

Review of Graft Choices for anterior Cruciate Ligament Reconstruction

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Abstract:

There is much literature about differing grafts used in anterior cruciate ligament reconstruction. Much of this is of poor quality and of a low evidence base. We review and summarize the literature looking at the three main classes of grafts used in ACL reconstruction ; Autograft, Allograft and Synthetic graft. Many options have been clinically successful, but the ideal draft remain controversial. Graft choice depends on surgical experience and preference, tissue availability, patient activity level, prior surgery and patient reference. Patellar tendon autograph , the most widely used graft source, Appears to be associated with an increased incidence of anterior knee pain compared with hamstring autograft. We conclude that although there is no clear best graft, there are clear differences between the different ring graft choices. Surgeons need to be aware of the evidence behind these differences, in order to have appropriate discussions with their patients, so asked to come to an informed choice of craft type to best suit each individual patient and their requirements.

Keyword:

Anterior cruciate ligament, Graft Choices, Artificial ligament, Reconstruction.

INTRODUCTION:

Anterior cruciate ligament (ACL) reconstruction is a common operation[1]. The aim of surgery is to restore functional stability to the ACL deficient knee. The functional stability provided by the normal ACL is both in resisting antero posterior translation as well as rotational subluxation.

ACL reconstruction can be performed using a variety of different surgical techniques as well as different graft materials.Reconstruction of the anterior cruciate ligament (ACL) is one of the most common sports procedures performed accounting for 120,000 cases per year [2]. With the increase in the number of primary ACL reconstructions, subsequent need for revision ACL reconstruction (ACLR) is also increasing [3]. A recent systematic review of Level-I and II prospective studies with a minimum duration of five years follow-up demonstrated that the ACL graft rupture rate ranged from 1.8% to 10.4%, with a pooled percentage of 5.8% [4]. Other studies have shown failure rates of up to 15% in select patient populations [5].

The choice of the graft is broadly between an autograft, allograft or a synthetic graft. The two most commonly used autografts are bone-patellar tendon-bone (BPTB) and hamstrings tendon. A recent Cochran review on the outcomes of BPTB and hamstrings tendon was inconclusive . There have been several studies comparing the outcomes of allografts with autografts [6-8].Synthetic graft technology has evolved from non-biological to biological grafts. The grafts are developed so as to have better strength compared to native ACL. Their use is designed to reduce not only the donor site morbidity but surgical time also.

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The greatest function which they are supposed to serve is to provide immediate post-operative stability to the knee thus promoting early mobilization, faster rehabilitation and quicker return to pre injury level activities. LARS is the latest development in the synthetic ligament substitutes. It consists of polyethylen tetraphthalate (PET) as the structural component. The LARS has been designed to mimic ligamentous anatomy. It has 2 parts i.e. intra articular and intraosseous part. The intraosseous part is composed of longitudinal fibers of PET held together with transverse knitted structure. While the intraarticular part has parallel longitudinal fibers of PET twisted perpendicular to each other. Since the 1980's several artificial ligaments were used for reconstruction of the anterior cruciate ligament (ACL) serving different complications.

The LARS presents a synthetic material consisting of non-absorbing polyethylene leatherette fibre used for ligament reconstruction. Synthetic ligament is an artificial ligament device for joining the ends of two bones. The device composed of a multilayered or tubular woven ligament having an extra-articular region, at least one bend region, at least one end region. Each region should be woven to give support and flexibility to the particular types of stresses. The study assesses that the use of LARS and patella ligament in young adults. *Am J Sports Med* 2009;27:27–34TM in reconstruction of ACL is an excellent option for treating >40-year-old patients requesting rapid return to daily activities/sports also at the first surgery.

Autograft Choices:

Employee bone or tissue harvested from the patient's body. Most surgeons have preferred auto graft and the most two common auto grafts are Bone-Patellar-tendon-bone (BPTB) and HTs. Less risk of donor site morbidity, superior mechanical properties auto grafts are preferred to allograft.

Bone Patella Tendon Bone (BTPB):

BPTB is the most commonly used autograft for young and active populations. The graft is generally chosen from the middle one third of patellar tendon, its better incorporation and faster healing promises it as a desired graft for ACL reconstruction. The method of harvest includes a horizontal or longitudinal skin incision followed by resection of the mid-portion of the patella (inferior pole) and tibial tuberosity with the intervening tendon as a complete unit. Thus the graft has bone block at both ends which allows potentially superior integration of the graft into the tibial and femoral tunnels. The graft is then detached and fed through the tibial tunnel into the femur in the same way as a hamstrings graft. Fixation can take place using a variety of different methods ranging from an interference fit with no fixation device to screw or suspensory fixation[9].

There are many reports of the morbidity and complication associated with BTPB grafts. Complications include patella tendon rupture, patella/tibial fracture, quadriceps weakness, loss of full extension, anterior knee pain and difficulty kneeling[10,11]. Long term results after BTPB graft reconstructions have been studied by many authors. Mihelic et al[12] retrospectively studied outcome of 33 operated BTPB grafts with 17 to 20 year follow-up with 83% of patients having stable knees with normal or near normal IKDC grades and an IKDC score of 83.15, they do not however report re-rupture rates.

Gerhard et al[13] report 16 year mean follow-up of 63 patients after BTPB ACL reconstruction with 84% returning to previous sporting levels with 78% normal or near normal IKDC grades and a KOOS score of 84. Nineteen percent of patients had radiographic evidence of moderate to severe osteoarthritic changes, worse with meniscal injury at the time of ACL reconstruction. One point six percent of patients needed revision ACL reconstruction but a total of 33% needed further knee surgery during follow-up. Ahn et al[14] looked at 117 patients with mean 10.3 year follow-up

after BTPB reconstruction and showed 90.6% normal or nearly normal IKDC subjective scores. Re-rupture rates were 5.1% and all were reported after additional injury. They did also report other complications including arthrofibrosis, limited range of motion, synovitis and patella fracture. Ninety-four point eight percent of patients complained of pain when kneeling on soft ground and 61.5% complained of knee pain on walking. Pernin et al reviewed 24.5 year data on 100 patients after a combination of BTPB reconstruction with lateral extra-articular augmentation with iliotibial band. IKDC subjective scores at final follow-up were 74.7, however overall only 46% had IKDC grades A or B. They report 19.5% clinical failures of which 72.2% had a meniscal injury at the time of first operation. It is important to note that they acknowledge a drop-out rate of 75% from initial enrolment which may bring a large bias into the results. Maletiset al [15] reported from 2791 BTPB autograft patients a revision rate of 1.18% at 1.5 years (or 0.66% per 100 years observation) which was favourable in comparison to both HS and Allograft.

Hamstring Autograft:

There are several different surgical procedures documented for use of hamstring tendon grafts for ACL reconstruction. In most procedures, the tendon of the semitendinosus muscle is used; either alone, or in addition to the gracilis tendon. In a procedure that is now commonly used, both semitendinosus and gracilis tendons are harvested and are doubled up giving a 4 fibre construct, known as the DSTG. [16] Harvesting is achieved through a small incision close to pes anserinus on the medial aspect of the proximal tibia. As with the BPTB graft, hamstring grafts are inserted into tunnels drilled in the tibia and femur. There are various methods for attachment of the graft including metal or bio-resorbable screws, sutures and the end button-RT. [17] This operation is technically more demanding and requires surgical experience as muscle or nerve damage can occur in the harvesting technique and harvested tendons must be prepared and tensioned prior to implantation in the knee. [18]

Double or quadruple hamstring tendon grafts have the added theoretical advantage of forming a multi-band structure to more closely replicate the two bands of the ACL. [19] Laysetal [20] reported results from a cohort study with 15 years follow-up comparing HS to BPTB. Re-rupture rates were 17% in the HS group and 12% in the contra lateral knee. Re-ruptures were more common in men, patients with non-ideal tunnel position. Mean IKDC Subjective symptom scores were 90 (out of 100) and mean functional scores 9.1 (out of 10). asik et al [21] reported the results of 271 patients with 4 strand HS grafts fixed using a transfix pin. Their follow-up length was a mean of 6.8 years and 86% scored normal or nearly normal on IKDC score. Re-rupture occurred in 1.5% of patients in this shorter follow up study. Streich et al [22] reported a single blinded evaluation of 40 patients with 4 strand HS grafts at 10 year follow-up. They report 8% re-rupture rate and an IKDC score of 90.3 and all joints were either grade a or B (normal or nearly-normal).

Janssen et [23] al found that animal and human in vitro and vivo researches have demonstrated three characteristic stages of graft healing after ACL reconstruction: an early graft healing phase with central graft necrosis and hypocellularity and no detectable revascularization of the graft tissue, followed by a phase of proliferation, the time of most intensive remodelling and revascularization and finally, a ligamentization phase with characteristic restructuring of the graft towards the properties of the intact ACL. However, a full restoration of either the biological or biomechanical properties of the intact ACL is not achieved. In a large systematic review and meta-analysis by CL ardern and NF Taylor [24], With a mean follow-up of 4.0 years, 12,643 primary ACLRs were identified, with 3428 PT and 9215 HT grafts, among which 69 revisions with PT grafts and 362 revisions with HT grafts were performed. Researchers found that the overall 5-year revision rate was 4.2%. a higher revision rate was recorded for HT versus PT grafts at all follow-up times.

When adjusted for sex, age, and type of graft, the HR for revision was 2.3 (95% CI, 1.8-3.0) for HT grafts compared with PT grafts. The HR for revision in the youngest age group was 4.0 (95% CI, 3.1-5.2) compared with the oldest age group. Sex had no effect on the revision rate. Patients with HT grafts had twice the risk of revision compared with patients with PT grafts. Younger age was the most important risk factor for revision, and no effect was seen for sex.

Allograft:

Using bone or tissue from another body, either a cadaver or live donor. Allograft could avoid donor site complications such as patellar fracture, muscle weakness and knee pain[25,26]. Several types of allograft can be used, including patellar tendon, quadriceps tendon, Achilles tendon, tibialis anterior tendon, tibialis posterior tendon, hamstring tendon, and fascia lata[27]. Achilles tendon is an option because of its favorable mechanical properties[28,29], no concern for graft tunnel length mismatch, graft diameter is easily matched to the patients, more cylindrical than patellar graft, has a greater cross-sectional area which gives better strength[30,31]. Tibialis anterior allografts have similar strength to quadrupled hamstring graft[32,33]. Allograft undergo a similar process of incorporation like autograft[34].

Autograft can cause donor site morbidity, including various complications like anterior knee pain, pain when kneeling, patellar fracture[35], patellofemoral crepitation[36], numbness caused by damage of the infrapatellar branch of the saphenous nerve, and possible loss of quadriceps strength[37]. Allograft is expensive and delayed graft incorporation in compared with autograft[38]. Due to the drawbacks of Allograft and auto grafts synthetic ligament graft is now the main attraction for ACL reconstruction. Auto graft can cause donor site morbidity and allograft may cause blood bone diseases to the patients[39]. Currently, motion limitations are the most common complications of ACL reconstructions for augmented devices.

Early rehabilitation have been invented to minimize these types of problems but when the biological graft is very weak this increased activity takes place during the early post-operative period. Throughout the early rehabilitation excessive stress on graft could cause damage to the graft tissue, resulting rupture of the graft. Thus, in the non-augmented graft, the advantage of early rehabilitation to improve range of motion must be balanced against the risk of overloading the weak postoperative graft[40,41]. Study of the epidemiology of the multicenter ACL revision study (MARS)[42-44] cohort demonstrated that 54% of the surgeons used an allograft at the time of revision compared with 27% of the patient having had an allograft at the time of their primary reconstruction BTB Allografts where the most frequent allograft used in the MARS cohort at 50%, followed by tibialis anterior 23%, Achilles tendon 12% and tibialis posterior 11% [45-47]. However a significant number of graft where autograft at the time of revision 45% of which 49% were BTB autograft and 40% quadrupled hamstring autograft, indicating that many surgeons will still favor autograft when available in the revision setting, especially in the young, Hong demand athletes. Another common use of allograft is when more collagen is needed then can be uptown from autograft sources, such as the multi-ligament injured knee. Despite undergoing Opry to repair wood in three weeks from surgery, many surgeons are now recommending augmentation with additional collagen for lateral collateral or posterior lateral injuries. Levy et al found a significant increased incidence of failure when comparing repairs of the lateral collateral and posterior lateral corner injuries compared to reconstruction is using allografts[48-50]. A combination of allografts can be used depending on the number of ligaments in jury and reconstruction technique.

Quadriceps Tendon Graft:

The use of the quadriceps tendon as a graft for the ACL has been advocated by Staubli et al[51] and Fulkerson and Langeland[52], who documented the good biomechanical properties of this tendon[53].

Che-ne-tal[54]described the result of arthroscopic reconstruction of the ACL using quadriceps tendon-patellabone autograft in 12 patients. After a follow-up of 15-24months. 10 returned to their level of pre-injury sports and 10 had a normal or near normal IKDC scores.However, after 1 year, the quadriceps strength was only 80% of the normal knee in 11 patients. The advantages of this graft are [55,56] a thick tendon[57]good bio-mechanical properties,and[58]decreased anterior knee pain.The disadvantagesare weakness of quadriceps, After operation and unsightly scar and graft harvest,which is technically more difficult.In a review by Harris S. Slone[59], Fourteen studies were included in the review of clinical results, including 1,154 ACL reconstructions with quadriceps tendon autograft. Six studies directly compared quadriceps tendon autografts (n = 383) with bone-patellar tendon-bone autografts (n = 484). Stability outcomes (Lachman, pivot-shift, and instrumented laxity testing), functional outcomes (International Knee Documentation Committee and Lysholm scores), overall patient satisfaction, range of motion, and complications were similar between quadriceps tendon and other graft options.

Less donor-site morbidity was seen in patients who underwent quadriceps tendon ACL reconstructions.In a study by Ralph akoto[60], thirty patients have been evaluated at a 12 months follow-up. The technique achieved in 96.7% normal or nearly normal results for the objective IKDC. The mean subjective IKDC score was 86.1 ± 15.8 . In 96.7% the Tegner score was the same as before injury or decreased one category. a negative or 1+ Lachman test was achieved in all cases. Pivot-shift test was negative or (+) glide in 86.7%. The mean side-to- side difference elevated by instrumental laxity measurement was 1.6 ± 1.1 mm. Full ROM has been achieved in 92.3%. The mean single one-leg- hop index was 91.9 ± 8.0 at the follow-up. Potential advantages include minimum bone loss specifically on the femoral side and graft fixation.

Synthetic Grafts:

Synthetic ligament is an artificial ligament device for joining the ends of two bones. The device composed of a multilayered or tubular woven ligament having an extra-articular region, at least one bend region, at least one end region. Each region should be woven to give support and flexibility to the particular types of stresses. Some other advantages of synthetic ligament graft: (i) shorter operation times,(ii)lesser patient morbidity,(iii)economically efficient treatment, and (iv) lower risk of postoperative infection.The concerns over both autograft and allograft have led to the development of synthetic alternatives which ideally have no risk of donor site morbidity but also lack the risks associated with allograft of possible disease transmission, can be widely available with a long shelf life and simple storage and inventory arrangements. Synthetic ligaments are now into their third generation. First generation ligaments were knitted, woven or braided. These early ligaments were subject to early breakage and tended to elongate. Second generation ligaments had additional longitudinal and transverse fibres woven into the braid or knit.

The materials also advanced to use Polyethylene Terephthalate or Dacron to act as a permanent replacement and allow fibroblastic ingrowth. These ligaments also suffered with wear, fraying and low abrasion resistance. Both first and second-generation synthetics were plagued with problems related to wear debris and subsequent catastrophic synovitis. This led of large cohorts of patients with problematic knees and a general aversion to the use of synthetics for ACL reconstruction in the soft tissue knee surgery community. Third generation ligaments such as the LARS are similarly constructed of Polyethylene Terephthalate, however, they are now designed to specific indications. The ACL replacement has a knitted extra-articular portion with free longitudinal fibres which resist elongation but without any braids to cause intra-articular wear and the generation of biologically active wear debris.

The latest generation of synthetics have different indications from conventional graft choices. The design rationale is that the synthetic is used to augment the healing of a freshly injured ACL. Surgery should take place as soon as possible after the acute injury and every effort must be made to preserve the native ACL stump and draw the stump up to its femoral attachment using the synthetic to then protect the graft whilst tissue ingrowth and healing occur. Thus the synthetic is used as an augmentation device alongside biological tissue, not as a substitute graft in isolation. The results of first and second generation ligaments are not applicable to third generation ligaments due to the substantial re-design. A large scale systematic review was performed by Newman et al [61] which led to only 9 out of 156 articles being included. This study looked at data from 675 LARS ACL reconstructions and found an overall failure rate of 2.5% of which many of these were reported to be associated with technical errors in tunnel placement.

Synovitis, which had plagued earlier synthetic grafts only occurred in only one patient in the included studies. This data suggests the third generation of synthetics have largely solved the problems of synovitis that led to the disrepute of the first and second generation. Dericks [62] described his experience of 220 patients reported 3 infections (1.4%) and 9 ligament ruptures (4.1%) with 83% of patients returning to full sports by 6 mo (and 61% by as early as 4 mo). The largest published study of LARS ACL reconstructions is by Gao et al [63] who retrospectively report on 159 reconstructions. They describe 94% of patients achieving IKDC grade A or B at a mean of 50 mo follow-up. All patients achieved return to sports by 6 mo with a re-rupture rate of only 1.9%. Nau et al [64] report the 24 mo results of a randomised controlled trial comparing BTPB and LARS ACL reconstruction in 27 and 26 patients respectively. They found no significant differences at final follow-up in the results of either graft with respect to IKDC, KOOS or Tegner scores.

They also did not report and ruptures but did list patients lost to follow-up and other complications, with no significant difference. The only difference that they reported is a trend to earlier return to sport in the LARS group possibly allowing a faster rehabilitation protocol. Pan et al [65] report retrospective follow-up of a minimum of 4 years in 32 LARS reconstructions and compare these to 30 BPTB reconstructions. IKDC grades and Tegner scores were similar in both groups, the LARS group had A or B grading in 87.5% and a score of 6.16 respectively. No re-ruptures were reported in either group. Of 109 patients, 32 (29%) had a medial meniscus tear, 20 (19%) had a lateral meniscus tear, 17 (15%) had both menisci torn and 40 (37%) had no meniscal tear. Analysis revealed that time from injury was not a significant factor for the presence of a meniscal lesion. The odds of development of a high-grade cartilage lesion in an ACL-deficient knee reconstructed more than 12 months from time from injury are 5.5 and 12.5 times higher when compared with knees that underwent ACL reconstruction less than 3 months and between 3 and 12 months after knee injury, respectively.

A total of 31.25% of the patients did not change their lifestyle that they had before the injury. None of the patients underwent resurgery in the same knee. In 85.4% of cases, X-ray images showed no signs of osteoarthritis after ACL. The clinical evaluation has shown the good outcome. The MRI conducted has shown the progressive partial integration of the scaffolds. Mean age of patients was 28.3 ± 7.58 years (range from 16 to 68 years). From 428 patients, 41.2% (175 patients) were between 26 and 35, 38.8% (165 ones) between 15 and 25 and 20% (85 patients) out of 36 years. 414 patients were male (97.2%) and 12 were female (2.8%). Sensitivity of anterior drawer test was 94.4% and sensitivity of Lachman test was 93.5%. There were no significant differences between the two groups with respect to the data of Lysholm scores, Tegner scores, IKDC scores, and KT-1000 arthrometer test at the latest follow-up.

Our study demonstrates that the similarly good clinical results are obtained after ACL reconstruction using BPTB autografts or LARS ligaments at midterm follow-up. In addition to BPTB autografts, the LARS ligament may be a satisfactory treatment option for ACL rupture[66]. Our results indicate that the LARS system should currently not be suggested as a potential graft for primary reconstruction of the ACL. In special cases, however, the LARS system can serve as an alternative graft[67].

Conclusion:

All the different types of grafts used in current everyday practice for the reconstruction of a ruptured ACL have a place in this complex field of surgery. There are good data to support all of them. There is no clear “best” graft to use. However there are some clear advantages with respect to the different grafts. Donor site morbidity has been a problem for the BTPB graft, however it appears to have consistently good results particularly with respect to graft stability and return to high level sports. HS grafts appear to be a good all-round graft choice with fewer donor site complications and good results, both sources of autograft are readily available in most patients and cost nothing, but do have some technical demands for safe and efficient harvest.

Allograft generally has slightly poorer results in terms of re-rupture rates, however can be invaluable in certain patient groups, particularly those with multi-ligament deficiencies or in the revision scenario. Allografts are expensive, but save time and undoubtedly remove one of the more technically demanding stages of ACL reconstruction surgery. They remove the potential for donor site morbidity but do not permit faster return to sport. Synthetic grafts are slowly regaining popularity as these too show good general results with no donor site morbidity and the ability to perform multi-ligament reconstructions without compromising the patella or hamstrings. They offer an off the shelf solution which shortens operative time and renders the surgical procedure is somewhat

less complex and no graft harvest is required however the surgery is technically different, and should ideally be performed on a different time scale from conventional ACL surgery. Graft choice, therefore, needs to be made after an educated discussion with the patient regarding their requirements and expectations with regards to donor morbidity and speed of rehabilitation as well as the surgeon’s personal experience and the surgical units experience and access to graft options. Certainly there is no one-size-fits-all graft yet, however, surgeons should offer the differing graft options and inform their patients of the differences as well as their own personal results with each graft suggested.

Author’s Preferred Treatment:

ACL reconstruction is indicated in patients that wish to return to a high level of athletic activity or have instability or giving out on activities of daily living or work despite non-surgical treatment. The decision to undergo surgery and the choice of tissue used, autograft versus allograft, is made after discussing with each individual patient their goals and expectations, and an agreement is reached after an understanding of the risks and benefits of each graft option. Many factors go into selecting the right graft for each patient, including age, activity level, and work demands. In general, the senior author (MB) recommends autograft use in patients under 25 years of age, and the option to use allograft in patients over 25, with the most important factor being the patient understanding the graft choice and the risks associated with the selected graft. Though final decision is made with the patient, Dr. Baraga frequently uses the quadriceps tendon autograft without bone, as it has been shown to give the same results but without the potential complications as the bone-patellar tendon-bone autograft and no graft size concerns as with hamstring autografts.

SUMMARY:

ACL injuries are common orthopedic injuries that can be treated either non-surgically or surgically.

There are several options of tissue grafts used to reconstruct the ACL—the choice of which to use is based upon multiple factors and should be discussed with your surgeon prior to surgery. Each tissue graft option is associated with unique pros and cons that the patient should be familiar with and discuss with their surgeon. For young (≤ 25 years old), highly active patients autograft is recommended over allograft due to higher rates of ACL re-tearing in these patients. ACL injuries are common orthopedic injuries that can be treated either non-surgically or surgically. There are several options of tissue grafts used to reconstruct the ACL—the choice of which to use is based upon multiple factors and should be discussed with your surgeon prior to surgery. Each tissue graft option is associated with unique pros and cons that the patient should be familiar with and discuss with their surgeon. For young (≤ 25 years old), highly active patients autograft is recommended over allograft due to higher rates of ACL re-tearing in these patients.

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