

Arthroscopy Up to Date: Anterior Cruciate Ligament Anatomy



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Purpose: To categorize and summarize up-to-date anterior cruciate ligament (ACL) research published in *Arthroscopy* and *The American Journal of Sports Medicine* and systematically review each subcategory, beginning with ACL anatomy. **Methods:** After searching for "anterior cruciate ligament" OR "ACL" in *Arthroscopy* and *The American Journal of Sports Medicine* from January 2012 through December 2014, we excluded articles more pertinent to ACL augmentation; open growth plates; and meniscal, chondral, or multiligamentous pathology. Studies were subcategorized for data extraction. **Results:** We included 212 studies that were classified into 8 categories: anatomy; basic science and biomechanics; tunnel position; graft selection; graft fixation; injury risk and rehabilitation; practice patterns and outcomes; and complications. Anatomic risk factors for ACL injury and post-reconstruction graft failure include a narrow intercondylar notch, low native ACL volume, and increased posterior slope. Regarding anatomic footprints, the femoral attachment is 43% of the proximal-to-distal lateral femoral condylar length whereas the posterior border of the tendon is 2.5 mm from the articular margin. The tibial attachment of the ACL is two-fifths of the medial-to-lateral interspinous distance and 15 mm anterior to the posterior cruciate ligament. Anatomic research using radiology and computed tomography to evaluate ACL graft placement shows poor interobserver and intraobserver reliability. **Conclusions:** With a mind to improving outcomes, surgeons should be aware of anatomic risk factors (stenotic femoral notch, low ligament volume, and increased posterior slope) for ACL graft failure, have a precise understanding of arthroscopic landmarks identifying femoral and tibial footprint locations, and understand that imaging to evaluate graft placement is unreliable. **Level of Evidence:** Level III, systematic review of Level III evidence.

See commentary on page 213

A *Arthroscopy: The Journal of Arthroscopic and Related Research* and *The American Journal of Sports Medicine (AJSM)* are the official journals of the Arthroscopy Association of North America and the American Orthopaedic Society for Sports Medicine, respectively. Both journals focus on the anterior cruciate ligament (ACL). Both societies are subspecialty societies of the American Academy of Orthopaedic Surgeons (AAOS), but not all ACL surgeons, American or otherwise, read both journals, and even for

those who do, with a topic receiving as much focus as the ACL, synthesizing the information can be difficult.

The purpose of this study was to systematically review recent studies relating to the ACL and published in *Arthroscopy* and *AJSM*, topically categorize these studies, and then concisely synthesize each subcategory for arthroscopic surgeons and related scientists. Our hypothesis was that an increase in preclinical knowledge results in improved clinical outcomes over time. The

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first subcategory in this series of systematic reviews is ACL anatomy.

Methods

In June 2015 we searched for articles including the terms “anterior cruciate ligament” OR “ACL” in the article title using the advanced search feature on both the *Arthroscopy* and *AJSM* Web sites. We included articles published in *Arthroscopy* or *AJSM* pertaining to the ACL and dated January 1, 2012, through January 1, 2015. We included randomized and nonrandomized clinical studies, basic science studies, meta-analyses, systematic reviews, and surgeon surveys. The exclusion criteria included articles not pertaining to the ACL; articles pertaining to ACL augmentation; articles pertaining to the ACL and open growth plates; and articles more pertinent to meniscal pathology, chondral injury, or multiligamentous injury.

All titles and abstracts were independently screened for eligibility by 4 reviewers (C.K.S., S.C.M., S.S.J., J.H.L.) with methodologic and content expertise using a piloted electronic database (Microsoft Excel; Microsoft, Redmond, WA), as described later. All discrepancies were resolved by consensus. Two reviewers (C.K.S., J.H.L.) then reviewed the full text of all studies identified by title and abstract screening to determine final eligibility. All discrepancies were resolved by consensus. Both reviewers then reviewed the full text of all studies identified by title and abstract screening to determine final eligibility.

Assessment of Methodologic Quality

Assessment of the methodologic quality of all included studies was performed using the Coleman Methodology Score. The reviewers resolved any discrepancies through discussion and re-evaluation of the study methodology until consensus was reached.

Extraction of Data

Before proceeding with abstraction of data and subsequent analysis, the reviewers performed a pilot review of included studies to determine topical subcategories for analysis. After resolution of discrepancies as described earlier, each category was used to create piloted electronic data extraction forms. Then, data were extracted independently by each reviewer. Finally, discrepancies were resolved as described earlier. Extracted data included study authors, study title, type of study, level of evidence, Coleman Methodology Score, study demographic characteristics (number of patients or specimens, mean age and range, distribution by sex), and study conclusion.

Statistical Analysis

Descriptive statistics were reported to reflect the frequencies or percentages of abstracted study data

when possible, whereas pooling of results was not conducted.

Results

Eighty-four articles from *Arthroscopy* and 128 articles from *AJSM* were included. In sum, we included 212 articles that were separated into 8 categories: anatomy; basic science and biomechanics; tunnel position; graft selection; graft fixation; injury risk and rehabilitation; practice patterns and outcomes; and complications. A review of ACL anatomy is presented in this article and includes 13 publications (Table 1).

Identifying anatomic risk factors for ACL tears could play a role in ACL injury and ACL graft reinjury prevention. Comparing magnetic resonance imaging measurements of intercondylar notch volume of pediatric patients with ACL injury versus normal controls showed a significantly decreased notch volume in those sustaining ACL injury. Female patients with a small notch volume are especially at risk.¹ This association is true in adults, and risk is further increased in patients who have a combination of a decreased notch volume and lower-than-average graft volume.² Another possible risk factor for ACL injury in both the pediatric and adult population is an increased posterior tibial slope.^{3,4} This association is also stronger in women than in men.⁵ Similarly, the research of Jung et al.⁶ in the adult population shows that an increased posterior tibial slope is directly correlated with increased rates of ACL mucoid degeneration. This is concordant with findings that patients with greater than 5° of tibial slope tend to have increased anterior laxity after ACL reconstruction (ACLR).⁷

While the presence of the anteromedial and posterolateral bundles of the ACL is well accepted, recent research raises the possibility of an intermediate bundle. However, the authors could not (anatomically or histologically) confirm the presence of a distinct intermediate bundle in human specimens, suggesting that anatomic tunnel placement is a more important determinant of clinical outcome than double- or triple-bundle reconstruction.⁸

In addition to cadaveric studies, researchers have investigated the radiographic anatomy of the ACL-reconstructed knee. Retrospective data assessing the reliability of postoperative radiographs to evaluate tunnel placement after ACLR show that radiographic measurements are not consistently reproducible in terms of intraobserver and interobserver analysis. The presence of metal interference screws did not improve reliability of measurements.⁹ In addition, there is substantial intraobserver and interobserver disagreement regarding tunnel position with the use of computed tomography scans.¹⁰

Systematic reviews independently helped to clarify the anatomy of the ACL femoral and tibial footprints.

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