Graft Selection in Anterior Cruciate Ligament Surgery

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Anterior cruciate ligament (ACL) reconstruction is one of the most commonly performed orthopedic surgeries in this country. As ACL reconstruction techniques have evolved and improved dramatically over the past few years from nonanatomic to anatomic, controversies regarding graft selection remain. While conclusions drawn from past studies regarding graft choice in ACL surgery have resulted from predominantly nonanatomic surgical techniques, there are useful guiding principles that can be followed when determining which type of graft to use in ACL reconstruction. Graft selection in ACL surgery should be individualized for each patient. It should be athlete-specific, male- and female-specific, and sport-specific. Desired timing for return to play and length of rehabilitation are other important considerations for the surgeon. Other variables to consider include donor site morbidity, graft fixation options, and differences in length of time required for graft incorporation and healing with subsequent return to play.

The ideal graft for ACL surgery should have similar anatomic and biomechanical characteristics to the native ACL, provide for strong initial fixation, allow for prompt biologic incorporation, and have minimal donor site morbidity for a particular athlete. It is generally believed that no one graft source optimally possesses all these characteristics for each patient. Thus, it is imperative that surgeons and patients discuss risks and benefits of all graft types, and then select a graft that is best for each particular clinical scenario.

Bone–Patellar Tendon–Bone Autograft

Bone–patellar tendon–bone autograft has been considered the gold standard for ACL reconstruction for many years. One reason is that bone–patellar tendon–bone autograft has the most peer-reviewed data in the literature, with the longest follow-up (compared to other types of ACL grafts). Another reason is that bone-to-bone tunnel healing seen with bone–patellar tendon–bone autograft is

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more optimal than soft-tissue-to-bone healing seen with most other types of grafts. Also, rigid initial fixation seen with bone-to-bone fixation is superior to other fixation techniques used with all soft tissue grafts (autografts and allografts). With bone–patellar tendon–bone grafts, fixation points are closer together than those seen in suspensory soft tissue fixation, which enhances overall graft stiffness, an important variable that prevents early and late stretching of the graft during the incorporation process.

Furthermore, many studies advocate possible earlier return to play with use of a bone–patellar tendon–bone autograft. Multiple studies have also shown an increased frequency of return to preinjury level of activity after use of bone–patellar tendon–bone autograft, particularly in young athletes who participate in Level 1 sports year round. In a recent study by Mascarenhas et al1 comparing bone–patellar tendon–bone autograft to bone–patellar tendon–bone allograft, twice as many autograft patients were able to return to very strenuous (jumping or pivoting) activities without the sense of instability.

Additionally, instrumented laxity measurements in bone–patellar tendon–bone autograft patients have shown less laxity than those for allograft patients.2 And in a recent metaanalysis by Prodromos et al3 comparing stability of autograft to allograft tissue after ACL reconstruction, allograft resulted in significantly more knee laxity compared to autograft. In this study, abnormal stability was 2 to 3 times more frequent after allograft ACL reconstruction.

However, potential disadvantages to using bone–patellar tendon–bone autograft exist. These generally relate to donor site morbidity and include anterior knee pain, patella fracture, decreased knee extension, and a potential adverse effect on the extensor mechanism of the knee.4-6 Patients who have low pain tolerance, are nonmotivated, or are too busy to participate in vigorous rehabilitative rehabilitation may have increased morbidity if bone–patellar tendon–bone autograft is used. The majority of the donor-site morbidity issues with this graft are a nonissue in a patient that is well-engaged in the rehabilitation process and achieves normal knee range of motion and patellar mobility within 6 weeks of the index operation.

**HAMSTRING AUTOGRAPH**

Quadrupled-hamstring autograft is frequently used in ACL surgery. It has been shown to be the strongest of all grafts in the laboratory, if equal tension can be applied to each strand.7 Also, it is generally considered to have less donor site morbidity compared to bone–patellar tendon–bone autograft. However, tendon-to-bone graft incorporation is slower than bone-to-bone healing (approximately 4 weeks longer). Other potential disadvantages include graft laxity, tunnel osteolysis, and hamstring weakness (particularly with terminal knee flexion).6

Both bone–patellar tendon–bone and hamstring autografts for ACL reconstruction have shown adequate clinical results in the literature for the majority of patients. However, in a recent systematic review of the literature by Reinhardt et al,8 hamstring autograft was found to result in graft failure more often than bone–patellar tendon–bone autograft. In this study, results were combined from 6 randomized controlled trials comparing bone–patellar tendon–bone and hamstring autografts. There were 11 failures out of 153 bone–patellar tendon–bone autograft reconstructions (7.2%), and 26 failures out of 165 hamstring autograft reconstructions (15.8%) \((P = .02)\).

In addition, Kim et al9 recently showed that in patients with excessive joint laxity, including hyperextension, bone–patellar tendon–bone autograft performed better than hamstring autograft at 2-year follow-up. This was especially true in women. In this study, testing of anterior tibial translation with a KT-2000 arthrometer (MEDmetric, San Diego, California) showed significantly increased anterior laxity after use of hamstring autograft. Lysholm clinical scores were also significantly better for bone–patellar tendon–bone patients. These results should be strongly considered when selecting appropriate ACL grafts in female athletes with knee hyperextension, especially those involved in high level sports at high risk for ACL injury (eg, soccer, basketball, volleyball, field hockey, and softball).

**ALLOGRAFT**

Allografts are commonly used in primary and revision ACL surgeries. The use of allograft tissue in primary ACL surgery has become more common than in the past, largely because of increased availability, better safety of tissues, and no donor site morbidity.

It is important to understand that use of different allograft tissue types may produce different clinical results. This has not been adequately discussed in the orthopedic literature. The majority of the published literature discussing allograft tissue use in ACL surgery relates to bone–patellar tendon–bone allograft, not all-soft-tissue allograft. Currently, more all-soft-tissue allografts are being used for ACL surgery than bone–patellar tendon–bone allografts. Surgeons must be careful not to “lump” all allograft tissue results as the same. It is imperative that each orthopedic surgeon know what is written in the literature regarding a particular type of allograft tissue selected for ACL reconstruction in a particular patient for which allograft is being considered.

The use of allograft tissue in ACL surgery has been shown to yield adequate clinical results in certain patients. However, a high allograft failure rate after ACL surgery has been demonstrated in young active patients.10-12 Additionally, Borchers et al13 recently showed a significantly higher ACL reconstruction failure rate after use of allograft, and also after return to a higher activity level. In patients with both...
characteristics (ie, allograft was used and they returned to higher activity levels), failure of ACL reconstruction was even more significant.

Furthermore, a study by Singh et al showed an unacceptably high failure rate of an all-soft-tissue allograft (anterior tibialis), particularly in young patients (≤25 years). And, as mentioned previously, increased knee laxity has been demonstrated after allograft ACL surgery, compared with the use of autograft.

The secondary sterilization processing of allograft tissue is important to reduce the incidence of disease transmission and eliminate infection, but many of these processes decrease mechanical properties. For example, Rappe et al showed a significantly higher failure rate with Achilles allograft that had been irradiated with 2 to 2.5 Mrad (2.4% failure rate for nonirradiated grafts, and 33% failure rate for irradiated grafts).

Sterilization processes vary tremendously among tissue banks and distributors, and thus surgeons must be familiar with those used by the American Association of Tissue Banks-certified musculoskeletal tissue banks they select. The surgeon is the ultimate tissue bank for the patient. Much remains to be learned about these companies’ proprietary sterilization processes and resultant effects on biologic graft incorporation. Basic science data is severely lacking in this respect, particularly as it relates to animal and human studies with Level 1 evidence.

**CONCLUSION/AUTHORS’ RECOMMENDATIONS**

It is imperative to match length of rehabilitation and timing for return-to-play to the biology of the graft incorporation process and timeline (for whichever graft is selected for ACL surgery). Rehabilitation-specific guidelines should be graft-specific. Bone–patellar tendon–bone autograft provides optimal graft incorporation because of bone-to-bone healing. Thus, rehabilitation and return-to-play are optimized with bone–patellar tendon–bone autograft. If soft tissue autograft is used, graft incorporation takes longer because soft-tissue-to-bone tunnel healing is required. Rehabilitation should be lengthened in this scenario, particularly within the first 12 weeks, which is critical for soft tissue healing in a bone tunnel. In addition, rehabilitation and return to play should also be extended if allograft tissue is used, because of the extended graft incorporation time required when compared to autograft tissue. Young, active patients (<22 years) present a particular challenge to the orthopedic surgeon performing ACL surgery. This is especially true with high level athletes, such as those participating in Level 1 sports year round, including high school, collegiate, and professional athletes. And this is even more challenging if these athletes participate in sports at high-risk for ACL injury, such as football and soccer. In this population, we strongly prefer bone–patellar tendon–bone autograft reconstruction. Reasons for this include more optimal healing afforded by bone-to-bone healing, higher rates of hamstring autograft failure (particularly in females), and higher rates of allograft failure in these young patients. After rehabilitating from surgery, these patients will “test” their grafts unlike any other patient population. We strongly feel that bone–patellar tendon–bone autograft is the optimal graft for this particular patient or athlete.

For patients younger than 40 years, who are active but not involved in highly competitive athletics year round, we prefer hamstring autograft (quadrupled gracilis and semitendinosus tendons). In our experience, hamstring autograft has been extremely successful in these patients.

In patients older than 40 years, we feel that allograft and hamstring autograft both produce excellent results. If a patient older than 40 years is highly active, we prefer hamstring autograft. However, based on patient preference and clinical scenario, we have experienced good results with both allograft and hamstring autograft in this age group. In addition, we prefer allograft tissue for revision ACL reconstruction as well as multi-ligamentous knee surgery.

Finally, the most important variable control led by the surgeon in ACL surgery is anatomic graft placement. Anatomic techniques must be used (ie, the femoral and tibial tunnels must be properly positioned) (Figure). If nonanatomic techniques are used; it makes no difference which type of graft is used, the risk of graft failure is highly increased.

**REFERENCES**


**Figure:** AP and lateral radiographs showing tunnel placement after bilateral ACL reconstructions (each performed by a different surgeon). Tunnels were placed anatomically for the right knee (A, B), while nonanatomic and vertical tunnels were used for the left knee (C, D).