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In Patients With a Ruptured Anterior Cruciate Ligament, Does an Autograft Versus Allograft Reconstruction Provide Superior Post-Operative Outcomes?

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IN PATIENTS WITH A RUPTURED ANTERIOR CRUCIATE LIGAMENT, DOES AN AUTOGRAFT VERSUS ALLOGRAFT RECONSTRUCTION PROVIDE SUPERIOR POST-OPERATIVE OUTCOMES?

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ABSTRACT

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Background: The literature surrounding anterior cruciate ligament (ACL) reconstruction (ACLR) exhibits the most commonly used grafts for a ruptured ACL are bone- patellar tendon- bone (BPTB) autografts, quadriceps tendon (QT) autografts, hamstring tendon (HT) autografts, and allografts. This paper was designed to compare the postoperative outcomes between autografts and allografts to determine which graft is superior.

Methods: A literature review of studies were searched and selected based on inclusion and exclusion criteria using Augsburg University Interlibrary loan system, PubMed, and Elsivier.

Results: The research demonstrates superior outcomes for autografts compared to allografts. Additionally, the research delineates outcomes based on the type of autograft used in ACLR. The literature describes BPTB autografts as having decreased laxity and failure rates compared to other autografts. The literature also suggests specific indications for autografts and allografts. Autografts have demonstrated decreased rates of graft failure and laxity, and are associated with better postoperative functional outcomes. Autografts are the graft of choice for younger, more active patients, but have been associated with increased donor-site morbidity including hamstring weakness, anterior knee pain, and hypoesthesia. Allografts are associated with increased laxity and graft failure, but are noted to have better subjective outcomes based on less donor-site morbidity.

Conclusion: Overall, autografts have been validated to be the superior graft choice when it comes to laxity and failure rates for younger and more active patients, but allografts have their

own indications for older, less active patients looking to maintain knee function without risking the complications associated with autograft harvest.

INTRODUCTION

ACL tears are common injuries, with more than 200,000 tears and an estimated 100,000 ACLRs performed each year in the United States[1]. Data collected from patients under 65 years-old from January 1, 2005 to December 31, 2013, found the average cost associated with an ACL reconstruction is $13,403.38 with insurance[2]. Considering the prevalence of ACL tears within the population and the cost of reconstruction the relevance of this topic is easily explained.

The most common surgical treatment for an ACL tear is an ACLR. The ACLR has been the gold standard treatment for ACL tears since the 1980's. This includes using tendon grafts to replicate the anatomy and function of the ACL. The two main types of grafts used for ACLR are autografts and allografts[1]. Autografts are tendons that are harvested from the patient and used to reconstruct the torn ACL. There are multiple sites for graft harvest in reconstruction. The most commonly used graft sites are the hamstring, patellar tendon, and quadriceps tendon. Conversely, an allograft comes from a donor cadaver. These grafts are sterilized in a variety of ways, but most common is gamma irradiation[1,3].

The purpose of this paper is to establish if ACLR using an autograft versus an allograft provides superior post-surgical outcomes in patients with a torn ACL. This will be evaluated by comparing subjective outcomes, objective outcomes, and associated complications with autografts versus allografts in regards to ACLR. Understanding the basis of how the knee is evaluated is helpful when interpreting results within the research. Historically, approaches to evaluate knee function relied on objective findings, such as radiologic evaluation, strength, range of motion (ROM), and laxity[4]. While objective measurements hold value in the assessment of knee function and are used for data in studies, patient-oriented questionnaires are just as significant. The subjective questionnaires allow patients to rate different aspects of how their knee feels and functions. The rating systems, or functional outcome scores, use subjective data provided by patients as well as objective measurements to determine a score[4-6]. From there, researchers can compare the pre-operative versus post-operative scores to help determine the risk-benefit profile of each intervention. The most commonly used rating systems that were utilized in research studies and will be presented and referenced throughout this paper are the International Knee Documentation Committee (IKDC), Lysholm Scale, Tegner Activity Score (TAS), and Cincinnati Knee Rating System (CKRS).

Moving on from the subjective assessments, objective tests are designed to measure knee function and take out the subjectivity that occurs with the scoring based rating systems. There are a variety of tests to put stress on the knee ligaments to determine instability that include the pivot-shift, Lachman, and anterior drawer tests. Another objective assessment that has been the most widely studied and is considered the gold standard for laxity measurement is the KT arthrometer[7]. To provide context of these objective tests, they will be referenced throughout this paper.

BACKGROUND RESEARCH

Prior to comparing and contrasting the different grafts, a review of knee anatomy, specifically the ACL, is necessary. Following the anatomy review, an in-depth explanation of each assessment for evaluating postoperative knee outcomes will be provided. Then, a comparison of outcomes between the types of autografts used in ACLRs will be discussed. After the discussion comparing the outcomes between the types of autografts, the allografts options for ACLR will be briefly mentioned. Finally, the main purpose of this paper comparing the outcomes between autografts versus allografts in general will be investigated before comparing the outcomes based on the specific types of autografts and allografts.

The anterior cruciate ligament (ACL) provides rotational and translation stability to the knee. It stabilizes the tibia from displacing anteriorly in relation to the femur. There are two bundles that comprise the ACL. The anteromedial bundle (AM) is responsible for stability in the anterior-posterior direction and is the tightest in flexion. The posterolateral (PL) bundle is responsible for rotational stability and is the tightest in extension (Fig. 1)[8]. The ACL receives its blood supply from the middle geniculate artery by way of the periligamentous vessels which form a network in the synovial membrane. It has the most vasculature at the proximal portion compared to the middle and distal segments of the ligament[8]. The ACL derives its nerve innervation from the articular branch of the tibial nerve[8]. With an understanding of ACL anatomy, the management and the history of a knee injury will now be established.

Initial management of a knee injury is to perform a history and physical exam of the patient. Obtaining a thorough history will direct you to the diagnosis but a workup of the injury is required, nonetheless. The most common presentation of a torn ACL is a patient stating that when they planted their foot and turned, they heard a “pop” and felt pain. The next step to managing a knee injury is to obtain high-quality images of the structures within the knee. The imaging modality to accomplish this is magnetic resonance imaging (MRI). An MRI allows the most detailed look at the structures of interest inside the knee. Now that the management of a knee injury has been clarified, an examination of the assessment tools to evaluate postoperative outcomes will be described.

To begin, there has been an association with hamstring tendon (HT) autografts of increased stretching leading to laxity and graft failure. Laxity can be measured using a few different methods. There are three dichotomous tests that will be mentioned throughout this paper. They are the Lachman, anterior drawer, and pivot-shift tests. The Lachman and anterior drawer test the laxity of the ACL by pulling on the posterior surface of the knee and trying to displace the tibia anteriorly in relation to the femur. The difference between the tests is the degree of flexion of the knee while performing the maneuver. The Lachman test has the patient lying supine with their knee flexed at 30 degrees while performing the maneuver. The anterior drawer has the patient supine as well, but this time the knee is flexed to about 90 degrees while performing the maneuver. The pivot shift test is a dichotomous test designed to put stress on the new ligament. It uses internal rotation and valgus stress to evaluate rotational stability as the tester takes the knee from full extension to flexion to replicate the movement pattern when ACL injury occurred[9]. A positive test occurs if the patient has pain, clunking or instability.

The drawback to these tests is they are supposed to be objective tests, but there is a fair amount of subjectivity to them. The difficult part of using these assessments is they rely on the assessor to estimate the amount of displacement of the tibia anteriorly. These estimates are the inaccurate measurements of laxity. Fortunately, technology has allowed us to create a way to eliminate the subjectivity of these tests.

The more reliable instrument to objectively assess knee laxity, specifically the ACL, is with an arthrometer. Arthrometers allow for reproducible results that are quick, easy, and increase objectivity compared to a clinical exam[7]. The KT-1000/KT-2000 arthrometer takes out the subjectivity of Lachman's and anterior drawer tests as it gives a measurement in millimeters of anterior laxity. The patient lies supine with the KT arthrometer attached to the leg (Fig. 2)[7]. Forces are then applied and the arthrometer measures the maximal anterior translation. Although the validity and reliability of KT arthrometry has been criticized, increased forces applied by the arthrometer generate valid measurements in sensitivity 93% and specificity 91%[10]. In ACL patients with intact ACLs, reliability ranged from intra-raters and inter-tester correlations from 0.83 to 0.97 and 0.41 to 0.92, respectively[7]. Discrepancies in measurements of as little as 2-3mm can diagnostically skew results and therapeutically alter treatment course, thus, the motivation to combine subjective patient data with the objective measurements and tests. The evaluation and assessment of the knee injury is a key driver to the indications of appropriate graft selection.

Another assessment method described in the literature is subjective evaluation. Subjective evaluation has proven as important and objective measurements in comparing postoperative outcomes. One such assessment that has been subject to rigorous statistical evaluation and has proven to be a valid and responsive patient-reported outcome measure is the IKDC[4]. The IKDC subjective knee form was created by a committee of knee experts from around the world to standardize the evaluation of patient outcomes post-knee surgery or treatment. The form contains 18-items and focuses specifically on the knee. The questions are based on symptoms assessing pain, stiffness, swelling, joint locking, and joint instability. The other areas it assesses are the ability to perform daily and sports activities like running, jumping and landing, stopping and starting quickly, going up and down stairs, standing, kneeling on the anterior aspect of the knee, squatting, sitting with the knee bent, and rising from the chair[4]. The patient responses include “yes-no”, while others are on standard Likert scales of 5 points, and 11 points. Total score is calculated by the sum of responses, divided by the maximum possible score, times 100, to give a maximum total score of 100. The lower scores correlate with higher symptoms or lower function level.

An additional subjective assessment that was created by sports medicine surgeons primarily to evaluate outcomes of knee ligament surgery is the revised Lysholm Scale[5]. The current version consists of eight items that measure pain, instability, locking, swelling, limp, stair climbing, squatting, and need for support. The responses are scored differently based on the item, but the total is out of 100. The lower scores correlate with higher symptoms or disability. In patients with mixed knee pathologies, the Lysholm scale is not reliable, but is consistent with grouped knee injuries[5]. The Lysholm scale has been validated as scores have correlated with other knee scoring systems[5].

Complimentary to the Lysholm scale, the TAS was created to assess patients with ACL injuries as the Lysholm scale has limitations in its evaluation of functional scores. The scoring is based on level of activity. A score of 0 represents missing work due to knee issues, and a score of 10 corresponds to competing in national level sporting events. Patients may only respond with a 6-10 if they actively participate in recreational or competitive sports[5]. The validity and reliability of the TAS is adequate and has demonstrated correlation to other knee scoring systems[5].

The final functional outcome scoring system that will be described in this paper is the CKRS. The CKRS contains items on a questionnaire that include symptoms, functional limitations with sports and daily activities, patient perception of knee condition, and sport- and occupational-activity levels. The CKRS have proven to be highly effective in detecting changes in knee evaluations, and acceptable reliability, validity, and responsiveness for the assessment of knee function[6]. With an understanding of the various ways to assess knee function, the research on the treatment of an ACL tear using ACLR will be discussed.

Traditionally, the gold standard surgical treatment of an ACL tear has been the ACLR using tendon grafts. There have been numerous studies to determine if autografts or allografts for an ACL tear is indicated. The research describes the most commonly used autografts are the HT (semitendinosus and gracillis), bone- patellar tendon- bone (BPTB), and quadriceps tendon (QT)[11, 12]. The outcomes associated with ACLR based on the location of donor autograft tendon used will be investigated next.

HT versus BPTB autografts

Persson et al reported an increase in graft failure with HT autograft compared to patellar tendon autograft in patients with at least 5-years follow-up. Persson et al was a retrospective cohort study with a mean follow-up of 4.0 years. The study included 12,643 primary ACLRs, with 3428 patellar tendon and 9215 HT grafts. There were 69 revisions with patellar tendon grafts and 362 revisions with HT grafts[13]. A higher revision rate was recorded for the HT group versus the patellar tendon group at all follow-up times as patients with HT grafts had twice the risk of revision compared with patients with patellar tendon grafts[13]. The younger age was the most important risk factor for revision, and no effect was seen for sex[13].

In contrast, Edgar et al. concluded HTs are as effective as BPTB grafts in strength and stiffness. A majority of studies found HT autografts to have less anterior knee pain, and less donor site morbidity compared to BPTB autograft[14]. Other studies also describe hamstring weakness as main contributor to hamstring tendon morbidity[14]. The research comparing patient outcomes of HT autograft versus BPTB autograft does not demonstrate a superior site for graft harvest. The decision to choose which location for the donor autograft is patient specific, and is determined by multiple factors.

QT versus BPTB autografts

Further comparison between the types of autografts that can be used in ACLRs to delineate a superior graft choice for ACL tears is warranted. Thus, a study by Mouarbes et al. compared outcomes of ACLRs using QT versus HT, and BPTB versus HT autografts in a systematic review and meta-analysis. The analysis included 27 studies with a total of 2,856 patients with a minimum follow-up duration of 12 months. In regards to QT versus BPTB outcomes, the study found no difference in stability, measured by arthrometry (p= 0.45), Lachman (p= 0.76), and pivot-shift (p= 0.23). The study found no difference in functional outcome scores of objective IKDC (p= 0.20), subjective IKDC (p= 0.36), and Lysholm (p= 0.10). Finally, the study did not elucidate a significant difference (p= 0.50) when comparing failure rates between the two groups, but the study demonstrated QT autograft was favored (p< 0.00001) in regards to donor-site pain over BPTB.

QT versus HT autografts

Additionally, the Mouarbes et al. study investigated the outcomes of QT autograft versus HT autograft in ACLR. The stability outcomes demonstrated no significant difference, measure by arthrometry (p= 0.75), Lachman (p= 0.41), and pivot-shift (p= 0.44). The study did demonstrate a significant difference in regards to the Lysholm functional outcome score favoring QT autograft over HT autograft. Other functional outcome scores did not elucidate any significant difference between QT versus HT autografts. The analysis did no demonstrate a significant difference in regards to anterior knee pain (p= 0.40), or graft failure (p= 0.46).

Allografts

As for allografts, they come in a variety of options. The allografts used in most studies are fresh-frozen hamstring, irradiated hamstring, mixture of fresh-frozen, and cryopreserved hamstring, fresh-frozen tibialis anterior, and fresh-frozen Achilles tendon grafts[12]. The implication of the preservation method used for allografts will be discussed later in this paper. With the wide array of tendon choices, it can be difficult deciding the best option for each patient.

Autografts versus allografts

After comparing the outcomes between the different types of autografts, the primary purpose of this paper is to compare the patient outcomes between tendon autograft versus allograft in ACLR. One study investigated autografts versus allografts in ACLR, but did not separate the type of autografts or allografts used in their meta-analysis. This was a meta-analysis and systematic review by Wang et al.[1] that included six studies with a combined total of 18,835 patients (14,862 autografts versus 3973 allografts). They determined there was no significant difference between autograft and allograft groups in regards to overall IKDC (p=0.21), ROM (p=0.94), vertical jump (p=0.09), and single-legged hop (p=0.50) testing[1]. The other objective measurements including KT-2000 (p< 0.0001), pivot-shift (p= 0.001), anterior drawer (p= 0.0001), and Lachman's (p= 0.0002) testing from 215 patients favored autografts compared to allografts[1].

The meta-analysis then compared the subjective outcome scores of the studies. They found the subjective IKDC (p< 0.0001), Lysholm (p= 0.01), and TAS (p= 0.03) from 279 patients demonstrated significant differences favoring autografts compared to allografts[1]. The study also found CKRS from 215 patients favored autografts over allografts (p= 0.04)[1].

The postoperative complications associated with ACLRs in studies comparing autografts and allografts found two patients from one of the studies developed a superficial wound infection in the allograft group[1]. Additional postoperative complications were reported in five patients from two studies that developed hypoesthesia of the medial saphenous nerve in the autograft group[1]. In four studies that investigated complications, they reported only two studies with associated complications with either autograft or allograft groups[1]. There was no significant difference found when comparing complications between the autograft and allograft groups, but the risk ratio favored the allograft group (0.48, p= 0.34)[1].

In addition to postoperative complications, the irradiation of allografts have shown to compromise the integrity of the graft, thus leading to less stability and potentially higher failure rates than fresh-frozen allografts or autografts[1]. There were 302 autograft failures and 157 irradiated allograft failures reported from two prospective cohort studies[1]. There were no reported failures in the three randomized controlled trials[1]. Therefore, a meta-analysis could not be performed due to the differing levels of evidence between the five studies. Other research shows increasing ACLR failure rates using allografts in younger patients and increased activity levels[16].

While studies comparing outcomes between all autografts versus all allografts demonstrate autografts superior to allografts, further research comparing the different types of grafts used in ACLR is necessary.

BPTB autografts versus allografts

First, BPTB autografts are considered the current gold standard for ACLR. Studies comparing outcomes of BPTB autograft versus BPTB allografts favored autografts over allografts. A contributing factor of BPTB autografts being gold standard has to do with the lower failure rates associated with BPTB autografts compared to allografts from multiple studies[17, 18]. The largest study concluded the graft rupture rate favored autografts at 4.3% compared to 12.7% for the allograft group[17]. Kraeutler et al. was a meta-analysis of 76 studies of 5182 patients (4276 autografts versus 906 allografts) with minimum of 2 years follow-up comparing only BPTB grafts. The study included data from patients between January 1998 to April 2012. The studies did not need to be comparative in nature, and dichotomous variables were summarized as odds ratios with less than 1 favored allograft, and greater than 1 favored autografts.

A smaller cohort study by Barrett et al. included 63 total patients over 40 years-old between April 1, 1999 and October 1, 2000 with 2 years follow-up minimum. The study observed allograft failure in 1 patient, and two other allograft patients reported positive Lachman's, pivot-shift, and 6mm KT-1000 side-to-side arthrometer difference[18].Those patients did not consider those results as failures and did not proceed with any interventions[18]. There were no failures in the autograft group[18]. No deep infections, neurological complications, or wound problems in either group[18].

While the objective findings and failure rates favored autografts, subjective evaluation reported from 17 studies, showed allograft patients returning to preinjury activity level faster than autograft patients[17]. In a retrospective review of 102 patients (63 autograft versus 39 allografts) using BPTB autograft or allograft sterilized with 2.5 Mrad of irradiation found no significant difference in subjective ratings as 95% of allograft patients and 98% of autograft patients rated their knee function as normal or near normal. Furthermore, 95% of allograft patients compared to 94% of autograft patients rated their activity levels as back to normal or near normal[19]. The study had an average follow-up of 4.2 years[19]. There were 10 studies evaluating the subjective IKDC and found the odds ratio (1.64) favored autografts[17]. Other functional scores found Lysholm odds ratio (2.61) from 21 studies and TAS odd ratio (1.35) from 12 studies significantly favored autografts[17]. While other studies, at final follow-up, found no difference between groups in regards to Lysholm scores ($p= 0.081$), and TAS ($p= 0.127$)[18]. There was no statistically significant difference between autograft and allograft groups with respect to the CKRS[17]. Overall IKDC odd ratio (0.45) from 37 studies, significantly favored allografts[17]. Rihn et al. found no difference in IKDC between groups.

Objective evaluation from 45 studies, demonstrated the pivot-shift test odds ratio (0.74) favored allografts[17]. KT arthrometer odds ratio (2.02) from 38 studies, and single-legged hop test odds ratio (4.09) from 16 studies significantly favored autografts[17]. Conversely, another study found the allograft group had decreased KT arthrometry (p= 0.04) compared to autograft group[19]. Furthermore, Rihn et al. found no difference in ROM, vertical jump, or single-legged hop tests between autografts and allografts. Similarly, another study's objective findings revealed no difference in Lachman's (p= 0.096), pivot-shift (p= 0.245), ROM , or KT-1000 (p= 0.398)[18]. There were 28 studies evaluating anterior knee pain and found the odds ratio favored allografts[17].

QT autograft versus allograft

Next, outcomes of quadriceps tendon autografts versus allografts will be compared. In the current literature, there is only one study comparing QTPB autografts to QTPB allografts. Kwak et al. included patient data from February 2009 to January 2014. The study was a retrospective matched case control study for age, sex, direction of injured knee and BMI of 45 patients receiving QTPB autograft and 45 patients receiving QTPB allograft. The average follow-up was 31.2 months.

Kwak et al. found no difference between autograft and allografts at final follow-up in regards to objective tests including anterior drawer (p= 0.652), Lachman's (p= 0.404), pivot-shift (p= 0.823), and KT-2000 (p= 0.235). Instability assessment scores improved in both groups (p< 0.001). One patient in each group demonstrated clinical failure with positive Lachman's test, but both patients' anterior drawer, pivot-shift, and KT-2000 measurements did not elicit instability.

Functional score outcomes including IKDC (p= 0.366), Lysholm (p= 0.170), and TAS (p= 0.434) also found no difference between the groups. Functional improvements were observed in both groups from preoperative to postoperative assessments (p< 0.001).

HT autografts versus allografts

Finally, the outcomes of HT autografts versus allografts will be compared. A study by Cvetanovich et al. found no difference between autografts and allografts in Lysholm (p= 0.53), TAS (p= 0.40), and IKDC (p= 0.80) scores[12]. Cvetanovich et al. was a systematic review and meta-analysis of randomized control trials comparing HT autograft versus allograft ACLR. The analysis included five studies (504 total patients) with 251 patients receiving autografts and 253 receiving allografts with a minimum of 2 years follow-up. The allografts used were fresh-frozen hamstring, irradiated hamstring, mixture of fresh-frozen and cryopreserved hamstring, fresh-frozen tibialis anterior, and fresh-frozen Achilles tendon.

Similarly, a prospective study by Edgar et al. comparing HT autografts versus allografts demonstrated no difference in Lysholm (p= 0.75), overall IKDC (p= 0.51), or TAS (p= 0.08) scores[14]. Edgar et al. was a prospective study including 104 patients (37 autografts versus 47 allografts) from 1997 to 2000. The study included skeletally mature patients between 15-55 years old, average age 29 years. The excluded patients had prior ACL or other ligamentous injury to either knee, and concomitant MCL, LCL, or PCL injury or other bony/cartilaginous repairs. The patient follow-up was a minimum of 3 years. The patients were informed of the autograft and allograft constructs and 75% consented to randomization for the study. The non-randomized and randomized groups were pooled to ensure validity of the study. The postoperative rehabilitation protocol was identical in both groups of patients, and clinical assessments were performed by blinded observers to the graft type of the patients.

Edgar et al. found preoperative average Lysholm scores were 71.3 and 67.7 for autograft and allograft groups, respectively. At final follow-up, the Lysholm scores improved to 91.0 and 92.7, respectively. In addition, average subjective IKDC scores improved from 57.5 to 87.6 and 54.9 to 87.0 for the autograft and allograft groups, respectively. The average TAS from preinjury to final follow-up was 7.2 to 6.8 and 6.8 to 6.9 for autograft and allograft groups, respectively. There were two patients in the autograft and two in the allograft group with failed grafts 1 year post-operation sustained injuries while playing sports.

Additionally, Wang et al.[11] found no difference in the Lysholm or overall IKDC scores between the HT autograft and allograft groups, but did elucidate differences in subjective IKDC and TAS favoring autografts. Subjective IKDC (p= 0.0006) and TAS (p= 0.03) showed a significant difference favoring HT autografts. Wang et al.[11] was a meta-analysis including eight studies (785 patients). All studies had at a minimum of 2 years follow-up, and were randomized patients using HT autografts and hamstring, tibialis anterior, tibialis posterior, or Achilles tendon allografts. The autografts were fresh-frozen, with three studies using irradiated allografts. The objective testing will be evaluated next as there is no clear indication for HT autograft versus allograft in regards to subjective assessment.

The objective tests comparing HT autografts versus allografts reveal no significant differences between HT allograft and autograft for Lachman's (p= 0.16), pivot-shit (p= 0.46), and KT arthrometer testing (p= 0.36)[12]. Other studies with similar results did not note any difference in stability outcomes of ROM, pivot shift test, anterior drawer test, and Lachman's test[11]. The arthrometry measurements did note a significant difference (p= 0.01) between the groups, favoring HT autografts[11]. At final follow-up, Edgar et al. did not elucidate the difference in KT measurements between HT autografts and allografts (p= 0.33), but both groups did show improvement in laxity ($p < 0.0001$). Preoperative and final follow-up KT measurements were 6.0 to 1.4 and 5.9 to 1.5 in the autograft and allograft groups[14]. The arthrometer measurements were maintained upon 3 year follow-up in 87% of autograft and allograft groups[14]. The comparison of the complications associated with HT autograft versus allograft will now be discussed.

The most common complication of ACLR using a HT autograft is donor site morbidity[11, 12]. HT autograft harvest site morbidity includes saphenous nerve damage and postoperative knee flexion weakness[12]. Studies have also found longer operating time for HT autografts compared to allografts[11, 12]. Although an increase in the reoperation rates for autografts compared to allografts was noted, it was not statistically significant[12]. There is a possible risk for disease transmission, delayed graft incorporation, graft laxity, and failure with prolonged use in allografts[12].

Wang et al.[11] did not find any differences between the groups in regards to other complications such as reoperation, pain, arthrofibrosis, effusion, tenderness, or infection. A postoperative complication of ACLR was hypoesthesia of the medial saphenous nerve using HT autograft that showed a significant difference ($p= 0.01$) in favor of allografts.

Of note, four of 396 HT autografts and 13 of 389 allograft failures were reported[11]. No significant difference ($p= 0.81$) in reoperation rate between the two groups as there were 7 in the autograft and 6 in the allograft group[12]. Failure rates included patients with laxity greater than 4mm with 5% compared to 11% in autograft versus allograft groups[14]. Three patients from the autograft and two from the allograft failure groups underwent revision surgery[14].

Based on the research findings, autografts are superior in regards to lower failure rates compared to allografts, but have an increase in donor-site morbidity. Thus, indications for use of autografts versus allografts remains to be a patient-centered decision, and risk factors must be taken into consideration.

METHODS

Research was done by searching Augsburg University Interlibrary loan system, PubMed, and Elsiver to identify studies that compared autograft compared to allograft tendon repair in ACL reconstruction. Title fields were searched for the following terms in each database: "ACL reconstruction", "Autograft", "Allograft", "BPTB autograft versus allograft", "Quadriceps tendon autograft versus allograft", "Measures of knee function", "Cincinnati knee score", and "ACL repair". A manual search was also performed for "pivot-shift scholar", and "cost of ACL reconstruction". Additionally, a manual search was performed for articles potentially missed by the electronic search. The studies included were based on selection criteria. The studies were reviewed for information pertaining to first author, publication year, study type, sample size, age (closed physes), sex ratio, information regarding the tendon autografts or allografts. Primary outcomes studied were subjective patient evaluations including IKDC, Lysholm, TAS, CKRS and post-operative pain score, and objective assessments including: ROM, anterior knee pain, KT arthrometer, single-legged hop, vertical jump, and associated complications/failures.

The studies included meta-analyses, systematic reviews, prospective cohort, and retrospective studies. There were a total of 120 studies included for meta-analysis, 30 studies for systematic review, 4 prospective cohort studies, and 3 retrospective cohort studies.. This included a total of 41,164 patients. The dates of the studies from database searches ranged from database inception to 2018 with a minimum follow-up duration of 1 year post-operation. Excluded studies were any with less than 1 year duration follow-up post-operation. Other inclusion and exclusion criteria were study specific, and are mentioned within this paper.

DISCUSSION

Recalling the high prevalence and cost associated with ACL tears and reconstructions, an understanding that the best outcomes are ideal for patients to ensure knee function is restored and pain is eliminated. First, the comparison of outcomes between the types of autografts used in ACLRs will be discussed. Then, the comparison of the outcomes between autografts versus allografts will be examined before the comparison of the outcomes based on the types of autografts and allografts.

HT vs BPTB auto

The literature with the most robust cohort study and longest duration of postoperative follow-up demonstrates BPTB autograft to be associated with decreased revision rates and graft failure compared to HT autograft[13]. Other studies have demonstrated HTs to be non-inferior to BPTB autografts with less anterior knee pain, but did note an increase in hamstring weakness[14].

QT vs BPTB auto

The study by Mouarbes et al. comparing the outcomes between QT and BPTB autografts found no difference in stability, measured by arthrometry, Lachman, and pivot-shift. Furthermore, there was no difference in functional outcome scores of objective and subjective IKDC, and Lysholm. Additionally, there was no difference found in regards to failure rates, but did note that QT was favored in regards to donor-site morbidity over BPTB.

QT vs HT auto

In the same study by Mouarbes et al., they compared the outcomes between QT and HT autografts. The study found no difference in stability, measured by arthrometry, Lachman, and pivot-shift. There was no difference in other functional outcome scores except Lysholm which favored QT over HT. Finally, there was no difference elucidated between QT and HT autografts in regards to anterior knee pain or graft failure.

Autograft vs allograft

Before diving into the comparison of outcomes between the types of autografts versus allografts, a general comparison of outcomes of autografts versus allografts will be elucidated. Autografts were favored in KT, pivot-shift, anterior drawer, and Lachman tests[1]. Additionally, autografts were favored in subjective IKDC, Lysholm, TAS, and CKRS[1]. Arguably the most important outcome measured in the Wang et al.[1] study that favored autografts was failure rates when compared to irradiated allografts. The Wang et al.[1] study found no difference between autografts and allografts in regards to objective IKDC, ROM, vertical jump and single-legged hop. There was no difference in complications observed, but the risk ratio favored allografts.

The tests examining anterior and rotational stability of the knee showed significant differences between the preservation and sterilization allograft groups. As previously noted, allografts are preserved in a variety of ways, and studies have proven increased gamma irradiation to have detrimental effects on the properties of allografts leading to significantly poor rotational and anterior stability compared to autografts[1, 21-23]. The irradiation of allografts have been shown to cause adverse effects in a dose-dependent manner as a reduction in biochemical effects on allografts is seen under 2 Mard of gamma irradiation[1, 11].

Additionally, the type of preservation and sterilization method significantly impacts which graft the patient chooses. Studies were not able to demonstrate enough evidence to delineate which graft failure rate was higher, but decreased stability was associated with gamma irradiation on allografts[1, 11]. The failure rate of the Wang et al.[1] study could not be evaluated due to the differing levels of evidence. In addition, there were no reported failures in three of the randomized control trials out of the data from five included studies. More randomized control trials are needed to compare the failure rates between autografts and allografts.

Other comparative studies have demonstrated higher failure rates in gamma-irradiated allografts[1]. The observed 33% failure rate and increased KT-1000 measurements in irradiated allografts compared to a 2.4% failure rate in non-irradiated allografts validate the detrimental effects of gamma-irradiation on allografts[24].

In an interview on July 27th, 2021, Dr. Nicholas Weiss, an orthopedic surgeon with Twin Cities Orthopedics, commented on how he chooses his graft selection based on age.

> For older folks allograft is appealing as they will likely have a good result and the morbidity of harvest is eliminated. Studies show that an allograft for younger patients has a high failure rate. Likely because of the increased stress placed on the graft with higher level activities. Weekend warriors or 'older' patients are reasonable for allograft. Allograft is unpredictable in quality and weakens with preparation so I have moved away from it for most.

BPTB auto vs allo

The first type of autograft that will have its postoperative outcomes compared to allografts is the BPTB autograft. BPTB autografts demonstrated lower failure rates compared to allografts[17, 18]. Barrett et al. also found BPTB autografts had decreased laxity as measured by arthrometry, Lachman, and pivot-shift tests compared to allografts. Other studies found subjective IKDC, Lysholm, and TAS to favor BPTB autografts over allografts, but did not elucidate differences in CKRS[17].

There was no difference in the functional outcome scores of Lysholm or TAS[18, 19]. Rihn et al. also did not find a difference in other knee ratings or activity levels between groups as knee function and activity level ratings were normal to near normal. No differences were elucidated in ROM, vertical jump, or single-legged hop in the Rihn et al. study. The objective measurements demonstrated KT arthrometry, single-legged hop to favor autografts over allografts[17].

Allografts were favored over BPTB autografts in preinjury return to activity. Barrett et al. noted the return to preinjury activities was limited in this study due to the age group, but 56% of allograft and 25% of autograft patients were back to sporting activities by 6 months. There were also fewer autograft patients able to return to preinjury activities at the time of follow-up in the Kraeutler et al. study. Additionally, Kraeutler et al. found the overall IKDC to favor allografts over BPTB autografts. Other assessments favoring allografts over autografts were arthrometry[19] the pivot-shift test[17], and subjective assessment of knee pain[17].

The study by Kraeutler et al. demonstrated the pivot-shift test favored allografts versus autografts only when the reconstruction was performed using an anteromedial approach. However, further investigation revealed a higher proportion of the autograft reconstructions used the trans-tibial approach when compared to allograft reconstructions. The surgical technique did not demonstrate a difference in pivot-shift when comparing anteromedial and outside-in approaches to a transtibial approach.

QT auto vs allo

The next comparison of outcomes to allografts are the QT autografts. The current literature demonstrates no difference in laxity or stability as measured by anterior drawer, Lachman, pivot-shift, and KT arthrometry[20]. In the study, both groups showed an increase in stability post-operation[20]. Additionally, the study found no difference in functional outcomes scores[20].

HT auto vs allo

Finally, the comparison of outcomes between HT autograft versus allografts. Significant differences favoring HT autografts over allografts were demonstrated in the functional outcome scores of IKDC, and TAS [11]. The objective assessments that favored autografts were KT arthrometry[11].

The research demonstrates no difference in Lysholm, IKDC[11, 12, 14] and TAS[14]. Research noted improved functional outcome scores in both HT autograft and allograft groups post-operation[14]. Objective outcomes also showed no difference in stability and laxity as measured by Lachman[12], anterior drawer[11], pivot-shift[11, 12], ROM[11], pivot-shift[11], and KT arthrometry[12, 14]. Even though there was no significant difference between the groups, the groups demonstrated improvement in laxity and maintained those measurements for 3 years[14]. Furthermore, there was no difference appreciated in regard to reoperation rates[12], pain, arthrofibrosis, effusion, tenderness, or infection[11] between HT autograft and allografts

The complications associated with HT autografts are well documented. Saphenous nerve damage, knee flexion weakness[11, 12]. Also, longer operation time was associated with HT autografts compared to allografts. On the contrary, allografts have been associated with complications such as disease transmission, delayed graft incorporation, and graft laxity and failure[12].

A central challenge most of the studies touched on was the need for more high-quality, randomized control trials with more patients, and longer follow-up to help determine which graft choice definitively provides superior outcomes. Some of the studies included a small number of randomized control trials that researchers were able to utilize. This also included some data that had a small sample size. For a definitive conclusion to be made, there needs to be a large enough sample size that allows statistical significance to be relevant. Statistically significant results from studies with small sample sizes do not carry the same weight as studies with a more robust sample size.

Furthermore, most of the studies had follow-up duration of only two years post-operation. While this gives an insight into short- to intermediate-term outcomes, it does not provide sufficient assessment of the long-term outcomes of autografts and allografts in ACLR. Also, most of the studies included patients of varying demographics, but there were studies that only investigated the outcomes of certain age groups. This is helpful to gain an understanding of that specific patient population, but the results of the study cannot be extrapolated to other age groups.

Another important limitation to the current research is lack of standardization of comparison between grafts. Comparing the same types of grafts between patient cohorts (ie BPTB autografts versus BPTB allografts) increases the study's validity of results. It is imperative to comprehensively formulate a database where researchers can select the types of grafts to compare. Additionally, standardization of the evaluation of patients is necessary. Some studies were excluded due to the fact they had no preoperative rating scales to compare the postoperative ratings to. This is a real disadvantage and hinders the scientific method.

CONCLUSION

When an ACL is torn and an ACLR is the treatment selected by the patient and surgeon, it is imperative to understand which graft choice provides superior outcomes. The primary objective of this paper was to determine superior post-operative outcomes of autografts versus allografts in patients with ACL tears. Specifically, this paper addressed the outcomes based on subjective rating scales, objective measurements, and the complications observed in patients with short- to intermediate-term follow-up. The large studies demonstrate autografts the superior graft choice over allografts in overall postoperative ACLR outcomes. The data is not consistent across the smaller studies with respect to each individual outcome category (i.e. subjective, objective, and failures), but the overall trend demonstrates allografts to be equal or inferior to autografts in most categories. In addition to the overwhelming evidence supporting autografts superior to allografts in almost every outcome, other differences must be considered to support the autograft construct superior.

Dr. Weiss was asked about his approach to an ACLR for a patient with a torn ACL.

> Age isn't a real determiner. It's patient activities, specifically their desire to return to jumping, cutting and pivoting activities. For older patients, it's reasonable to try PT (physical therapy) first. They may be able to cope, especially if they have arthritis as the stiffness associated often protects. Regardless of age, if someone is having instability with activities of daily living, they are reasonable candidates for ACL reconstruction. Younger patients often would like to return to athletic activity and so we typically go right to surgery to protect their knee from further damage. For younger, high-activity patients, a 'stiffer' graft such as BPTB or quadriceps tendon autograft are good options. For others, hamstring or quadriceps tendons are good options. I think it will continue to be close to even split with BTB, HS and QT for autograft. They are all three reasonable options. QT is really gaining traction. Will continue to see better fixation methods for it. In appropriate candidates, we may see a surge in ACL repair as well. Time will tell if this is a better approach than reconstruction.

The morbidity associated with autograft harvest of the hamstring tendon is an important consideration for athletic and daily activities. Loss of knee flexion strength was demonstrated 2 years post-hamstring autograft ACLR[14], and QTPB autograft demonstrated loss of torque at peak extension of the quadriceps muscle at 6 months post-operation[20]. With the disadvantages of autografts clarified, the outcomes associated with allografts in ACLR will now be discussed.

Allografts have indications for those patients who are not as young and active as autograft patients. Allografts are a preferred graft choice for patients concerned with the complications of donor-site morbidity associated with ACLR using an autograft like hamstring or quadriceps weakness, nerve damage, and anterior knee pain. The literature also demonstrates the importance in the type of allograft preservation. Irradiated allografts have shown poor stability and increased failure rates, thus would not be a first-line choice for ACLR. Evidence from larger studies evaluating arthrometry reveals increased laxity or failure rates in allografts compared to autografts. With advantages of allografts including no donor-site morbidity, shorter operative time, and graft length selection preoperatively, allografts are increasing in popularity.

Finally, a patient-centered decision should be at the forefront of surgeons' agendas. The most difficult part of a surgeon's practice, according to Dr. Weiss, is managing expectations. "This is the toughest part of practice. It is important to review realistic expectations but even then, patients may not remember or understand. Everyone heals at different rates. I tell patients that the biggest mistake they could make is comparing themselves to others. No other person has the exact same situation as theirs so it's apples to oranges." The contributing factors for surgical intervention are continually evolving, and are not universally agreed upon amongst physicians. The type of surgery is based on tear location, tissue quality, age, activity level, and patient preference. The first step in deciding the type of surgical treatment is appropriate depends on the patient. The data and research aids in the decision-making process for which graft is chosen for an ACL tear, but ultimately, it comes down to patient preference, surgeon experience, and clinical relevance in real-OR application.

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APPENDIX

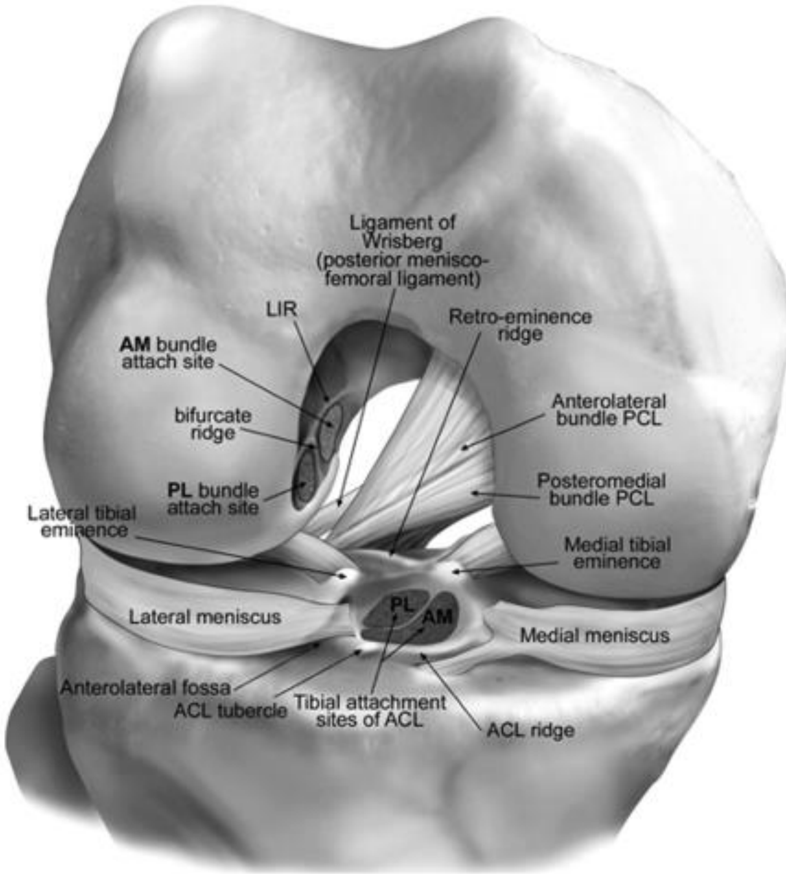

Fig. 1 Illustration showing ACL anatomy

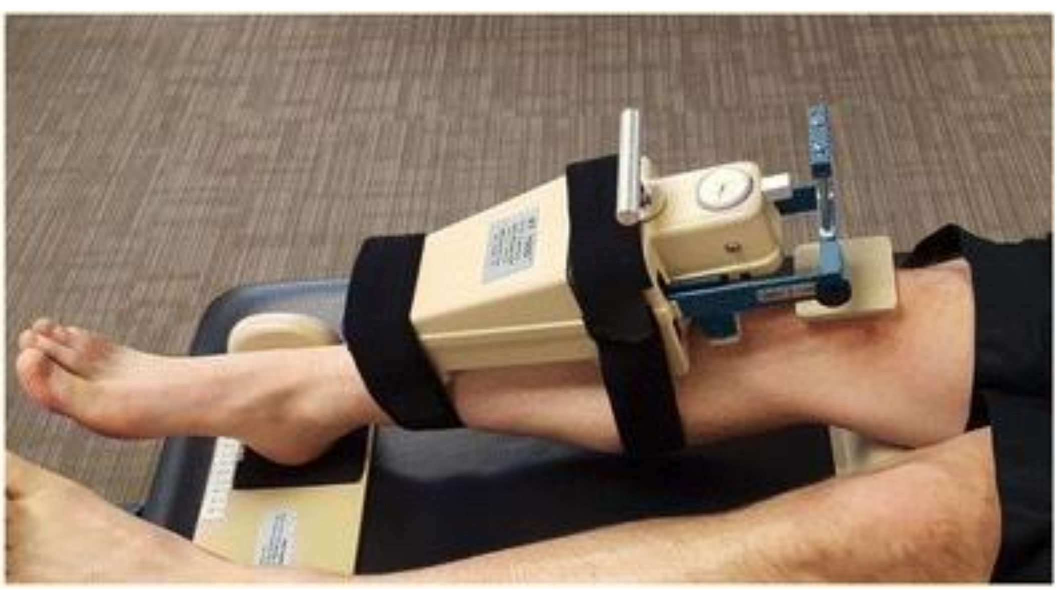

Fig. 2 Showing KT-1000 knee arthrometer

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