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ACL: RISK FACTORS, OUTCOMES, PREVENTIONS (R GALLO, SECTION EDITOR)

Outcomes Following ACL Reconstruction Based on Graft Type: Are all Grafts Equivalent?

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Abstract

Purpose of Review Anterior cruciate ligament reconstruction is one of the most common orthopedic procedures performed, accounting for over 200,000 cases annually. Despite the high prevalence, there is still much debate as to the optimal graft choice. The purpose of this review is to evaluate the current literature and discuss the reported outcomes for the most common graft choices.

Recent Findings The most common autografts being used include bone-patellar tendon-bone (BPTB), hamstring tendon (HT), and quadriceps tendon (QT). Hamstring tendon might have a slightly higher re-tear rate when compared with BPTB (2.84 versus 2.80). However, BPTB has a higher rate of anterior knee and kneeling pain in the short- and mid-term follow-up. This has not been shown to be the case in long-term follow-up. Allograft is a viable option for revisions and primaries in patients greater than 35 years old; however, re-tear rate increases significantly in younger patients.

Summary ACL reconstruction graft choice is a highly studied and yet still exceedingly debated topic. Most large studies report either no significant difference or a small difference in failure rate and outcome scores between the different autograft choices. Allografts have been demonstrated to have an increased risk of failure in younger athletes and should be reserved for revision cases and those aged 35 years and older. Graft choice should ultimately be decided upon based on surgeon comfort and experience and individual patient characteristics.

Keywords ACL reconstruction · Bone-patellar tendon-bone autograft · Hamstring autograft · Quadriceps autograft · ACL graft choice

Introduction

Anterior cruciate ligament (ACL) tears account for nearly 50% of all sports-related knee injuries and cost the US healthcare system an estimated 1 billion dollars annually [1]. Despite the high prevalence and socioeconomic burden of this injury, there is still debate amongst orthopedics as to the optimal treatment strategy. Most young, active patients elect to proceed with surgical management, because non-operative treatment is associated with an unacceptably high risk of recurrent instability, secondary meniscal tears, arthritis, and future total knee arthroplasty [2]. Although there appears to be renewed interest in primary repair of the ligament, especially using internal brace ligament augmentation (IBLA), the data is limited and therefore the technique is not currently recommended for widespread use [3, 4]. Thus, the gold standard for surgical management remains ACL reconstruction with autograft or allograft. An ACL reconstruction is performed more than 200,000 times annually and is among the top 10 most frequently performed orthopedic procedures [5].

Graft selection is a vital aspect of the pre-operative planning for ACL reconstruction, but the ideal graft source still remains controversial. The most common graft options include bone-patellar tendon-bone (BPTB), hamstring tendon

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(HT), and quadriceps tendon (QT) autografts, along with a variety of allograft options. The choice of graft is generally based on multiple determinants including surgeon preference, patient factors, and graft characteristics. Historically, BPTB autograft was considered the gold standard due to the ease of harvest, opportunity for bone-bone healing, and biomechanical properties [6]. However, recent trends indicate that the use of HT autograft is on the rise due to the limited donor site morbidity and comparable clinical outcomes [7, 8•]. The use of allograft eliminates donor site morbidity, but has been associated with increased failure rates, higher costs, and risk of disease transmission [9–12].

A wide array of studies comparing the various graft options in ACL reconstruction has been published throughout the years. The purpose of this review is to summarize the most recent relevant literature regarding outcomes based on graft type and to discuss whether one graft type demonstrates clinical superiority compared with the others.

Bone-Patella Tendon-Bone Autograft

BPTB autografts are utilized in approximately 23% of ACL reconstructions [8•, 13]. One of the major advantages afforded by the BPTB autograft is the biomechanical similarity shared with the native ACL. Woo et al. demonstrated that the maximum load to failure of the native ACL in younger patients (age 22–35) is 2160 N when it is tested in its anatomic orientation [14]. This is only 800 N less than the maximum load to failure of the BPTB autograft, shown by Cooper et al. [15]. However, it is important to note that the maximum load to failure decreases with age [14]. Shani et al. demonstrated a mean maximum load to failure of 1580 N in cadaveric specimens with an average age of 41.5 years [16]. This is in contrast to the 2977 N load to failure seen in the Cooper et al. cadavers which had an average age of 28 years. These findings agree with previous studies showing that the biomechanical strength of ligaments and tendons declines with age [14, 17].

Another advantage to using the BPTB autograft is its ease of harvest, requiring minimal dissection to access the patellar tendon. During harvest, optimal graft dimensions include a width of 10 mm in order to maximize the strength of the reconstructed ligament while minimizing the risk of patella fracture and intra-articular impingement [18]. The weakest aspect of the construct is at the interface of the bone plug and interference screw on the tibial side, likely due to the high amount of cancellous bone in the tibial metaphysis [5]. Load to failure of the bone block fixation and interference screw has been shown to be between 550 and 560 N, regardless of whether titanium screws or BioScrews are used [19]. This is very close to the forces experienced by the reconstructed ligament in early rehabilitation, which can be as high as 450–500 N [20].

While there are many advantages to BPTB autograft, its most significant disadvantage is donor site morbidity. There are many described morbidities including patella fracture, patellar tendon rupture, anterior knee pain, kneeling pain, and extension lag [21, 22•]. The incidence of patella fracture is rare (0.4–1.3%) and is thought to be due to deep and irregular saw cuts. Patellar tendon rupture is also rare (0.18–0.25%) and is thought to be due to poor centralization during harvest leading to the lateral or medial side being too thin [21]. Anterior knee pain and kneeling pain are fairly common with BPTB with 52% of patients reporting anterior knee pain and 65% of patients reporting kneeling pain at 2-year follow-up. This was significantly more than hamstring autograft patients at 2 years (17% and 35% respectively); however, at 15-year follow-up, there was no significant difference between the two groups. A similar trend was seen for knee extension deficit. Up to 3 years post-operatively, there was a significant difference in extension lag; however, this difference was not seen at 15-year follow-up [22•].

Hamstring Autograft

Hamstring autografts are becoming increasingly popular, accounting between 33 and 53% of all performed ACL reconstructions [8•, 13]. Graft preparation involves doubling the harvested semitendinosus and gracilis tendons (or quadrupling, if only semitendinosus is harvested), thereby conferring a maximum load to failure of approximately 4590 N [23]. The final quadrupled graft ideally would measure at least 8 mm in diameter or greater, because it has been shown that failure rates increase with smaller diameter grafts [24]. A variety of soft tissue fixation methods exist including interference screws, endobuttons, staples, and washers, as well as femoral side fixation with cross pins [5]. Although Kousa et al. previously demonstrated the biomechanical superiority of the Bone Mulch Screw (Arthorotek, Warsaw, IN) on the femoral side and the Intrafix (Ethicon) on the tibial side, to our knowledge, no studies have been performed that report a statistically significant difference in clinical outcomes when comparing fixation methods [25, 26]. Regardless of the chosen fixation method, soft tissue grafts can frequently take up to 6 weeks longer to incorporate into the host bone than BPTB autograft [27].

As with BPTB autograft, HT also has donor site morbidity which includes anterior knee pain, sensory deficits, and strength deficits. Anterior knee pain is a relatively common complaint that does decrease over time as discussed in the BPTB section. Sensory deficits are also somewhat common and have been seen in 40–88% of patients. The sensory deficit is typically related to disruption of the infrapatellar and sartorial branches of the saphenous nerve along the incision [28•]. The incidence of post-operative knee flexion/extension and internal rotation strength deficit has been somewhat varied

in the literature. In the early post-operative course, strength deficits can be common but are typically transient and resolve over time [28•, 29]. One randomized controlled trial found significant weakness at 3 months that resolved by 6 months [29]; however, other studies have shown strength deficits and morphological changes in the hamstring muscles up to 2 years post-operatively [28•, 30].

Quadriceps Tendon Autograft

Since first being introduced in 1979, the QT has been a less popular graft option in ACL reconstruction. It originally fell out of favor after Noyes et al. demonstrated a maximum load to failure that was only 14 to 21% that of the native ACL [31]. In their study, however, they used a suboptimal composite graft consisting of partial thickness QT, patellar tendon, and prepatellar tissue. More recent biomechanical studies have shown a maximum load to failure of between 2185 and 2352 N, much more comparable with the native ACL [16, 32]. This has caused the QT to re-emerge as a reasonable treatment option. In fact, the number of ACL reconstructions performed with QT autograft has risen from 2.5% in 2010 to 11% in 2014 [13, 33]. Donor site morbidities reported include anterior knee pain, numbness, and strength deficits. A systematic review by Hurley et al. found a lower incidence of anterior knee pain with QT compared with BPTB and no difference with QT compared with HT. There was also a lower rate of sensory deficit with QT compared with BPTB. In regard to strength, only 2 studies in the analysis evaluated this variable. One found no difference in strength between QT and BPTB, one found greater knee extension strength with HT over QT, and one found greater flexion strength with QT over HT [34•]. It should be noted that this systematic review contained only studies with short-term follow-up, mostly retrospective in nature, and only limited conclusions can be drawn from the results.

Allograft

A wide variety of allograft sources can be utilized including hamstring, patellar, quadriceps, Achilles, and anterior/posterior tibialis tendons, and are often selected in revision cases, to avoid donor site morbidity, or when there are barriers to harvesting adequate autograft tissue. A recent cross-sectional study analyzing over 16,000 community-based ACL reconstructions has shown that 42.4% of primary and 78.8% of revision ACL reconstructions utilized allograft tissue [35]. Often considered biomechanically inferior to autograft, the strength of the allograft construct can be maximized by using grafts from younger donors (< 40 years), central third patellar tendon or looped soft tissue grafts, avoiding excessive irradiation of the graft (doses > 20 kGy), and maximizing the graft cross-sectional area [12]. The success of allograft has also been shown to correlate with age. It is well documented that younger, highly active patients have a significantly higher re-tear rate with allografts, as high as 25% has been reported [36]. However, rate of re-tear decreases as age increases normalizing around age 35–40 years [37–39]. Allografts have also been widely used in revision scenarios, particularly in patients that have already had an autograft harvested. Condello et al. found no significant difference in failure rates or outcomes when comparing allografts to autografts for revisions [40•]. However, the MARS group, in a large multicenter trial, found improved patient-reported outcomes and lower risk of re-rupture with autograft revision reconstructions [41]. In this study, autograft revision reconstruction had a 2.78 times less chance of re-rupture compared with allograft revision reconstruction.

Overall Graft Outcomes

Graft re-tear is a feared complication of ACL reconstruction. There have been a large number of randomized controlled trials and meta-analyses investigating re-tear rate between different graft choices. A recent meta-analysis comparing BPTB autografts to Hamstring autografts in over 47,000 patients showed a slight increase rate of hamstring graft tears compared with BPTB (2.84% versus 2.80% respectively) [42•]. As an alternative, QT use has been increasing in the past 10 years. A study comparing QT to BPTB and HT in 2856 patients showed similar rates of graft failure between all groups but did find that QT had less donor site pain than BPTB and better Lysholm scores than HT [43•]. In order to avoid donor site morbidity altogether, allograft is a viable yet controversial graft option. Maletis et al. prospectively compared 14,015 patients that underwent BPTB, HT, or allograft. They found no significant difference in failure rates with allografts irradiated with < 1.8 Mrad compared with hamstring autografts (HT and irradiated grafts had a slightly higher failure rate than BPTB), but did notice a higher failure rate in allografts irradiated with > 1.8 Mrad. They did not find a significant difference between unprocessed allografts compared with autografts. It is important to note that the average patient ages at the time of reconstruction from the autograft groups were 22 years for BPTB and 24 years for HT, while the average age for the allograft reconstruction group was 35 years [39].

Several factors have been proposed that increase risk of re-rupture and worse outcomes following primary ACL reconstruction. Kaeding et al. reported on 2488 patients from the MOON consortium and found a 4.4% graft re-tear rate which

was positively associated with younger age, higher Marx activity level score, and use of allograft (average age of cohort was 27). There was no notable increase in risk due to sex, tobacco use, type of autograft used, concomitant meniscal injury, or sport played [44]. A recent systematic review evaluated studies from the Scandinavian knee ligament registry that reported on patient-reported outcomes and function. This study found that factors such as younger age, male sex, tobacco abstinence, and hamstring autograft increased patient-reported outcome scores. It was also noted that subjective knee functional scores were negatively impacted by concomitant meniscal injuries [45].

Author's Preference

The senior author's preferred graft is the bone-patellar tendon-bone autograft, both for primary ACL reconstruction and for revision ACL reconstruction, when this graft is still available. In instances when the index ACL reconstruction used a patellar tendon graft and the initial procedure was more than 8 or 10 years prior, we have occasionally reharvested the bone-patellar tendon-bone graft for revision, with success. For revision cases in which the patellar tendon of the same knee is not available, hamstring autograft and allograft are reasonable options. In rare cases of very high-level athletes who accept the risk, we have used the contralateral bone-patellar tendon-bone autograft. Autograft hamstring tendon reconstruction is the preferred graft for adolescents with widely open growth plates. In older, less active patients, allograft is a reasonable option, although we typically still use a patellar tendon autograft if there is no contraindication to its harvest.

Conclusion

ACL reconstruction graft choice is a highly studied and yet still exceedingly debated topic. Most large studies report either no significant difference or a small difference in failure rate and outcome scores between the different autograft choices. Allograft has also been shown to have equivocal outcomes in older patients when compared with autografts but has been associated with higher tear rates in younger patients. Graft choice should ultimately be decided upon based on surgeon comfort and experience and individual patient characteristics.

Compliance with Ethical Standards

Conflict of Interest Matthew Widner, Mark Dunleavy, and Scott Lynch declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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