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Anatomic Double-Bundle Anterior Cruciate Ligament Reconstruction: The University of Pittsburgh Approach

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Anterior cruciate ligament tears are a common occurrence and create significant functional limitations for patients sustaining these injuries. Approximately 100,000 reconstructions are performed each year in the United States. Single-bundle reconstructive techniques have been relatively successful; however, concerns remain over pain, degenerative joint disease, residual instability, and failure to return to prior levels of activity. Traditional single-bundle procedures fail to recreate the native anatomy of the knee and, therefore, the natural kinematics of the knee. Intensive research in these areas has created the opportunity for anatomic double-bundle techniques to improve the outcome of traditional reconstruction.

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The management of anterior cruciate ligament (ACL) ruptures continues to evolve. Treatment strategies have progressed from primary repair and synthetic graft augments to single-bundle reconstruction with various auto- and allograft sources. Despite the overall success with single-bundle reconstruction, this method continues to have postoperative shortcomings inherent to the principles of the surgical technique.

Anatomic studies have shown that the ACL consists of 2 bundles: anteromedial (AM) and posterolateral (PL).[1,2] Furthermore, each bundle exhibits variable tension depending on the degree of knee flexion.[3] With knee flexion, the anteromedial bundle tightens with corresponding laxity of the posterolateral bundle. The inverse is true with knee extension as the posterolateral bundle tightens and the anteromedial bundle relaxes. Additionally, the posterolateral bundle has been found to contribute to the rotational stability of the knee.[4] Biomechanically, single-bundle techniques restore anterior-posterior stability via recreation of the anteromedial bundle, but such techniques have limited ability to address rotational stability.[5] Kinematic laboratory testing comparing single-bundle to anatomic double-bundle ACL reconstructions favors the latter based on evidence that in situ graft forces approximate those of the native ACL.[6] This failure of single-bundle constructs to recreate normal anatomy leads to postoperative kinematic limitations and potential compromise of the surgical outcome.

The early development of the double-bundle reconstruction occurred in the 1980s with the work of Mott and Müller; however, detailed knowledge of the native anatomy was limited, and little attention was given to the technique because single-bundle procedures were quicker, less surgically demanding, and enjoyed relatively successful outcomes.[7,8] A primary tenet of anatomic ACL reconstruction is that every patient has a unique anatomy. Unfortunately, the desire for the technique to be expedient and comparatively simple often leads to nonanatomic placement of the reconstructed ligament.

The relative infancy of the "anatomic" double-bundle technique has limited long-term outcome data, but early results are encouraging. Fu et al[9] published the preliminary results of the University of Pittsburgh experience with anatomic double-bundle reconstruction with no patients reporting pain or instability with activities of daily living and approximately 78% reporting no symptoms during strenuous activity.[9] Biomechanically, several level I and II studies have recently shown favorable double-bundle results when compared

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with single-bundle constructs.[10-12] Advantages include decreased pivot shifting, anterior laxity, and improved International Knee Documentation Committee (IKDC) scores.

The evolution and refinement of the orthopedic community's understanding of ACL anatomy has led to a particular interest in anatomic ACL reconstruction with the double-bundle technique, the potential for more natural kinematics, and the possibility of improved postsurgical outcomes.

Patient Evaluation

A thorough history and careful physical examination are critical for the identification of ACL tears as well as determining nonoperative and surgical strategies for the injured knee. Patients typically describe either a low-energy, noncontact twisting injury or direct trauma to the extremity. The mechanism is an important component because it may suggest other pathologies, such as varus/valgus-associated collateral ligament injuries or damage related to a patella dislocation. Instability or "giving out" is a common complaint, particularly with deceleration and pivoting type activities. A "pop" or similar sensation is often described as well as swelling of the affected joint. Particular attention should be given to locking or "catching" of the joint because this suggests meniscal damage.

A physical examination is performed with both lower extremities exposed, allowing for comparison. Inspection for joint effusion, ecchymosis, and atrophy are noted as well as overall limb alignment. Range of motion is compared. Palpation of the knee, including the joint line, bony prominences, and parapatellar area may suggest a meniscal tear, ligamentous tear, or patella dislocation. The pivot shift is more sensitive for ACL tears but can be difficult to perform in the acute presentation secondary to guarding and pain. Lachman and anterior drawer tests are also performed. The remainder of the examination is focused on ruling out other injuries and includes Dial, McMurray, posterior drawer, and reverse pivot shift tests as well as varus and valgus stress at 0° and 30° of flexion. Quantitative measurements are performed with the KT-2000 arthrometer (MEDmetric, San Diego, CA). A side-to-side difference greater than 3 mm is suggestive of ACL attenuation or tear. Preoperative physical therapy may be of benefit because it can assist with improving range of motion as well as with modalities for quadriceps strengthening, gait, and decreasing the joint effusion.

Imaging

Plain film radiographs are obtained and are necessary to evaluate open growth plates, rule out associated fractures, assess joint space narrowing, and reveal abnormalities related to limb alignment. Weight-bearing extension and 45° flexion posteroanterior x-rays as well as non–weight-bearing 45° lateral and axial (merchant) views of the bilateral patellofemoral joints are obtained. It is also common in our practice to have magnetic resonance imaging (MRI) to evaluate the ACL tear pattern as well as associated pathologies. We have developed a specific MRI sequence protocol including the oblique coronal and sagittal series that allows for additional focus on the ACL (Fig. 1). For scenarios involving revision ACL surgery, we obtain a preoperative computed tomography scan with 3-dimensional reconstructions to evaluate prior tunnel placement as well as the degree of bone loss (Fig. 2).

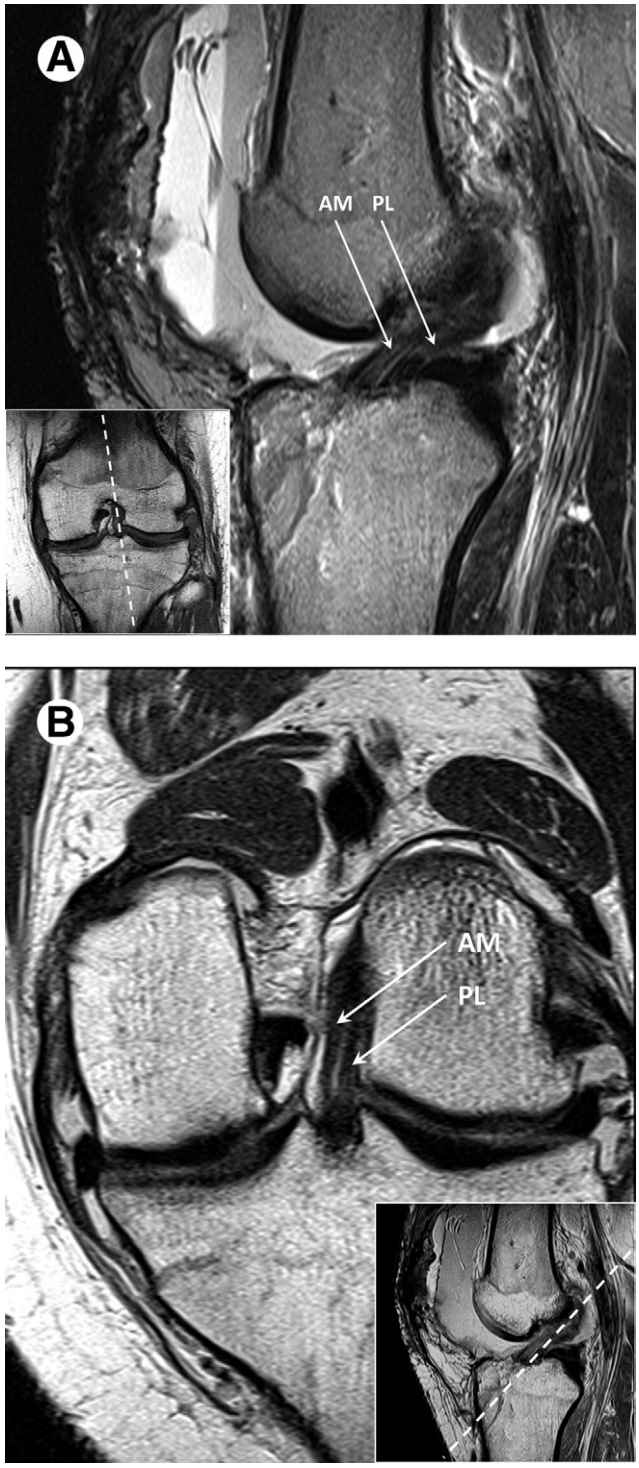

Figure 1 Special orientation of the MRI slices allows better visualization of the ACL. (A) Oblique sagittal slice revealing both the AM and PL bundles. (B) Oblique coronal slice. The AM and PL bundles are identified.