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Choosing an allograft or autograft in orthopedic surgeries for athletes

Abstract

Athletes and their doctors have the choice of using an allograft or autograft in reconstruction surgeries. The purpose of this study is to see if there is a difference in the healing mechanism and surgical outcome in using an allograft or autograft during orthopedic surgical procedures, as well as to analyze graft rejection and disease transmission through donor tissue.

Doctors and athletic trainers were interviewed in order to learn about the healing mechanisms and advantages and disadvantages of allografts and autografts in order to conclude if one was better than the other. College level athletes on different sports teams were given a questionnaire that asked questions on the surgical procedure they got and whether or not the surgeon used an allograft or autograft. Specific questions relating to recovery time, stability, and overall function of the area of surgery were asked in order to analyze the outcome. The subjects were screened by choosing athletes with the same surgical reconstruction except one using an allograft and one using an autograft. The questions relating to the outcome of the surgery were compared in order to see if one produced a better outcome over the other. Athletes were found to have better success with autograft as predicted by doctors.

Introduction

As an athlete, it is important to question whether using an allograft or autograft is best for his or her orthopedic reconstruction surgery. Recovery time, pain, stability, strength, and infection are all things to consider when choosing a graft. Many cohort studies have been carried out on patients who have received allograft or autograft tissue, especially with ulnar collateral ligament (ACL) reconstructions, but none have been done on just athletes. Athletes need to be considered differently when choosing a graft because of the high impact activity performed postoperative. Athletes have extra factors to consider because their recovery time needs to be as quick and effective as possible so they can return to their sport as quickly as possible without complications. There are numerous different graft choices, and they all have their advantages and disadvantages. It is urgent that athletes can have full graft incorporation as quickly as possible so they do not re-injure the injury with high impact activity. This study focuses mainly on graft types with ulnar collateral ligament (ACL) reconstruction in the knee.

The two main graft choices are allografts, a graft from a donor, and an autograft, self-tissue harvested from somewhere else in a person's body. Anterior cruciate ligament tears have several graft choices for reconstruction. There are main advantages and disadvantages for allografts and autograft, as well as certain advantages and disadvantages of different graft types within these two categories. Both grafts have to revascularize and create a new blood supply when introduced into the new area. The graft has to incorporate itself in the new location; until the graft is fully incorporated, there is a chance of re-rupturing if weight bearing or impact occurs too soon.

Autografts are incorporated to the body faster because it is the body's own tissue and it is not seen as foreign, so blood vessels and cells can more quickly grow into the tissue graft (Autograft versus Allograft for ACL Reconstruction). Autografts have a zero percent infection rate. There are two main grafts to choose from for ACL reconstructions, the patellar tendon and the hamstring tendon. The patellar tendon graft is the gold standard and has been since the 1980s, boasting a 90-95% success rate for athletes (ACL Graft Choices 2016). The patellar tendon bone-tendon-bone (BPTB) graft is advantageous because of the bone-to-bone healing (Vang 2006). When the patellar tendon in the front of the knee is harvested, the surgeon leaves chunks of bone on both ends of the tendon. This way when the tendon is placed where the ruptured ACL was, the new graft is healing bone on bone instead of tissue on bone. This bone on bone healing is much faster and athletes can return to full high impact activities within six to eight weeks (Vang 2006). The disadvantages of this graft includes morbidity at the donor site such as pain especially while kneeling, loss of extension, patellar fracture, and patellar tendonitis (Yao 2015). It is one of the most painful grafts to harvest because of the bone on the ends of the tissue, leaving bone injury to the donor site. However, the pain is not an indication of injury, so, if the athlete can tolerate a little extra pain, this would be the best graft choice for an ACL reconstruction. There has been some indication of weakening of the quadriceps muscle from harvesting the BPTB graft which requires longer physical therapy time before returning to sports.

The hamstring tendon graft although has less of a chance of quadriceps atrophy, the healing process is 12 weeks, versus six to eight, because the graft heals tissue to bone, there is no bone on the end of the tendons like the BPTB graft (Vang 2006). Similarly, the quadriceps

graft tendon is tissue to bone healing, so it has similar advantages and disadvantages as the hamstring tendon. The physical therapy for ACL reconstruction is vigorous and sometimes prevents the ends of the grafts from completely healing to the bone since tissue to bone healing takes longer for the graft to incorporate (Vang 2006). There are also more complications while harvesting such as cutting the tendon in half or injuring nerves or other ligaments around the self-donor site (ACL Graft Choices 2016). However, long term outcomes show no difference in recovery between the BPTB graft and the hamstring tendon, even though the BPTB is predicted to get athletes to return to their sport faster.

The advantage for tissue allografts is that the patient can recover faster because there is no secondary incision site, so there is less swelling and pain. However, even though a person receiving an allograft feels one hundred percent better, that does not mean the graft is fully incorporated. This is okay for an average person doing medium level activity, however, for athletes, the prolonged incorporation is a problem. Allografts take longer to incorporate and create a new blood supply because the body sees the tissue as foreign (ACL Graft Choices 2016). Even though the athlete may feel ready to return their sport weeks before they are actually cleared, they have to make sure the doctor feels the graft is fully incorporated before starting high impact activity again. Therefore, with longer incorporation but less pain, there is an increased risk of re-rupturing. Allograft failure has been found to be three times higher than autografts (Autograft versus Allograft for ACL Reconstruction).

A prospective longitudinal cohort of ACL reconstruction outcomes was performed by Multicenter Orthopaedic Outcomes Network (MOON) in order to determine predictors of ACL reconstruction failure (Kaeding 2010). The same surgeon was used who had the same protocol

for recovery time with all graft choices in order to eliminate confounding factors (Kaeding 2010). One surgeon who performed 158 allograft orthopedic reconstructions had 10.13% re-rupture (Kaeding 2010). When analyzing surgeries from 568 surgeons performing both allograft and autograft reconstructions, 18 of the patients, or 3.2%, had a re-rupture (Kaeding 2010). The study did statistical tests to make sure the results of one surgeon were generalizable. In another model of the cohort, 24/691 (3.5%) of autografts reported graft failure and 21/235 allografts reported graft failure (Kaeding 2010). The highest percent of graft tears found in this study were between the ages of 10-19 (Kaeding 2010). Below the age of ten, there was a 2.3x less of a chance to be at risk for graft tearing (Kaeding 2010). With these retrospective studies, the odds of tearing an allograft tissue ligament, for anterior cruciate ligament (ACL) reconstruction was four times higher than tearing an autograft (Kaeding 2010). These findings had a 95% confidence interval, making it reliable data.

Not only are allografts at more of a risk for re-rupturing, there is a small risk of disease transmission and infection. The risk of infection is very minimal, less than one percent (Greenwald 2010). The risk of disease transmission is higher. Numerous cases have been reported in the United States, however the risk of transmission through musculoskeletal tissues is unknown. Reasons for uncertainty include: a lack of standardized protocol for harvesting tissues, failure of a surgeon to recognize or confirm that the allograft was the source of the infection, and there is a lack of reporting why infections occur (Greenwald 2010). Disease transmission through tissue grafts can occur through an infected donor, or through procurement, processing, or packaging of the graft (Doral 2015). Other factors include the virulence and tissue tropism of the organism, the host's immune system and general health,

medical staff's clinical experience and understanding of assay characteristics, and epidemiologic exposures such as outbreaks and nosocomial vectors (Greenwald 2010). Infectious diseases can be bacterial or viral. Bacterial is more common and viral infection transmission is extremely rare, but there have been incidences. Infectious disease derived from donors are considered to be very rare and physicians consider allografts to be very safe, so in order to detect this type of infection, clinicians need to be more aware and have the skills and knowledge to detect it (Greenwald 2010).

Although fairly uncommon, the Center of Disease Control (CDC) has had several reports of infection through disease transmission. Disease transmission infections can be serious, sometimes even fatal. The bacteria gets into the bloodstream while the graft is revascularized, which is why it is so dangerous. Disease transmission became a concern for the CDC in 2000 when there were several bacterial infections leading to septic arthritis reported in patients with ACL reconstruction who received a bone-tendon-bone graft (Doral 2015). Four cases were found in 2000 alone. A sixteen-year-old girl was infected with *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Enterococcus faecalis* which lead to septic arthritis. A forty-year-old man was infected with *P. aeruginosa*. As well, A fifty-five-year old woman was infected with *Citrobacter werkmani* and a group B hemolytic *streptococci* (Doral 2015). Additionally a twenty-nine-year old woman was infected with *Klebsiella oxytoca* and *Hafnia alvei*. All three cases lead to septic arthritis (Doral 2015). The septic arthritis leads to pain from inflammation in the joint caused by the bacterial infection. In 2001, two recipients of the same donor were infected. The CDC reported a twenty-three-year old man who was infected with *Clostridium sordelli* and passed away after three days post operation in a femoral osteochondrial allograft

reconstruction while the other recipient developed septic arthritis that was nonfatal (Doral 2015). In 2002, there were twenty-six cases of transmitted bacterial infections through tissue allografts (Doral 2015). Fifty percent of infections were due to Clostridium species (Doral 2015).

Viral transmissions are more rare but have occurred, and include hepatitis, human immunodeficiency virus (HIV), and human T-lymphotropic virus (HTLV) (Doral 2015). The CDC has only reported four cases of Hepatitis C in the years 1992, 1995, and 2003 (Doral 2015). One case of HTLV was reported in Sweden and two cases of HIV were reported in the U.S. in 1984 and 1992 (Doral 2015). The donor was found to be infected with HIV after the transplantation already occurred, which is why screening donor tissues today is so important. Disease transmission of viruses is only possible through human error by missed detections of serological tests (Doral 2015). Only 1 in 1.2-2 million have gotten HIV from tissue allograft donation (Autograft versus Allograft for ACL Reconstruction).

Because of the few viral infection transmissions and numerous bacterial infection transmissions through tissue allografts, screening donor tissue and sterilization methods have become stricter. Screening steps include: consent from the donor for screening, patient history from the primary caregiver, a physical examination, as well as tissue and blood screening tests for hepatitis B and C, HIV, HTLV, and syphilis (Doral 2015). Irradiated allografts are thought to have a zero percent infection rate, however surgeons do not use this extensive sterilization because the radiation significantly weakens the graft which puts the patient at risk of graft failure (Autograft versus Allograft for ACL Reconstruction). There has to be enough radiation, but not too much where the tensile strength of the tissue is destroyed. Donor tissue is retrieved aseptically and then undergoes secondary sterilization (Doral 2015). Sterilization is done using

ethylene oxide or a low enough dose of irradiation that won't cause biologic or biomechanical damage (Doral 2015).

Rejection of allografts is very rare and almost nonexistent because there is very little protein antigen after the grafts are washed. As well, grafts with bone on the ends are completely cleaned to rid any marrow components (ACL Graft Choices 2016). However, it potentially can happen if the graft is not sufficiently washed and there is enough antigen left to create a response. Graft rejection is a cell mediated response. The body detects the antigens on the allograft, also called alloantigens, and activates the immune system against the allograft (Ingulli 2010). The alloantigens are both major and minor histocompatibility antigens (Ingulli 2010). Major histocompatibility complex (MHC) on the chromosome 6 in humans is called human leukocyte antigen (HLA). HLA are polymorphic and have the strongest response to allograft tissues; they are genes that encode MHC I and II (Ingulli 2010). The MHC present the antigens to T cells and the T cell receptors interact with the MHC on the surface of antigen presenting cells (APC) (Ingulli 2010). Minor histocompatibility antigen is expressed in only some individuals and differ from donor to recipient, eliciting an immune response. Minor histocompatibility gene can encode epitopes that bind to MHC I and II and cause a response of CD4+ and CD8+ cells (Ingulli 2010). Any changes in protein between the donor and recipient can cause rejection of the allograft.

The alloantigen can undergo either a direct or indirect pathway to elicit an immune response. In the direct pathway, T cells directly recognize MHC on the donor that is non self (Ingulli 2010). T cells recognize polymorphic residues of MHC on the allograft with no regard to the peptide bound to it (Ingulli 2010). Cells in the graft have to leave the graft and come into

contact with T cells in secondary lymphoid tissue in order for the T cells to be activated by allograft MHC (Ingulli 2010). Dendritic cells are responsible for first activating an acute response against the allograft. They migrate to the graft and pick up antigen, which they present to the T cells through the indirect pathway (Ingulli 2010).

In the indirect pathway, T cells recognize MHC on the allograft, process it, and self MHC presents it as peptides to the immune system (Ingulli 2010). APCs present donor tissue MHC as peptides associated to self MHC (Ingulli 2010). Any protein that differs from the donor are potential targets for antigen rejection. Allograft antigens can go into circulation where dendritic cells from secondary lymphoid tissue engulf the foreign antigen. Donor cells can also migrate to secondary lymphoid tissue to get engulfed by dendritic cells. Or, APCs can migrate into the graft, pick up the alloantigens, and then migrate to secondary lymphoid tissue (Ingulli 2010). Both peptides and MHC complexes of the donor tissue antigen can be presented to CD4+ and CD8+ T cells through the indirect pathway (Ingulli 2010).

The indirect pathway needs a lot less foreign antigen present to activate an immune response than the direct pathway (Ingulli 2010). When only donor and recipient MHC I differ, the indirect pathway is activated. The CD8+ T cells that are specific to peptides on MHC I of the donor cannot kill the graft's parenchymal cells because the graft only has donor MHC I molecules and not the recipients (Ingulli 2010). Therefore, the recipient's APCs would have to move into the graft via the indirect pathway in order for an immune response to occur.

Allografts can also create an innate immune response causing acute rejection of the graft. When the blood flow through to the tissue is restored via vascularization, the cell mediated and humoral factors of the innate immune system are activated. Ischemia is when the

tissue fails to revascularize, and there is a loss of blood flow to the tissue supply. Ischemia can create reactive oxygen species (ROS) and create toxic effects towards the graft (Ingulli 2010). ROS activate caspases, which are proteases that induce apoptosis, and induce chaperoning proteins, which are secreted from stressed or damaged cells and are ligands to toll like receptors (TLR) (Ingulli 2010). Chaperonins bind to TLR4 and TLR2 in order to activate immature TLR that express dendritic cells or vascular endothelium (Ingulli 2010). The TLRs cause dendritic cells to relocate to secondary lymphoid tissues from the graft and create an immune response against the allograft (Ingulli 2010).

In addition to revascularization failure, lymphocytes also play a role in acute rejection of allografts. T cells can damage graft cells by having specificity for peptides from the donor graft that are bound to self MHC and by releasing cytokines to directly damage the cells (Ingulli 2010). The chemokine receptor most involved in rejection is the CXC chemokine receptor CXCR3, expressed by activated T helper 1 cells and natural killer cells (NKC) (Hancock 2001). Chemokine ligand IP-10 is the only one of the CXCR3 that is thought to be activated through surgical procedures (Hancock 2001). IP-10 expression initiates the recruitment of natural killer cells, and then after, host T cells (Hancock 2001). Host leukocytes initiate and increase the expression of IP-10 which induces a host alloresponse and an acute graft rejection (Hancock 2001). B cells and allograft antibodies contribute to acute and chronic allograft rejection. B cells produce anti-graft antibodies and present the antigen from the allograft to T cells that are alloreactive via the indirect pathway, damaging the graft (Ingulli 2010).

Even though these allograft recipient risks of rejection and disease transmission are small, they should still be considered and kept in mind. The more conscious people have

become of disease transmission, the less of a risk there has been. Disease transmission can be prevented and graft strength can be sustained with proper screening and sterilization. Athletes have more to consider beyond these small risk possibilities. Athletes need to receive the graft that will have the fastest incorporation, fastest recovery time, and most stability. Athletes who receive an autograft are suspected to have a faster and better recovery.

Methods

Division One student athletes were given questionnaires (Fig 1) to assess their surgical recovery outcome. All sports, including men's and women's, were given questionnaires. Questions pertaining to recovery time, stability, pain, and overall success in returning to their sport were asked to analyze the surgical outcomes. Measurements were obtained through athletes rating on a number scale (Fig 1). Range of motion ranged from 1-5 (5 being full range), stability from 1-10 (10 being most stable), pain from 0-10 (0= no pain), and performance from 1-10 (10 being able to perform at full potential) (Fig 1). Athletes were recruited by giving the questionnaires to the team captains. The team captains had the team fill out the questionnaire and were picked up from their locker rooms once they were completed. The subjects were screened by choosing athletes with the same surgical reconstruction, except one having an allograft and one having an autograft used in the replacement. They were also screened by only using subjects who have actually finished recovering and have made it past the estimated recovery time of the surgeon. Questions about physical therapy time and difficulty were asked in order to better analyze the data. Physical therapy protocols from doctors differ, so details on physical therapy helped to exclude physical therapy as a confounding factor in making one

recovery better over the other. Recovery time estimated by the doctor was also asked in order to have a baseline for how quickly the athlete returned to their sport based on the doctor's predictions. Surgeries with different recovery times were taken into consideration when analyzing the athlete's outcomes.

Athlete questionnaire:

Answer all that apply

Injury:

Surgical Procedure (what was repaired or replaced):

If replacing was necessary, was an allograft (donor tissue) or autograft (tissue from somewhere else in your body) used, or doesn't apply:

Recovery process:

What was the estimated recovery time of your doctor?:

In what time were you actually recovered and able to return back fully?:

What was the recommended amount of physical therapy time (if any)?:

Did you do more, less, or the same amount of physical therapy that was recommended?:

How strenuous was the physical therapy? (only stretching, light, medium, strenuous exercise?):

End result:

Full range of motion? Rate 1-5 (5 being full range):

Stability rate 1-10 before and after surgery (now):

Pain level rate 1-10 before and after surgery (now):

Performance (how better able to execute skills) rate 1-10 before and after surgery:

Overall happiness with the surgery rate (horrible, bad, indifferent, decent, good, excellent):

Fig 1. Athlete Questionnaire. Questions pertained to orthopedic reconstruction months to years post operation.

Results were quantified and categorized by surgery and graft type before analysis.

A local surgeon who is familiar with most of the athletes was interviewed to get both points of view. The surgeon was asked the questions in figure 2 about recovery time and outcome, healing processes, surgical procedure differences, risk of re-injury, and rejection. The doctor's opinions were compared to the athletes' results to see if recovery time and outcome resulted as predicted. The doctor's responses were compared to the athletes' responses to see if there was consistency in the doctor's predictions about different graft, and the ability of athletes to return to their sport.

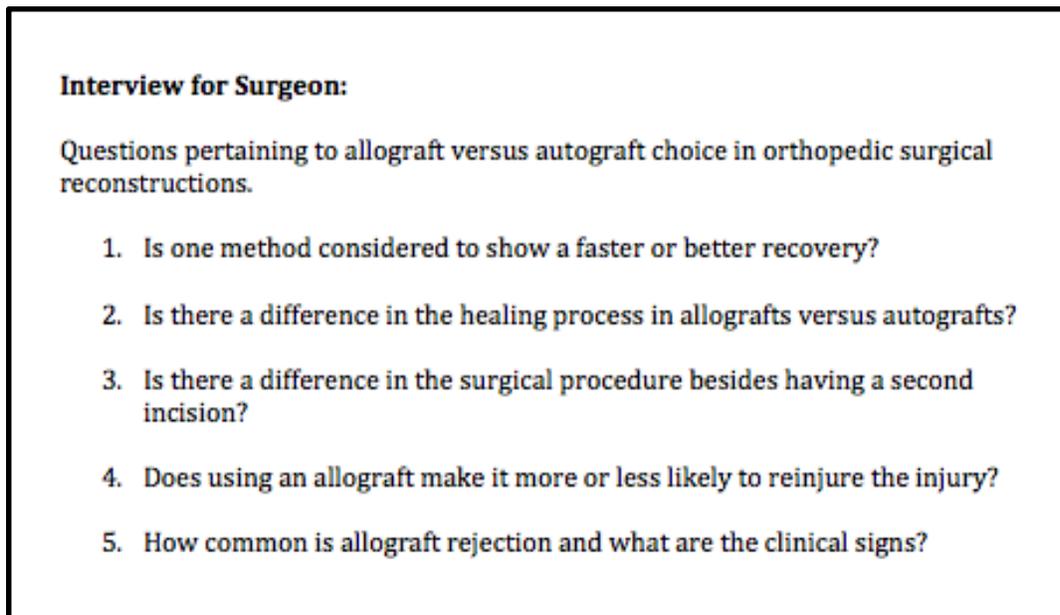


Fig 2. Interview for Surgeon. Questions pertaining to surgeon's opinion and knowledge of the differences between allografts and autografts.

Results:

The quantified data from the questionnaires for athletes receiving ACL reconstruction is shown in figure 1. Sports and genders varied. Those who participated were one female hockey player, two female gymnasts (one had 3 ACL reconstructions), one female lacrosse player, one

male soccer player, two female soccer players, one male basketball player, and one male track runner (had 2 ACL reconstructions).

ACL reconstruction results:

Graft Type	Estimated recovery	Actual recovery	Physical Therapy	Range of Motion	Pain (0=none)	Stability (10=most stable)	Performance (10=full potential)
Autograft: Patellar tendon	4-6 months	6 months	4 months; light to strenuous	4.5	2	10	10
Autograft: Patellar tendon	6 months	6 months/1 year after complication	3 months; strenuous	4	10	4	9
Autograft: Hamstring tendon	6-8 months	6 months	>3 months	5	1	10	10
Autograft: Hamstring tendon	6-8 months	6 months	>3months	5	1	10	10
Autograft: Hamstring tendon	6-8 months	6 months	6 months; light to strenuous	5	0	10	10
Autograft: Hamstring tendon	6 months	7 months	6 months; light to strenuous	4	2	8	8
Autograft: Hamstring tendon	6 months	6-7 months	< 4 months	5	1	10	10
Autograft: Hamstring tendon	6 months	Re-ruptured	< 4 months	5	2	10	8
Autograft: Hamstring tendon & meniscus repair	6 months	1 year	6 months; medium to strenuous	4	1	10	10
Autograft: Hamstring tendon & meniscus repair	7 months	1 year	7 months; medium to strenuous	4	1	9.5	10

Allograft	6-9 months	8-9 months	> 4 months	5	2	7	7
Allograft	6-9 months	9 months	> 4 months	5	2	8	7 (9 baseline)

Table 1. Quantified data of questionnaires for athletes who had ACL reconstruction. Sports and genders varied.

The estimated recovery time for autografts from most surgeons was around 6 months (table 1). The estimated recovery time for both allografts was a little longer, 6-9 months (table 1). Physical therapy remained pretty constant through the types of grafts. The patellar tendon autograft patients were recommended and completed 3-4 months of similar intensity (table 1). The hamstring autograft patients were recommended and completed 4-7 months, varying pretty significantly except consistent with who was advised 6 and 4 months (table 1). Allograft patients were consistent in their physical therapy time of 4 months (table 1). Range of motion was very consistent, staying between a rating of 4 and 5. Pain level was also very consistent being around 0-2, except for one patient with a high pain level of 10 (table 1). Stability was slightly lower in patients who received an allograft. Besides the one outlier with a stability rate of 4, all of the autografts ranged from 8-10, mostly 10, while allografts patients rated only 7 and 8 for stability (table 1). Performance level was also rated higher by patients receiving an autograft, ranging from 8-10 while patients who received an allograft only rated performance as a 7 (table 1).

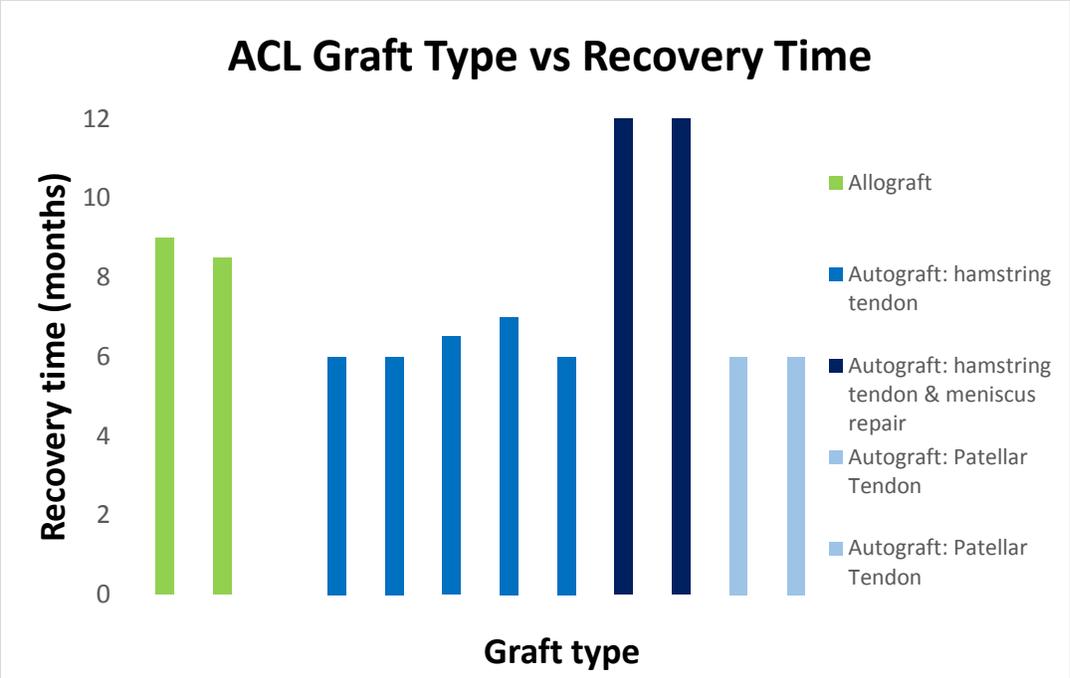


Fig 3. Athletes who received different graft type’s recovery time. Each bar represents an athlete.

Recovery time for the athletes receiving allografts took longer overall, except for the athletes who also had a meniscus repair (Fig 3).

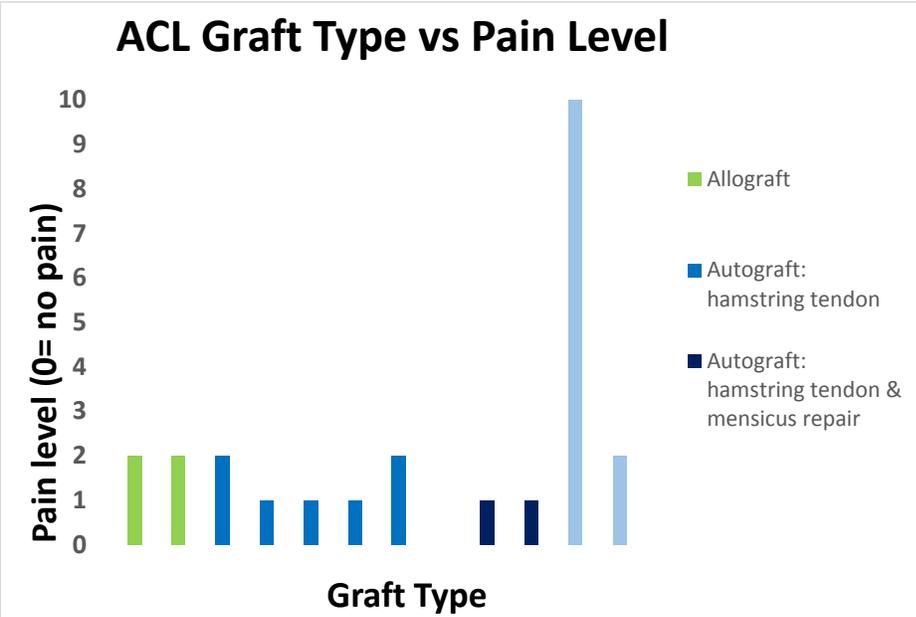


Fig 4. Athletes who received different graft types rated pain level on a scale of 0-10 with 0 being no pain.

There was very minimal difference in pain level, except for one athlete (Fig 4). Pain level ranged from 0 to 2 in all patients except for one (Fig 4).

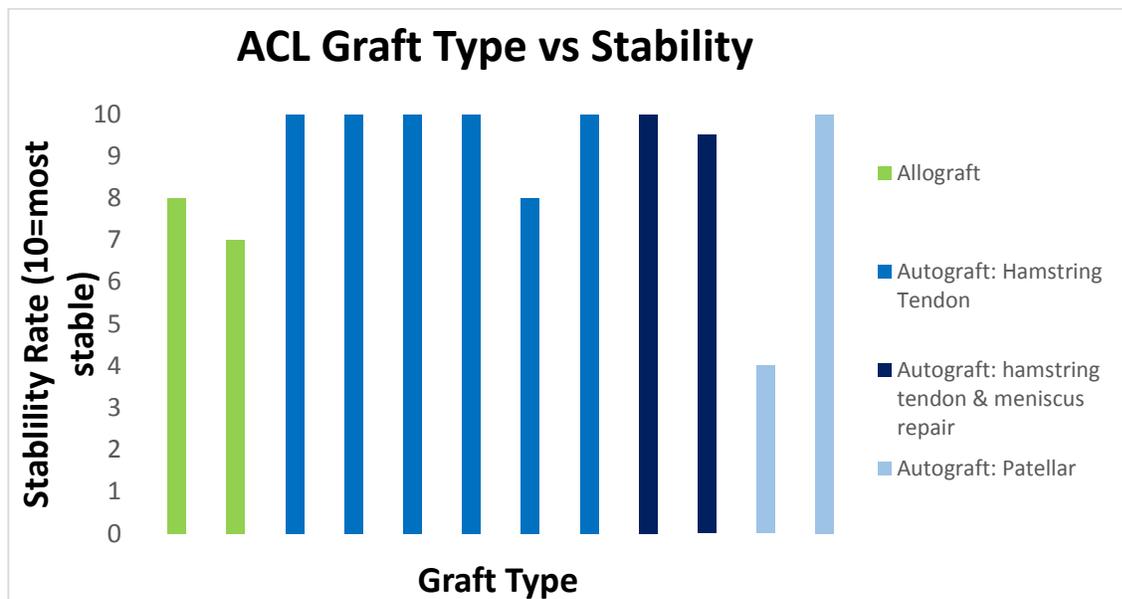


Fig 5. Athletes who received different graft types rated their stability rate 1-10, with 10 being the best.

There was a difference in stability level between athletes who received allografts and athletes who received autografts. Athletes who received allografts rated their stability lower than athletes who received an autograft (Fig 5). Except for the one athlete who reported a pain level of 10 also reported a stability rate of 4 (Fig 5).

Posterior talofibular ankle ligament tears are common in female gymnasts. Table 2 is the quantified data of the questionnaires with three female gymnasts who had posterior talofibular ankle reconstruction.

Posterior talofibular ankle reconstruction results:

Graft	Estimated recovery	Actual recovery	Physical therapy	Range of Motion	Pain (0=none)	Stability (10=best)	Performance (10=full potential)
allograft	6 months	5 months	3 months, strenuous	5	0	10	10
Autograft: a toe tendon	1 year	9 months	none	5	0	8	9
Autograft	4 months	4 months	4 weeks	4	0	6	10

Table 2. Female gymnasts receiving different grafts for posterior talofibular ankle ligament reconstruction.

The two athletes who received an autograft varied in results. One estimated recovery time was significantly longer than the others (table 2). Therefore, the actual recovery time was a great deal longer, while also no physical therapy was completed or recommended (table 2). There was no difference in pain level or range of motion. As well, performance rate remained consistent, and stability was less for athletes who received autografts (table 2).

Table 3 shows the quantified results from the questionnaires of athletes who received ulnar collateral ligament (UCL) reconstruction. Results include three female gymnasts and one male hockey player.

UCL reconstruction results:

Graft	Estimated recovery	Actual recovery	Physical therapy	Range of Motion	Pain (0=none)	Stability (10=best)	Performance (10=full potential)
Allograft	12	12	6 months (more on own)	5	1	7.5	8

Autograft: hamstring tendon	12	10	1.5 years (precautionary)	5	0	8	7
Autograft: gracilis tendon	10	10	9 months	5	1	9	9
autograft	9	10.5	4 months, 5 times a week	4.5	3	8	8

Table 3: Results of athletes who received UCL reconstruction.

The actual recovery time was less for athletes receiving autografts (table 3). Range of motion and stability remained consistent while pain level and performance varied (table 3).

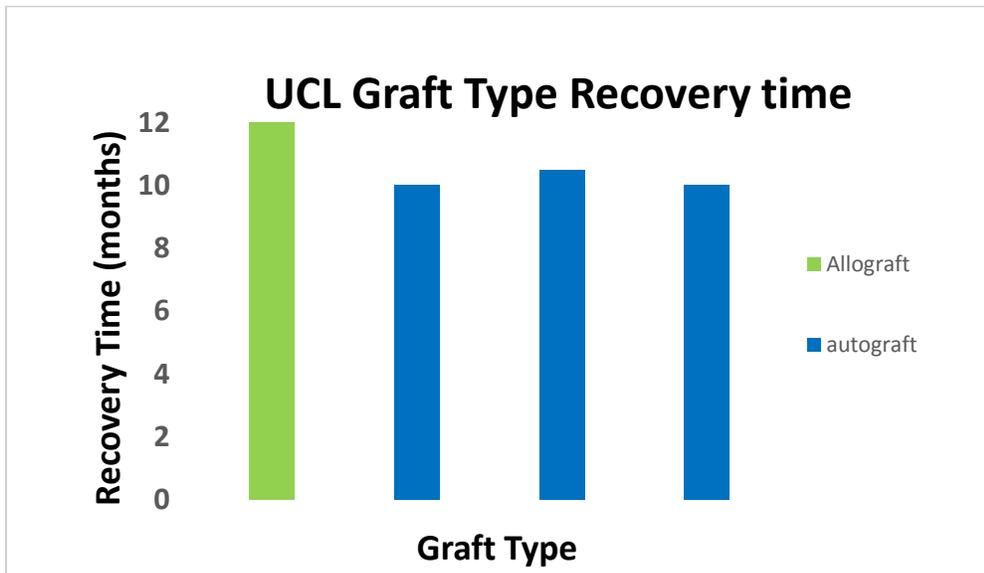


Fig 6. Allograft versus autograft recovery in athletes receiving ulnar collateral ligament reconstruction.

The athlete receiving the allograft took a full year to recover while the athletes who received autografts recovered in 10 or 10.5 months (Fig 6).

Results from the surgeon included his opinions and experiences on using allografts and autografts in ACL reconstructions. In short, allografts have a faster recovery without considering athletes, and autografts have a better recovery. The allograft recovery in short term is quicker because there is less pain since there is no secondary incision so there is less trauma and

inflammation (Noerdlinger 2016). However, the body sees allografts as foreign and the body has to create and lay down new collagen fibers over the graft, making the allograft take longer for the body to incorporate (Noerdlinger 2016). There was a DNA study of allografts where the tissue in the allograft becomes the patient's own tissue since the body begins creating its own new tissue (Noerdlinger 2016). This remodeling however makes the allograft weaker around three to four months post operation (Noerdlinger 2016). The autograft is more painful, there is a lower chance of re-rupturing, and it is a faster recovery to return to sports (Noerdlinger 2016). Re rupture rates are higher with allografts than autografts and Dr. Noerdlinger notices this throughout his own work (Noerdlinger 2016). Dr. Noerdlinger says he would use an allograft for older people and non-athletes who are not doing high impact activity and an autograft for athletes. For athletes, allografts take about nine to twelve months before full recovery while autografts take four to five months for full recovery (Noerdlinger 2016).

Discussion:

Allografts and autografts have many different advantages and disadvantages to be considered. Also, circumstances such as high impact activity should be strongly considered while choosing a graft.

The gymnast who received the patellar tendon autograft who had abnormally high pain level and abnormally low stability had screws that did not dissolve. It is possible for the body to reject screws, however, it is extremely rare for the body to reject dissolvable screws. Recovery rate was accounted for when the ligament was fully incorporated. The ligament was ready for use by 6 months, however, with having to perform another surgery to remove the screws, the

recovery process ended up taking a year. This situation accounts for the abnormally high and low rates.

Another gymnast had a zero for recovery rate who received a hamstring tendon autograft because the graft ruptured. All other ratings were for before the tendon had ruptured. This is consistent with the findings that hamstring tendons take longer to incorporate than BPTB grafts because of the soft tissue to bone healing. BPTB grafts are less likely to rupture because bone left on both ends of the graft promote a stronger bone on bone healing and faster incorporation. The BPTB grafts showed no difference in comparison to the other grafts on stability, pain, and performance. However, the BPTB graft did show faster recovery rates than all of the other graft types, as hypothesized due to the bone-on-bone healing being stronger and faster.

The athletes who had a meniscus repair along with ACL reconstruction using a hamstring tendon autograft had the longest recovery of all of the grafts, including allografts. Although this is inconsistent with the prediction that autografts should take less time to incorporate and therefore have a faster recovery, the inconsistency could be due to the fact of having two surgeries in one. Having to fix the meniscus too means another incision, more inflammation, and more trauma leading to a longer recovery.

UCL and ACL reconstruction both showed faster recovery with autografts. With UCL there was a 1-1.5 month faster recovery for the autographs. While ACL reconstructions using autographs took 2 months faster, resulting in a 6-7 month recovery versus an 8-9 month recovery with an allograft. This faster recovery showed no compromising in pain level, stability,

range of motion and performance; if any change was seen it was a better rating than the allograft.

In the comparison of allografts versus autografts for posterior talofibular reconstruction, the results varied, however, new techniques are the result for this variation. The gymnast who had a recommended recovery time of one year had her surgery in 2011, while the other two had theirs in 2013 and 2014. The technique for this surgery has changed since 2011, which is why both the gymnasts who received an allograft and autograft a couple years later had a faster recovery. Of these two gymnasts, the one who received the autograft recovered a month earlier, with less physical therapy of only 4 weeks versus 3 months. The higher stability rating and better range of motion of the gymnast who received the allograft could be accounted for by the more vigorous and longer time period of physical therapy. Physical therapy helps strengthen the weakened area for better stability, explaining why the athlete who received an allograft had better stability months after the operation. In looking at the athlete's estimated recovery time of one year, she still recovered three months faster than the recommended time, supporting the hypothesis that autografts incorporate faster and result in a faster recovery.

When taking into consideration undissolved screws, new techniques, and physical therapy, the results support the hypothesis that autografts lead to a faster recovery over allografts for athletes, especially in ACL reconstructions. Results did not show that in long term after recovery that one graft was better than the other, which fails to support the hypothesis.

Faults in this experiment include the small sample size. Not as many athletes had reconstruction surgeries as expected. Many longitudinal and retrospective studies have been done comparing allografts and autografts, but none have been done strictly with athletes. As

said by Noerdlinger, allografts permit a faster recovery for non-high impact individuals because of not needing a second incision which means less inflammation. Studies can be misleading to athletes if allografts are reported to have a faster recovery. Therefore, more studies need to be performed pertaining to athletes only for reliable results. In future research, I would branch out my questionnaires beyond UNH athletics. Although there were a couple athletes from other schools or pre-professional baseball players, the majority of the results able to be used after screening was limited to mostly UNH athletes. More athletes receiving allografts in particular would be found in order to make a credible comparison. Future studies would include more surgeries beyond ACL, UCL, and posterior talofibular ligament reconstruction in addition to more athletes. Although findings do support the hypothesis, there is not enough substantial data to say that the data is truly reflective of athlete's recovery processes with allografts versus autografts.

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