds ratio was 5.03, demonstrating significantly more graft ruptures in the allograft group (95% CI, 1.38-18.33; $P = 0.01$).[81] As previously discussed, allograft was found to be inferior to autograft with respect to maximum force to failure, cross-sectional area, and collagen fiber profile 6 months after surgery in a goat model.[67] On the basis of this study and the other results previously mentioned, allograft tissue may be more prone to failure.

Graft failure rate is a variable that must also be considered when determining the ideal graft for each patient. Based on current literature on graft rerupture rates, a surgeon might want to consider placing autograft in younger patients with more physical demanding lifestyles while saving allograft for older patients with less physically demanding lifestyles.

Synthetic Grafts

Synthetic grafts are yet another choice for ACL reconstruction. Artificial ligaments became popular in the early 1980s,[82] with a goal to create a ligament in abundant supply that provided greater technical ease of use during surgical reconstruction, significant strength, accelerated postoperative rehabilitation, and lack of harvest-site morbidity.[82] Tissue engineering should provide a functional and biomechanically appropriate ACL that is able to promote continuous tissue remodeling. Although efforts have been made with carbon fibers, Dacron, polyester, and other types of synthetics, no material has yet proven successful to meet the demands placed on the reconstructed ACL. Further research and experimentation to find the ideal substitute continues, but there is no evidence yet of a strong substitute for the ACL.

Summary

BPTB autograft and HT autograft are the most widely used graft sources for ACL reconstruction. The ideal graft for ACL reconstruction should have biomechanical properties similar to those of the native ACL, allow for stable fixation, rapidly incorporate into host tissue, and have a low rate of morbidity.[4] There remains a continuous search for better graft options that reduce donor-site morbidity and rapidly incorporate into host tissues to provide a biologically stable interface to permit earlier mobility and return to activities. Because the ideal graft choice is patient specific, the surgeon must have a thorough understanding of the risks and benefits of each graft choice to determine which graft option best fits the patient's demands and goals and the surgeon's preferences and technical capabilities.

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