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Operative Techniques in
Orthopaedics

Matching the Anterior Cruciate Ligament Graft to the Patient

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The aim of anterior cruciate ligament (ACL) reconstruction is to restore normal knee functioning. Key to successful ACL reconstruction understands how to match the ACL graft to the bone tunnel while taking into account interpatient variances. Bone tunnel location and size should be determined according to the original ACL footprint anatomy of each patient. Therefore, appropriate assessments of individual anatomy should be obtained before surgery using imaging techniques. Additionally, graft type should be carefully selected after fully considering biomechanical properties, donor site morbidities, patient activities and lifestyle, and patient preference. This report describes technical issues associated with imaging assessments of ACL anatomy and summarizes the features of currently available graft materials. Despite advancements in ACL reconstruction, certain points remain unclear, such as how much of the native ACL footprint should be covered by the reconstruction graft during surgery. Therefore, further studies are needed to improve the optimum matching of grafts to the requirements of each individual patient.

KEYWORD anterior cruciate ligament, graft selection, anatomical ACL reconstruction, individualized ACL reconstruction

Introduction

The ultimate goal of the anterior cruciate ligament (ACL) reconstruction is to restore normal knee functioning, as well as the preinjury activity level of each patient. To achieve this aim, anatomical ACL reconstruction has been introduced as "the functional restoration of the ACL to its native dimensions, collagen orientation, and insertion sites."[1] Three simple surgical steps can be used to describe ACL reconstruction—bone tunnel creation, graft preparation, and graft fixation into the tunnels. Therefore, it is very important to know how to fit the ACL graft into the bone tunnel, a point that requires knowledge of and adaption to individual patient traits and ACL variations.

Bone tunnel location and size should be determined according to native ACL footprint anatomy. As this varies among patients,[2,3] meticulous assessments of individual anatomy should be performed preoperatively and intraoperatively. Some precautions should be taken into account to obtain accurate clinical images of the ACL footprint, particularly as these images will ultimately determine the best possible locations for tunnel placement.

Graft selection is another critical point for ACL reconstruction. A wide variety of potential graft materials exist, and preoperative selection normally considers graft volume, strength, donor site morbidity, availability, and patient activity level, lifestyle, and personal preference. Many of these points will clearly differ based on inherent patient traits. In turn, several types of graft material are currently available, although the use of some materials is restricted in certain countries. Each graft material has specific weaknesses and strengths, and it is important for patient welfare and surgery success that ACL surgeons take into account the unique characteristics of each material.

This article describes known technical limitations associated with ACL anatomy imaging techniques and summarizes the features of currently available ACL graft materials.

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Clinical Importance of Anatomical Assessments for Graft-to-Patient Matching

The native ACL insertion site should be restored as closely as possible to achieve optimum anatomical ACL reconstruction. Therefore, it is important to acknowledge that the size and shape of the original ACL footprint is inconsistent among patients.[2,3] Patients with a small insertion site might not be candidates for double-bundle ACL reconstruction because of technical difficulty.[1,4] On the contrary, patients with a large insertion site and treated with single-bundle ACL reconstruction would lose the biomechanical advantage offered by the double-bundle technique.[5] In addition to the insertion site, intercondylar notch size should be evaluated. Knees with a shallow notch are likely to incur graft impingement at the top of the notch, if the graft is excessively large or if multiple grafts are used. In turn, a narrow notch is inadequate for achieving anatomical tunnel drilling from the anteromedial portal owing to interference by the medial condyle. To determine the most suitable ACL graft and reconstruction procedure for each patient, the size and shape of the native ACL footprint, as well as intercondylar notch size, should be properly assessed preoperatively and intraoperatively.[6]

Preoperative Imaging Assessments

Imaging assessments are frequently used to establish the ACL footprint. The most commonly used radiographic methods for determining tunnel location before ACL reconstruction are the Bernard Quadrant Method[7] for the femur, the Amis-Jacob line method for the tibia,[8] and a plain radiograph for two-dimensional mapping of the tunnel location. Three-dimensional ACL footprint analysis is also possible with computed tomography (CT) imaging.[9-11]

Although a plain radiography or CT scan can be used to define the ACL footprint center, information needed to evaluate the anatomical placement of tunnels,[12] these imaging techniques lack the ability to detect ACL footprint size and shape. In other words, a plain X-ray and CT scan cannot provide all of the information needed for optimum graft-to-patient matching. Regarding this, magnetic resonance imaging (MRI) is an advantageous option as it can display soft tissues in the knee joint, including the ACL.[13] As intrasubject variability in footprint anatomy is minimal,[14] an MRI assessment of the ACL in the contralateral, uninjured knee is currently the best possible imaging option for evaluating the native ACL footprint anatomy of the injured ligament.

Intraoperative Arthroscopic Assessments

Direct measurement of ACL footprint dimensions, including of footprint size and distances from some anatomical landmarks,[22,23] can be performed at the time of surgery, when the final decision of tunnel size and location is normally determined.[6] To ensure anatomical accuracy during reconstruction, the ACL footprint and related anatomical landmarks must be clearly visualized. To properly view the lateral wall of the intercondylar notch, the 3-portal technique using the anteromedial, or central, portal is recommended.[24,25] Similarly, a high-angle scope, such as a 70° scope, can be used from the anterolateral portal to obtain a straight view of the lateral wall.[26] However, the arthroscopic view of a high-angle scope is somewhat distorted.[27,28] Furthermore, the knee flexion angle should be consistently maintained, otherwise the tunnel might be misplaced.[29]

Femoral intercondylar notch width can be preoperatively measured using X-ray,[15,16] CT,[17,18] or MRI[19,20] imaging or all of these. During intraoperative evaluations of intercondylar notch dimensions, a ruler can be easily used to provide direct data. Both preoperative and intraoperative information can be used to finally select a particular surgical option, such as the single- vs double-bundle technique.[21]

Graft Selection

Autografts

Hamstrings

The hamstrings, which encompass the semitendinosus and gracilis tendons, are the most commonly used graft source worldwide.[30,31] This can also be said for ACL reconstruction with either a double or single bundle.[4] The ubiquity of the hamstrings is owing to the flexibility of this soft tissue graft, which facilitates a variety of procedures. In particular, this graft can pass through a deviated tunnel angle and fit into any type of tunnel shape. Another major advantage of the hamstrings graft is fewer donor site morbidities as compared with other types of autografts, such as the bone-patella tendon-bone (BPTB) and quadriceps grafts. More specifically, hamstrings grafts have been repeatedly reported to cause less anterior knee pain than the BPTB.[32-34] A point of possible concern for the hamstrings tendon graft is biomechanical strength. This concern appears valid when considering that the ultimate failure loads of each semitendinosus (1216 N) and gracilis tendon (838 N)[35] are far less compared with the native ACL ($\approx$ 2000 N).[36] However, a 4-stranded use of the hamstrings tendon provides failure loads from 2422-4590 N,[37,38] which appear clinically acceptable as compared with native ACL strength.

Despite many positives, some donor site morbidities of the hamstrings tendon graft should be recognized by surgeons. First, saphenous nerve injury is the most common complication after the hamstrings tendon harvesting. Up to 74% of hamstring-harvested patients experience sensory disturbance in the area of the sartorial (ie, terminal) branch of the saphenous nerve.[39] To prevent nerve injury as much as possible, a simple technical modification would be the use of an oblique incision for harvesting.[40] Another possible donor site morbidity after hamstring harvesting is weakness in knee flexion.[41] As the hamstrings are one of the dynamic stabilizer