What Is The Best Graft To Use For Anterior Cruciate Ligament (ACL) Reconstruction In Adult, Male Football Players; Bone-Patellar Tendon-Bone Autograft Versus Hamstring Tendon Autograft?

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Citation

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Abstract

This paper is a review of two studies comparing hamstring tendon autograft reconstruction with patellar tendon autograft reconstruction for the repair of ACL tendon rupture. The two studies being reviewed are “Patellar Tendon Versus Hamstring Tendon Autografts for Reconstructing the Anterior Cruciate Ligament” and “Patellar Tendon Versus Hamstring Tendon Autografts for Reconstructing the Anterior Cruciate Ligament: A Meta-Analysis Based on Individual Patient Data.” The purpose of the review is to answer the question, “What is the best graft to use for ACL reconstruction in adult, male football players; bone-patellar tendon-bone autografts versus hamstring tendon autografts?”

INTRODUCTION

Every year in the United States there are approximately 200,000 ACL tears and 100,000 ACL repairs performed each year (1,2). ACL tears are common injuries to college and professional football players and it has been shown to significantly affect their careers. According to Brophy et al, eight percent of all the players who attend the annual National Invitational Camp or NFL Scouting Combine, have a history of injury to the ACL, and six percent have had an ACL reconstruction in the past (3). In addition, college level athletes who have a history of ACL injury, ACL reconstruction, or both are less likely to be drafted into the NFL (3).

A recent study by Carey et al entitled “Outcomes of Anterior Cruciate Ligament Injuries to Running Backs and Wide Receivers in the National Football League,” concluded that twenty-one percent of running backs and wide receivers in the NFL who sustained an ACL injury were never able to play in the league again (4). In addition, those players who did return to play in the NFL had a statistically significant drop in player performance to about two-thirds of their full potential (4).

There have been several surgical procedures developed for the repair of this injury including bone-patellar tendon-bone, hamstring tendon, and quadriceps tendon autograft techniques. Each procedure has its own unique advantages and disadvantages. Being that bone-patellar tendon-bone autograft and hamstring tendon autograft procedures are the most commonly used techniques, the purpose of this paper is to attempt to answer the question, “What is the best graft to use for ACL reconstruction in adult, male football players; bone-patellar tendon-bone autografts versus hamstring tendon autografts?” This is an important question for all athletes who

depend on their ACL to provide stability to their knees, but have injured this ligament.

BACKGROUND

Incidence: There are roughly 200,000 ACL injuries annually (1, 2). Approximately seventy percent of ACL injuries occur through non-contact mechanisms; the other thirty percent are a result of direct contact with another player (2). Women are at a higher risk for ACL injury than are men, and athletes playing sports that require fast “change of direction” maneuvers are also at an increased risk for ACL injury.

Anatomy: The knee joint is stabilized by four major ligaments including the ACL, posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL). The MCL and LCL cross the joint on the medial and lateral aspects respectively, preventing varus and valgus angulation of the knee. The ACL and PCL are within the joint space itself and crossover one another, preventing anterior and posterior translation of the tibia. The ACL also prevents tibial rotation and varus and valgus angulation of the knee when in full extension.

The knee joint incurs a high amount of stress because it has to support almost the entire body weight of an individual; therefore, it needs a cushion and the meniscus and synovial fluid serve this function. The meniscus is a cartilaginous layer between the end of the femur and the tibia which acts as a cushion. The joint is lined with synovium and the joint space is filled with synovial fluid which acts both as a lubricant and as a cushion.

The ACL is mostly made of Type I collagen. It has a similar structure to that of tendons, with the biggest difference being a higher elastin content. Blood is mainly supplied to the ACL from the middle genicular artery, through its insertion site which is on the anterior aspect of the tibial plateau. When injured, the ACL can avulse off of the bone at its insertion site, or tear anywhere along its length. Tears of the ACL, however, most commonly occur halfway between its origin and insertion sites when “the ligament is transected by the pivoting lateral femoral condyle” (1). This is a result of the ACL’s anatomical location. It sits in the intercondylar notch of the femur and if the tibia moves laterally, it can crush/cut the ACL between the tibia and the medial or lateral condyle of the femur, depending on which direction the tibia translates.

Women are at increased risk of ACL injury compared to men for several reasons (2). For females, age matters when assessing risk of ACL injury. Females are always at a higher risk than males at any age. Hormonally, estrogen has been shown to weaken the ACL so their risk increases even more after puberty. Anatomically, women have a narrower femoral notch, a slightly smaller ACL that is slightly different in shape, and a larger Q-angle (also known as the quadriceps femoris muscle angle) which is the angle formed by the rectus femoris and the patellar tendon. With a narrower femoral notch there is less room for the ACL and the femur grinds on the ligament making it weaker and more prone to injury. The female pelvis widens in preparation for childbirth thus increasing the Q-angle. As the Q-angle increases so does the likelihood that the knee will turn inward, thereby increasing the strain on the ACL.

Biomechanically speaking, women tend to use their quadriceps muscles for jumping, whereas men tend to use their hamstring muscles. The quadriceps compress the knee joint and pulls the tibia forward, opposing the ACL, whereas the hamstrings aid the ACL by preventing forward translation of the tibia.

Etiology: ACL injuries occur commonly during contact sports with rotation of the knee. This can happen, for example, in football when a runner is being tackled by a defender. Another common setting occurs during non-contact, deceleration maneuvers. Other causes of injury to the ACL include hyperextension, and valgus stress. Thus, the risk of ACL injury increases with participation in basketball, soccer, football, and other sports that rely on quick “change-of-direction” maneuvers.

Fitness level and training also play a role in the risk of ACL injury. Training programs have been designed specifically for the purpose of reducing the risk of injury to the ACL. The hamstrings, as mentioned above, are an ACL agonist and when contracted relieve tension on the ligament. Although the quadriceps is an ACL antagonist, strength and endurance of all the lower limb muscles should be well balanced. Training also involves teaching proper technique and body position during physical activity and has been shown to reduce the risk of ACL injury.

Clinical presentation: When questioning the patient about the event that occurred they will often state that they heard or felt a pop or snap in the knee. The patient often states that the knee gave out on them. Often the injury occurs when the knee is twisted, or when the patient attempted to change directions briskly. The patient should be questioned about previous injuries to the knees or legs. If injury has occurred to the supporting structures around the knee in the past, even more stress can be placed on the ACL, thereby increasing the risk of injury. Therefore, asking these questions gives the clinician a better understanding of what to expect during the physical exam as well as information regarding risk assessment. Pain is a common complaint but not always indicative of the severity of the injury because partial ACL tears tend to be more painful than complete tears.

The physical examination typically begins with inspection. It is standard to

examine the joint above and below the joint in question; therefore, the hip and ankle on the affected side should be examined and compared to the unaffected side. Immediately after an ACL injury has occurred, there is typically a fair amount of swelling about the knee. Comparison of the affected knee with the unaffected knee will differentiate swelling from normal anatomy. Inspection is followed by palpation of the bony and soft structures around the knee, feeling for any obvious bony malformations, points of tenderness, or swelling. Distal pulses as well as sensation need to be assessed to rule out more serious problems involving nerve and blood supply to the extremities. Range of motion as well as special testing for ligament stability of the knees should also be performed. Special tests may include the Lachman's test, the Pivot Shift test, the Anterior Drawer test, the Posterior Drawer test, McMurray's test, and testing for varus and valgus instability. The sensitivity and specificity of these tests vary and depend on multiple factors; how recent the knee injury occurred, amount of pain, the patients' tolerance for pain, the amount of swelling, or the level of apprehension on the part of the patient when performing the tests. Other factors which may interfere with the reliability of these tests include the clinician's experience and skill in performing the tests.

Diagnostic evaluation: Diagnosis can sometimes be made given the history and physical alone, although an X-ray or MRI may also be necessary. A plain X-ray is not always helpful but occasionally, when the ACL is injured a piece of bone can avulse off and will be visible on X-ray. Ligaments are soft tissue and radiolucent so they do not show up well on a plain X-ray. An MRI can be diagnostic because it allows a distinct, clear view of the soft tissues around the knee, including the ACL. It also allows the clinician to determine the location and extent of the damage as well as any involvement of the menisci and/or other ligaments in the knee. Although the MRI is the preferred test, a CT scan can also be used to diagnose and determine the extent and location of damage to the ACL.

Arthrocentesis can be used both as a diagnostic tool and a therapeutic procedure. Drainage of a bloody effusion helps relieve pressure and decrease pain, thereby increasing the accuracy of the physical examination. It also helps confirm the severity of the injury. Aspirated fluid can be sent for analysis to rule out other causes of knee swelling like infection or gout. An arthrogram is an X-ray of the knee after injection of a contrast medium into the joint and is used when plain X-rays are not diagnostic. It is a more invasive study than an MRI or CT scan, and therefore is not the preferred study when an ACL injury is suspected.

A KT-2000 arthrometer is an instrument that measures anterior and posterior tibiofemoral displacement, providing an objective evaluation of knee stability. It is indicated for patients suspected of having an injury to either the ACL or PCL and can assist the clinician in the diagnosis of these injuries. The machine prints a graph of the results providing a visual interpretation and a permanent record of knee stability for the clinician to follow the patient's progress. Therefore, it can be used pre-operatively and post-operatively to show the difference in stability before and after reconstructive surgery, as well as throughout recovery, to check for loosening of the implanted graft after ligament reconstruction.

There are other ways to assess the knee. The International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC) is a questionnaire that measures symptoms, knee function, and sporting activity. Patient responses are rated from zero to ten. A zero represents the lowest level of function or the highest level of symptoms whereas a ten represents the highest level of function or the lowest level of symptoms. Responses to the questions are tallied and plugged into an equation to give the IKDC score. Scores vary anywhere from zero to one-hundred. One-hundred is the best score that can be obtained. This score represents no limitations of activities of daily living or sports activities. It also represents the complete absence of symptoms.

A Tegner score is obtained from the Tegner activity scale which is designed to measure activity level in patients with ligamentous injuries. A zero is the lowest score possible and represents a patient on disability or sick leave. A ten is the highest score attainable and represents patients participating in competitive sports at a nationally or internationally elite level.

Differential Diagnosis: The differential diagnoses when considering ACL tears includes but is not limited to ACL strain, meniscal injury, injury to the PCL, MCL, or LCL, fracture of the proximal tibia or distal femur, internal derangement, and knee dislocation. Fracture, internal derangement, and knee dislocation, if not ruled out by physical exam, can be ruled out by an X-ray, although MRI may be needed. Injuries to the soft tissues around the knee can often be determined from the history and physical, but when further imaging is needed X-ray is of limited use and MRI is the test of choice.

Treatment: Treatment for an ACL tear can be put into two categories; surgical and nonsurgical. Whichever approach is taken, initial treatment should include RICE (rest, ice, compression, and elevation) as well as pain medication. NSAIDs will help reduce swelling and control pain, as will arthocentesis as mentioned above. Nonsurgical treatment can be successful and may be indicated in patients in any of the following five scenarios: patients who have an isolated ACL tear (i.e. no meniscal or other ligamentous involvement); patients with a partial tear without instability about the knee; patients who have a complete tear and are without any instability symptoms during lower activity sports (if the patient is willing to give up all higher activity sports); patients with sedentary lifestyles or jobs with minimal light-duty work; and children with open growth plates (2).

Nonsurgical treatment involves physical rehabilitation. The goal of physical rehabilitation is to regain stability of the knee joint because the torn ACL will never completely heal without surgery. However, increased stability of the knee joint can be achieved by strengthening the muscles that surround it. The hamstring muscle group normally assists the ACL in preventing the tibia from sliding anteriorly, thus strengthening and conditioning the hamstrings will be of particular benefit to the patient. Although the calf muscles and quadriceps muscles do not directly assist the ACL normally, strengthening them does contribute to the knee's overall stability.

Surgical Treatment: There are several different types of surgical repairs which include primary repair, extra-articular repair, intra-articular repair, and combined extra and intra-articular repair. Primary repair involves sewing the existing, damaged ACL back together. Extra-articular repair involves manipulating structures on the lateral side of the knee to increase their effectiveness, preventing excessive lateral movement of the tibia. The overall goal is to prevent the lateral tibial plateau from sliding too far anteriorly and correct anterolateral rotatory instability. There has been limited success with this technique however (6). Intra-articular reconstruction involves replacing the injured ACL with graft material. The graft can come from a cadaver (allograft) or from the patient (autograft). The combination of intra and extra-articular reconstructions has been used by some surgeons without improvement of the clinical outcome but with evidence demonstrating load sharing between the two elements (6).

ACL tears are typically replaced by a grafted tendon as opposed to sewing the injured ACL back together (primary repair) since primary repaired ACLs have been shown to fail over time (2).

Although allografts can be used, autografts are preferred. Allografts are not as strong as autografts and are only indicated in patients undergoing revision ACL surgery or in those patients who only want to return to lower demand activities. Allografts have been known to transmit disease however this has decreased since grafts are now prepared using the freeze-drying technique (7). This technique however, also kills the cells thereby reducing the strength of the graft (7).

Advantages to allografts include decreased operative time, smaller incisions, less post-operative pain, and the advantage of not having to remove the patient's own healthy tissue for the graft. Despite these advantages, autografts are still preferred.

The two most commonly used autografts are patellar tendon and hamstring tendon autografts. When the patellar tendon is grafted, the middle third of the patellar tendon is removed along with a piece of bone at each end from the tibia and the patella. An advantage of this graft is that it is similar in length to the ACL. It also allows the pieces of bone at each end of the graft to fuse with the patient's own bone, which many surgeons believe provides the strongest method of healing (7). A disadvantage of the patellar tendon graft is that by removing the middle third of the patellar tendon, it is weakened and the patient is put at risk for patellar tendon rupture as well as fracture of the patella. A history of patellar tendon rupture or fracture of the patella would be a contraindication to patellar tendon autograft reconstruction. In addition, patients who undergo ACL reconstruction with this graft often complain of anterior knee pain which can last for years post-operatively (7). Hence, another potential contraindication to patellar tendon autograft would be having a job that required the patient to be on his or her knees, such as in carpentry. The surgery for patellar tendon autograft produces a bigger scar than the surgery for hamstring tendon autograft, and the scar is located on the anterior lower leg. For this reason, it may not be the best option for patients who are concerned about aesthetics.

An advantage of using the hamstring tendon autograft is that anterior knee pain is not much of an issue, since there is less pain overall. This would be the preferred method of reconstruction for someone with a low pain tolerance, a job requiring them to be on their knees, or with a history of knee pain. With the hamstring tendon autograft the incision is smaller, and thus, would be a better option for someone who is concerned about aesthetics. The disadvantage is with the fixation technique; since there is no "bone-to-bone" healing, it takes longer for the graft to become rigid and heal into place. Therefore, hamstring tendon autograft reconstruction may not be the best option for patients in whom the clinician suspects are highly anxious to return to their sport and might be overly aggressive in the immediate postoperative rehabilitation period.

Patellar tendon and hamstring tendon autografts are equally strong and therefore, both are indicated in patients who desire to return to high-demand sporting activities. Prior to surgery, patients go through physical rehabilitation for several weeks to strengthen the supporting muscles around the knee which helps speed recovery time post-operatively. Physical therapy not only helps to stabilize the knee but it allows the swelling in the knee to subside which helps make the surgery easier.

Complications: Like all surgeries, ACL reconstruction has certain risks associated with it. Complications of surgery include numbness, infection, damage to structures around the knee, DVT, and risks associated with anesthesia. The graft itself may loosen, stretch, tear, or develop scar tissue. Decreased range of motion, grating of the patella with the femur, fracture of the patella, pain at the graft site, and re-injury are all possible complications (7).

Prognosis: Long-term success rates for patients treated with surgical reconstruction are 82-95 percent (2). Approximately eight percent of patients experience recurrent instability and graft failure (2).

Prevention: Prevention of ACL injuries is based on training drills that focus on balance, power, and agility. By improving neuromuscular conditioning and muscular reactions, patients can decrease their risk of injury to the ACL (8).

METHODS

This paper asks the question "What is the best graft to use for ACL reconstruction in adult, male football players; bone-patellar tendon-bone autograft versus hamstring tendon autograft?" which is a question regarding treatment. The best studies to answer this question include a Meta-Analysis, Systematic Review (LEVEL I), or prospective randomized trials (LEVEL II). A search was conducted on the Pubmed and MEDLINE with full text database, using the EBSCO search engine.

Inclusion criteria included articles involving humans, males, adults (ages 19-44 years), be available in Full Text, have an Abstract available, and be in English. Key words used for searching included "ACL", "Anterior Cruciate Ligament", "graft selection", "athletes", "reconstruction", "patellar tendon", and "hamstring tendon" in various combinations. Exclusion criteria included articles involving animals, and papers written in languages other than English. Due to the current preference of autografts over allografts for ACL reconstruction by most surgeons, studies including allografts for ACL reconstruction were also excluded. No date restriction was used.

Studies comparing bone-patellar tendon-bone autografts and hamstring tendon autografts were chosen, being that these are the two most widely used ACL reconstructions. "Patellar Tendon Versus Hamstring Tendon Autografts for Reconstructing the Anterior Cruciate Ligament," was chosen because being a Meta-Analysis it provides the highest level of evidence, Level I. "Prospective and randomized evaluation of ACL reconstruction with three techniques: a clinical and radiographic evaluation at 5 years follow-up," was chosen for two main reasons. First, it is a randomized trial. This is the best type of study to attempt to answer questions pertaining to treatment. Second, it included patients involved in "cutting sports" at competitive or amateur levels. Data from the single hamstring plus extra-articular plasty group in this study was excluded, as this data did not help to answer the question presented here.

DISCUSSION OF ARTICLES

The first study entitled "Patellar Tendon Versus Hamstring Tendon Autografts for Reconstructing the Anterior Cruciate Ligament: A Meta-Analysis Based on Individual Patient Data," written by David Jean Biau, et al., set out to test the hypothesis that "There is no difference between ACL reconstruction with patellar tendon or hamstring tendon autografts with regard to postoperative knee laxity and instability" (9). This study utilized knee stability data on individual patients from six randomized controlled trials comparing patellar tendon autograft ACL reconstruction to hamstring tendon autograft ACL reconstruction.

Six trials were included in this Meta-Analysis. Individuals who had any of the following criteria were excluded from all six trials: evidence of osteoarthritis; cartilage lesions greater than Noyes grade IIA in severity; an open growth plate; injury to the posterior cruciate ligament on the same side as the ACL injury; or previous ACL reconstruction. Exclusion criteria that varied amongst the trials included the following: time interval from injury to reconstruction; age of the patient; injury to other ligaments; meniscal injuries; and damage to cartilage (one study excluded individuals with any cartilage lesion, regardless of severity).

Individuals were selected and randomized between January 1995 and March 2000. In four of the six studies, there were two groups of patients. One group underwent patellar tendon autograft ACL reconstruction and the other group underwent hamstring tendon autograft ACL reconstruction. The other two studies, however, had three groups of patients. In these studies, there was a group that underwent hamstring tendon autograft ACL reconstruction and a group that underwent 4-strand hamstring tendon autograft ACL reconstruction; both of which were included in the Meta-Analysis. One study had a third group that underwent 3-strand hamstring tendon autograft ACL reconstruction. That group was excluded from the Meta-Analysis. The other study had a third group which underwent 4-strand hamstring tendon autograft ACL reconstruction with extra-articular reconstruction. This group was also excluded from the Meta-Analysis.

All patients underwent arthroscopically assisted ACL reconstruction for ACL rupture, which was confirmed at the start of the procedure. A single or double anterior vertical incision was utilized to harvest 9 or 10 mm patellar tendon autografts. An oblique anteromedial incision was utilized to harvest a 4-strand hamstring autograft. In all but two patients, this type of incision was used to harvest the 3-strand hamstring autografts.

In this Meta-Analysis, a total of 423 individuals were included from the six different trials. In order to be included in this Meta-Analysis, an individual needed to have a unilateral ACL injury which caused symptoms to occur. The patellar tendon group contained 216 randomly assigned individuals. The hamstring tendon group contained 207 randomly assigned individuals. Data collected on each patient included age at time of surgery, gender, preoperative Lachman and Pivot-Shift test results, associated injuries to ligaments and/or menisci, surgical technique, post-operative rehabilitation, and follow-up. Data for each individual was taken directly from the original studies and not from published articles. This accomplished two things; it allowed for construction of a single data set that could then be analyzed and enabled all randomized individuals to be included, regardless if they were excluded from the

published report.

In order to test their hypothesis that “There is no difference between ACL reconstruction with patellar tendon or hamstring tendon autografts with regard to postoperative knee laxity and instability,” the authors used two tests to measure the outcomes of the study: the Pivot-Shift test and the Lachman test. In other words, if the patient had a positive Pivot-Shift test result (glide or worse) and a positive Lachman test result (3 mm or greater difference in anterior tibial translation compared with the other knee) after ACL reconstruction using either the patellar tendon or hamstring tendon autografts, this would identify instability and laxity of the knee.

In regards to the primary outcome, 10% of individuals in the patellar tendon group, and 16.9% of individuals in the hamstring tendon group had a positive Pivot-Shift test result. In regards to the secondary outcome, 25.5% of individuals in the patellar tendon group, and 25.9% of individuals in the hamstring tendon group had a positive Lachman test result.

Given these results, the authors concluded that better stability was achieved with the patellar tendon autograft than with the hamstring tendon autograft. Despite coming to this conclusion they stated that “our results should not be taken as definitive evidence that patellar tendon autografts provide better stability, and further research is needed.”

In analyzing this publication by Biau, et al., it is credible in that it was written by experts in the field, and comes from a peer-reviewed journal. It was recently published (2009), and is up-to-date. It is clearly focused and tests the hypothesis appropriately. The Pivot-Shift and Lachman tests are subjective, and perhaps the use of the KT-2000 arthrometer would have provided more accurate results and less subjectivity. Pivot-Shift testing has been described, however, as the best measure of functional knee instability and is therefore appropriate to test the hypothesis.

The abstract summarizes the article concisely and gives the reader a clear idea of its purpose. The article is written well with sufficient background information, and a clear explanation of the study design and data analysis. The results were presented in a well organized, scholarly manner. A flowchart and several tables were utilized to present the data for further clarification.

The authors eliminated variability by only using studies that included 4-strand hamstring tendon autograft reconstruction (although one study did include two patients who underwent a 3-strand hamstring reconstruction) and excluding other variations of the hamstring tendon reconstruction. Even though two 3-strand hamstring reconstructions were included, the population size is large enough that, even if there is a significant difference between 3 and 4-strand hamstring tendon autograft reconstruction it would not be enough to alter the results.

The demographics differ from the question presented in this paper. Women were included in this article and made up 46.5% of the patient population. Gender's affect on knee stability was recognized and the Meta-Analysis was adjusted to better estimate the treatment effect. Results showed no significant differences between the treatment group and gender. The mean age in each group from the six trials varied from 26 to 32 years of age. This is slightly older than the average male football player since only a small percentage of the population continues to participate in this sport beyond the collegiate level; however, it is still a valid comparison. Younger patients had a positive Pivot-Shift test result more often than older patients but this finding is consistent with both the patellar tendon and hamstring tendon groups. The authors could offer no explanation for this finding. A possible explanation is that younger patients are more aggressive with rehabilitation and returned to more vigorous activity earlier.

The assignment of patients to treatments was randomized although the patients were not "blind to the treatment" that they received.

There were two significant confounding variables between the two groups preoperatively. It is unsure how these variables affected the results. Only 15.1% of the patellar tendon group had cartilage lesions as compared to 20.8% of the hamstring tendon group. Conversely, only 20.4% of the hamstring tendon group had damage to the lateral meniscus as compared to 25% of the patellar tendon group. The groups in each trial were similar at the start in regards to gender, mean age, Lachman test result, Pivot-Shift test result, and medial meniscus lesions.

Results of the Pivot-Shift test showed that 10% of patients in the patellar tendon group had a positive result compared to 16.9% of patients in the hamstring tendon group. The odds ratios, unadjusted and adjusted for gender, age, and trial effect, demonstrated significant favor for the patellar tendon group. Results of the Lachman test showed that 25.5% of patients in the patellar tendon group had a positive result compared to 25.9% of patients in the hamstring tendon group. The unadjusted odds ratios did not significantly differ from the odds ratios adjusted for gender, age, and trial effect.

A limitation of the Meta-Analysis is that there were variations in reporting that may have contributed to the differences across trials indicating that they were not true differences. A potential source for bias is that individual patient data from eight other trials reporting postoperative Pivot-Shift test results were not available and thus were not included. Only the overall results were available, and did not differ significantly from the results of this Meta-Analysis. Other sources of bias included factors that could not be adjusted for in the intra-operative and post-operative periods. Intra-operative factors included tunnel placement and graft cycling. The authors felt that effects from differences in tunnel placement and graft cycling were probably evenly distributed between both groups however. Given that, all surgeons were proficient with both techniques. Post-operative protocol, on the other hand, may have created significant bias. The healing process for hamstring autograft takes longer than for bone-patellar tendon-bone autografts and realistically the rehabilitation should be unique for each surgical procedure to account for this, but post-operative protocol in each of the trials included in the Meta-Analysis was identical for both groups.

Although clearly defining two distinct groups of patients eliminates variables and allows for more clear-cut results, it also limits the study's application to real world settings by not accounting for these variables. This is one of the reasons why the authors, despite having clear evidence that patellar tendon autografts yielded more knee stability, state that their results should not be taken as definitive evidence for the superiority of patellar tendon autografts. The second reason is that their study is the first Meta-Analysis of surgical randomized trials based on individual patient data. Critically, large Meta-Analyses of prospective individual patient data accounting for technical surgical improvements and multiple confounding factors affecting knee stability post-operatively would have a higher clinical value.

The next study entitled "Prospective and randomized evaluation of ACL reconstruction with three techniques: a clinical and radiographic evaluation at 5 years follow-up" compares three operative techniques including bone-patellar tendon-bone autografts (first group of patients), four-strand hamstring autografts (second group), and semitendinosus-gracilis intra- and extra-articular reconstruction (third group) (10). The data pertaining to the third group of patients will not be reviewed in this paper as it does not help answer the question, "What is the best graft to use for ACL reconstruction in adult, male football players; bone-patellar tendon-bone autograft versus hamstring tendon autograft?"

The study was a prospective randomized study which included seventy-five patients, all of which were involved in cutting sports at competitive or amateur levels. In 1998, 311 local patients were evaluated for ACL rupture at the Rizzoli Orthopaedic Institute in Bologna, Italy. Of these 311 patients, seventy-five who met the strict inclusion criteria, agreed to participate in the study. These criteria included: age less than fifty years; intact PCL and maximum grade 1 MCL injury; no history of patello-femoral pain; no joint degenerative changes; no prior knee surgery; no meniscus injury; no chondral injury; and a normal contralateral knee. The patients were randomly divided into three groups of twenty-five patients each. The groups were generated with the patient's consent by choosing the technique to use, with an alternate systematic sampling. Of the seventy-five patients, twenty-six were female and forty-nine were male. The mean age was twenty-nine and one-half years old with the youngest patient being fifteen and the oldest being forty-nine.

Functional assessments were performed at the five year follow-up. Tegner score was evaluated pre- and post-operatively to evaluate functional capability. IKDC score was determined and muscle performance was evaluated by measuring thigh circumference at five and fifteen centimeters superior to the patella as well as performing the one leg hop test to assess muscle performance restoration. Pivot-Shift testing, Lachman's test, and KT-2000 arthrometer testing were utilized for evaluation of knee stability and laxity. Documentation also included anterior knee pain and pain with kneeling in each group as well as ROM, and time required to return to sporting activities post-operatively. Finally, femoral and tibial tunnels were measured to look for widening of the tunnels.

Although extensive data was collected in this study using multiple facets of evaluation, only the Pivot-Shift test and Lachman test results will be used in this paper for comparison to the previous study. This is to allow for a fair comparison of the two studies.

The results of both the Pivot-Shift and Lachman tests are the same: pathologic laxity was less in the patellar tendon group as compared to the hamstring tendon group (Table 1). These results show that patellar tendon reconstruction returns the affected knee joint to a condition more similar to its original condition than does hamstring tendon reconstruction.

Eventually, every patient in both groups returned to their desired sport.

Including X-ray evaluations in this study allowed the authors to confirm proper tunnel positioning in both frontal and lateral views for both groups. This ensured that comparisons between the groups were based strictly on graft performance and fixation technique.

A shortcoming of this study was the population size. A larger population size

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could have shown stronger evidence. They did admit that patellar tendon autograft reconstruction yielded better results in terms of ACL laxity as shown with Pivot-Shift and Lachman test results. However, due to the results of subjective data, i.e. the IKDC subjective score, and the fact that all patients in both groups returned to their sport, they concluded that graft choice does not influence final clinical outcome of ACL reconstruction.

The authors recognized that successful outcomes were not determined primarily by graft type; rather success encompassed a multitude of factors including many biological and biomechanical factors. Some factors mentioned were properties and construction of the graft, the type of fixation, the post-operative program, the control of rotational stability and kinematic performance of the graft, the correct placement of the tunnels, and the biological stimuli that affected the ligamentization and tunnel fixation process.

When clinically analyzing this article, it comes from a peer-reviewed journal within the last five years, was written by distinguished scientists, and therefore appears reputable. The authors are from the Biomechanics Department of the Rizzoli Orthopaedic Institute. "The Rizzoli Orthopaedic Institute in Bologna, Italy, opened in 1896 as a specialized hospital for orthopaedics and traumatology and evolved into a musculoskeletal center that distinguishes itself from others in Italy and Europe through pioneering clinical and research advancements" (11). The article's introduction clearly states its purpose of analyzing data to evaluate the graft selection for ACL reconstruction, including both bone-patellar tendon-bone and hamstring tendon autografts.

The materials and methods section clearly defined the patient population. Although the sample size was minimal, strict inclusion and exclusion criteria were utilized in selecting the subjects, thereby decreasing confounding variables. An attractive aspect of patient selection and a significant reason why this article was chosen to help answer the question "What is the best graft to use for ACL reconstruction in adult, male football players; bone-patellar tendon-bone autograft versus patellar tendon autograft?" is the inclusion criteria that all patients should be involved in "cutting sports" at competitive or amateur levels. No significant differences were noted between the study groups pre-operatively. One surgeon performed all of the ACL reconstructions, thereby reducing variability in operative technique and skill. In addition, post-operative rehabilitation protocol was the same for all patients and evaluations were performed by two independent surgeons. Surgical techniques, post-operative protocol, functional assessments, radiographic evaluation, and statistical analysis were described in sufficient detail so that the study might be easily replicated.

The results were presented in a straightforward, scholarly fashion with multiple tables for further clarification of results. The sample size, being much smaller than the previous article's, could have been larger in order to better support the obtained results. That being said, having a smaller sample size reduced confounding variables. Despite doing this, the authors still recognized and emphasized additional, multiple factors affecting the outcomes of ACL reconstructions, and the need for more thorough and complete evaluation of these multiple factors.

A potential bias of this study was that one surgeon performed all of the ACL reconstructions. This may have had an adverse effect on the findings of this study if the surgeon's technique for either procedure was superior to the other, although unlikely.

CONCLUSION

The evidence presented in these two recently published studies re-emphasizes that both bone-patellar tendon-bone autografts and hamstring tendon autografts are viable graft selections for ACL reconstruction. Although evidence from both studies clearly showed better stability with bone-patellar tendon-bone autografts, the authors from these two studies did not feel confident enough to claim superiority to the patellar tendon autograft for reasons described above.

In the second study, all participants did return to their sport. However, nothing was said of their performance upon return, and they likely were not competing against the most elite athletes. For those athletes competing at the highest level, where a split second can make all the difference, laxity, or the lack thereof may make the difference. Thus, further evaluation of the effect of laxity on performance should be undertaken. The difference too, for these athletes, may be impaired electromechanical delay of the knee flexor muscles. In a 2009 article entitled "Electromechanical Delay of the Knee Flexor Muscles Is Impaired After Harvesting Hamstring Tendons for Anterior Cruciate Ligament Reconstruction," it was shown that significant electromechanical delay occurs after grafting hamstring tendons (12). Further investigation is needed however to determine whether or not this delay negatively impacts optimal performance.

In conclusion, it seems that the best graft for male football players undergoing ACL reconstruction has yet to be determined. With the advent of new techniques and technology, as well as the undertaking of larger more comprehensive studies, this may change in the future. For now, patellar tendon autografts and hamstring tendon autografts are both viable options for ACL reconstruction in adult, male football players.

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