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The Knee

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Orthopaedic Manual Physical Therapy Series
Charlottesville 2017-2018

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Knee Stability and Movement Coordination Impairments: Knee Ligament Sprain Revision 2017

Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Orthopaedic Section of the American Physical Therapy Association

J Orthop Sports Phys Ther. 2017;47(11):A1-A47. doi:10.2519/jospt.2017.0303

I	Evidence obtained from high-quality diagnostic studies, prospective studies, or randomized controlled trials
II	Evidence obtained from lesser-quality diagnostic studies, prospective studies, or randomized controlled trials (eg, weaker diagnostic criteria and reference standards, improper randomization, no blinding, <80% follow-up)
III	Case controlled studies or retrospective studies
IV	Case series
V	Expert opinion

GRADES OF RECOMMENDATION BASED ON		STRENGTH OF EVIDENCE
A	Strong evidence	A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study
B	Moderate evidence	A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation
C	Weak evidence	A single level II study or a preponderance of level III and IV studies including statements of consensus by content experts support the recommendation
D	Conflicting evidence	Higher-quality studies conducted on this topic disagree with respect to their conclusions. The recommendation is based on these conflicting studies
E	Theoretical/ foundational evidence	A preponderance of evidence from animal or cadaver studies, from conceptual models/ principles or from basic sciences/ bench research support this conclusion
F	Expert opinion	Best practice based on the clinical experience of the guidelines development team

Summary of Recommendations*

DIAGNOSIS/CLASSIFICATION

A Physical therapists should diagnose the International Classification of Diseases (ICD) categories of Sprain and strain involving collateral ligament of knee, Sprain and strain involving cruciate ligament of knee, and Injury to multiple structures of knee, and the associated International Classification of Functioning, Disability and Health (ICF) impairment-based categories of knee instability (**b7150 Stability of a single joint**) and movement coordination impairments (**b7601 Control of complex voluntary movements**), using the following history and physical examination findings: mechanism of injury, passive knee laxity, joint pain, joint effusion, and movement coordination impairments.

DIFFERENTIAL DIAGNOSIS

B The clinician should suspect diagnostic classifications associated with serious pathological conditions when the individual's reported activity limitations and impairments of body function and structure are not consistent with those presented in the Diagnosis/Classification section of this guideline, or when the individual's symptoms are not resolving with intervention aimed at normalization of the individual's impairments of body function.

EXAMINATION – OUTCOME MEASURES: ACTIVITY LIMITATIONS AND SELF-REPORTED MEASURES

B Clinicians should use the International Knee Documentation Committee 2000 Subjective Knee Evaluation Form (IKDC 2000) or Knee injury and Osteoarthritis Outcome Score (KOOS), and may use the Lysholm scale, as validated patient-reported outcome measures to assess knee symptoms and function, and should use the Tegner activity scale or Marx Activity Rating Scale to assess activity level, before and after interventions intended to alleviate the physical impairments, activity limitations, and participation restrictions associated with knee ligament sprain. Clinicians may use the Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI) instrument as a validated patient-reported outcome measure to assess psychological factors that may hinder return to sports before and after interventions intended to alleviate fear of reinjury associated with knee ligament sprain.

EXAMINATION – PHYSICAL PERFORMANCE MEASURES

B Clinicians should administer appropriate clinical or field tests, such as single-legged hop tests (eg, single hop for distance, crossover hop for distance, triple hop for distance, and 6-meter timed hop), that can identify a patient's baseline status relative to pain, function, and disability; detect side-to-side asymmetries; assess global knee function; determine a patient's readiness to return to activities; and monitor changes in the patient's status throughout the course of treatment.

EXAMINATION – PHYSICAL IMPAIRMENT MEASURES

B When evaluating a patient with ligament sprain over an episode of care, clinicians should use assessments of impairment of body structure and function, including measures of knee laxity/stability, lower-limb movement coordination, thigh muscle strength, knee effusion, and knee joint range of motion.

INTERVENTIONS – CONTINUOUS PASSIVE MOTION

C Clinicians may use continuous passive motion in the immediate postoperative period to decrease postoperative pain after anterior cruciate ligament (ACL) reconstruction.

INTERVENTIONS – EARLY WEIGHT BEARING

C Clinicians may implement early weight bearing as tolerated (within 1 week after surgery) for patients after ACL reconstruction.

INTERVENTIONS – KNEE BRACING

C Clinicians may use functional knee bracing in patients with ACL deficiency.

D Clinicians should elicit and document patient preferences in the decision to use functional knee bracing following ACL reconstruction, as evidence exists for and against its use.

F Clinicians may use appropriate knee bracing for patients with acute posterior cruciate ligament (PCL) injuries, severe medial collateral ligament (MCL) injuries, or posterolateral corner (PLC) injuries.

INTERVENTIONS – IMMEDIATE VERSUS DELAYED MOBILIZATION

B Clinicians should use immediate mobilization (within 1 week) after ACL reconstruction to increase joint range of motion, reduce joint pain, and reduce the risk of adverse responses of surrounding soft tissue structures, such as those associated with knee extension range-of-motion loss.

INTERVENTIONS – CRYOTHERAPY

B Clinicians should use cryotherapy immediately after ACL reconstruction to reduce postoperative knee pain.

INTERVENTIONS – SUPERVISED REHABILITATION

B Clinicians should use exercises as part of the in-clinic supervised rehabilitation program after ACL reconstruction and should provide and supervise the progression of a home-based exercise program, providing education to ensure independent performance.

INTERVENTIONS – THERAPEUTIC EXERCISES

A Weight-bearing and non–weight-bearing concentric and eccentric exercises should be implemented within 4 to 6 weeks, 2 to 3 times per week for 6 to 10 months, to increase thigh muscle strength and functional performance after ACL reconstruction.

INTERVENTIONS – NEUROMUSCULAR ELECTRICAL STIMULATION

A Neuromuscular electrical stimulation should be used for 6 to 8 weeks to augment muscle strengthening exercises in patients after ACL reconstruction to increase quadriceps muscle strength and enhance short-term functional outcomes.

INTERVENTIONS – NEUROMUSCULAR RE-EDUCATION

A Neuromuscular re-education training should be incorporated with muscle strengthening exercises in patients with knee stability and movement coordination impairments.

Anterior Cruciate Ligament

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ACL

- 148714 reconstructions in 2013
- 70% non contact
- Account for more than $500 million in healthcare costs per year
- Females 2.4 - 9.7x

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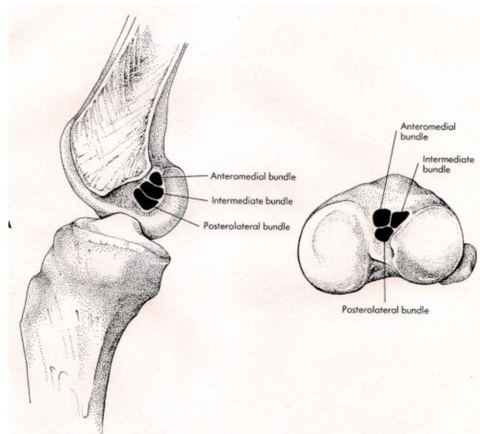
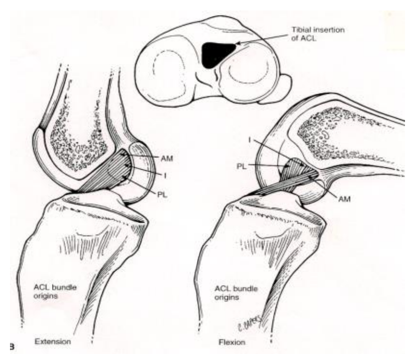
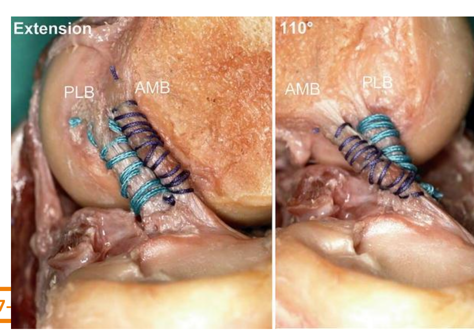
Anatomy

- Originates at posteromedial corner of the medial side of the lateral femoral condyle, attaches in a fossa anterolateral to the tibial spine
- Function:
  - Limits anterior tibial translation (85% at 30/90 degrees)
  - Secondary limitation of tibial IR, varus/valgus
  - Ultimate strength of a native ACL is ~2000N

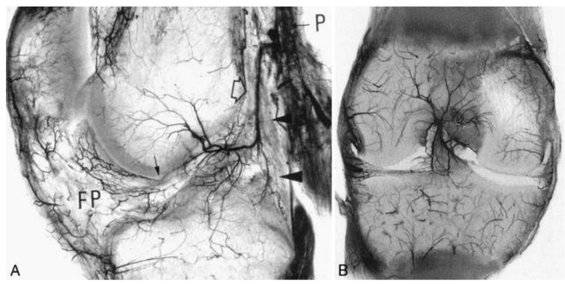


- **Anteromedial bundle**
  - **Tight throughout flexion**
  - **Anterior instability**
  - **Smaller**
- **Posterolateral bundle**
  - **Tight in extension**
  - **Greatest restraint to anterior translation from ext to 20deg flexion**
  - **Rotary instability**
  - **Larger**
- **Both**
  - **Secondary restraint to varus/valgus/tibial IR**
  - **Primary restraint to valgus force when MCL unable**





- Innervation:
  - Posterior articular branches of the tibial nerve
- Vascularization
  - Branches of the middle genicular artery
  - Infrapatellar Fat pad
  - Synovium



ACL

- Injury Mechanism:
  - Acceleration/deceleration at full extension or slight flexion (Excess Quad, Decr HS activation); coupled with tibial rotation
  - CKC IR/Valgus without HS co contraction
  - Medial tibial rotation
    - ACL winds around PCL
  - Lateral tibial rotation
    - ACL stretches over lateral condyle

A Systematic Summary of Systematic Reviews on the Topic of the Anterior Cruciate Ligament

Michael J. Anderson,* MD, William M. Browning III,* DO, MS, Christopher E. Urband,* MD, Melissa A. Kluczynski,* MS, and Leslie J. Bisson,*† MD

Purpose: To quantify the number of systematic reviews and meta-analyses published on the ACL in the past decade and to provide an overall summary of this literature.

Results: A total of 1031 articles were found, of which 240 met the inclusion criteria. Included articles were summarized and divided into 17 topics: anatomy, epidemiology, prevention, associated injuries, diagnosis, operative versus nonoperative management, graft choice, surgical technique, fixation methods, computer-assisted surgery, platelet-rich plasma, rehabilitation, return to play, outcomes assessment, arthritis, complications, and miscellaneous.

The Orthopaedic Journal of Sports Medicine, 4(3), 2325967116634074
DOI: 10.1177/2325967116634074

Rehab Before ACL Reconstruction?

Should patients reach certain knee function benchmarks before anterior cruciate ligament reconstruction? Does intense 'prehabilitation' before anterior cruciate ligament reconstruction influence outcome and return to sports?

Hägglund M, *et al. Br J Sports Med* November 2015 Vol 49 No 22

M Hägglund,[1] M Waldén,[2] R Thomeé[3]

- 6 week prehabilitation program prior to ACLR resulted in significantly increased KOOS scores and increased hop tests which remained 12 weeks after surgery compared to a control group

How does a combined preoperative and postoperative rehabilitation programme influence the outcome of ACL reconstruction 2 years after surgery? A comparison between patients in the Delaware-Oslo ACL Cohort and the Norwegian National Knee Ligament Registry

H Grindem,[1] L P Granan,[2,3,4] M A Risberg,[1,5] L Engebretsen,[3,6] L Snyder-Mackler,[7] I Eitzen[5]
Grindem H, *et al. Br J Sports Med* 2014;**0**:1–6. doi:10.1136/bjsports-2014-093891

Conclusions Patients in a prospective cohort who underwent progressive preoperative and postoperative rehabilitation at a sports medicine clinic showed superior patient-reported outcomes both preoperatively and 2 years postoperatively compared to patients in the NKLR who received usual care.

The effectiveness of pre-operative exercise physiotherapy rehabilitation on the outcomes of treatment following anterior cruciate ligament injury: A systematic review

Clinical Rehabilitation
1–11

DOI: 10.1177/0269215516628617

Shady Alshewaier[1,2], Gillian Yeowell[1] and Francis Fatoye[1]

Results: A total of 500 studies were identified, of which eight studies met the inclusion criteria and were included in the present review. The average Physiotherapy Evidence Database score for the studies included was 5.8, which reflects an overall moderate methodological quality.

The eight studies investigated a total of 451 subjects of which 71% (*n*=319) were males. The age of the participants in the eight studies ranged from 15 to 57 years. The duration of the intervention in the studies ranged from 3 to 24 weeks. This review found that pre-operative physiotherapy rehabilitation is effective for improving the outcomes of treatment following anterior cruciate ligament injury, including increasing knee-related function and improving muscle strength. However, whilst there was a significant improvement in quality of life from baseline following intervention, no significant difference in quality of life was found between the control and intervention groups.

Conclusions: There is evidence to suggest that pre-operative physiotherapy rehabilitation is beneficial to patients with anterior cruciate ligament injury.

Double-Bundle Versus Single-Bundle Anterior Cruciate Ligament Reconstruction

A Prospective Randomized Study With 5-Year Results

Piia Suomalainen,*† MD, Timo Järvelä,‡ MD, PhD, Antti Paakkala,† MD, PhD,
Pekka Kannus,§ MD, PhD, and Markku Järvinen,† MD, PhD
Investigation performed at Tampere University Hospital (TAYS), Tampere, Finland

Results: Preoperatively, there were no differences between the groups. Eleven patients (7 in the SBB group, 3 in the SBM group, and 1 in the DB group) had a graft failure during the follow-up and went on to ACL revision surgery ($P < .043$). Of the remaining 79 patients, a 5-year follow-up was performed for 65 patients (20 in the DB group, 21 in the SBB group, and 24 in the SBM group) who had their grafts intact. At 5 years, there was no statistically significant difference in the pivot-shift or KT-1000 arthrometer tests. In the DB group, 20% of the patients had OA in the medial femorotibial compartment and 10% in the lateral compartment, while the corresponding figures were 33% and 18% in the single-bundle groups, again an insignificant finding. Further, no significant group differences were found in the knee scores.

Conclusion: The double-bundle surgery resulted in significantly fewer graft failures and subsequent revision ACL surgery than the single-bundle surgeries during the 5-year follow-up. Knee stability and OA rates were similar at 5 years. In view of the size of the groups, some caution should be exercised when interpreting the lack of difference in the secondary outcomes.

The American Journal of Sports Medicine, Vol. 40, No. 7
DOI: 10.1177/0363546512448177

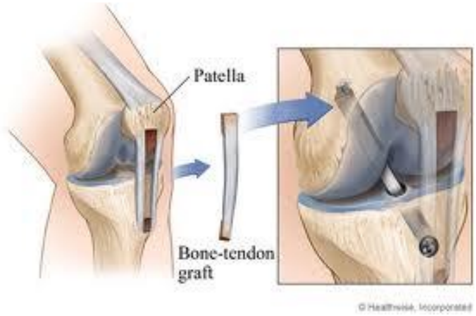
Clinical outcomes of double- vs single-bundle anterior cruciate ligament reconstruction: A systematic review of randomized control trials

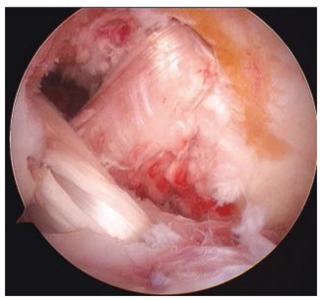
J. Kongtharvonskul[1], J. Attia[2], S. Thamakaison[3], C. Kijkunasathian[4], P. Woratanarat[4], A. Thakkinstian[1]

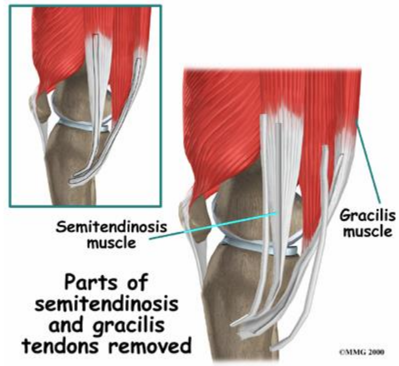
Clinical outcomes of anterior cruciate ligament (ACL) reconstruction with double-bundle and single-bundle techniques are still controversial. We therefore performed a systematic review to compare postoperative outcomes between the two techniques. Randomized control trials comparing the outcomes between the two techniques were identified from Medline and EMBASE since inception to April 27, 2011. Data were independently extracted by two reviewers. Thirteen of 318 studies were eligible; 9, 11, 7, and 8 studies were pooled for rotation, translation, function, and complication outcomes, respectively. The double-bundle technique was approximately four times (95% CI: 2.65, 11.99) and two times (95% CI: 1.16, 5.21) more likely to show a normal pivot shift and normal International Knee Documentation Committee (IKDC) grading compared with the single-bundle technique. However, there were nonsignificant differences in KT grading (OR = 1.66, 95% CI: 0.77, 3.82), IKDC score (0.29, 95% CI: −1.17, 1.75), Lysholm knee score (−0.87, 95% CI: −2.66, 0.93), Tegner activity score (0.37, 95% CI: −0.05, 0.79), and complications (OR = 1.11, 95% CI: 0.48, 2.57). Heterogeneity was present in some outcomes but there was no evidence of publication bias for any outcome. The double-bundle may be better than the single-bundle ACL reconstruction technique in rotational stability but not for function, translation, and complications.

Scand J Med Sci Sports 2012: ••: ••–••
doi: 10.1111/j.1600-0838.2011.01439.x

SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS







Quality of Life and Clinical Outcome Comparison of Semitendinosus and Gracilis Tendon Versus Patellar Tendon Autografts for Anterior Cruciate Ligament Reconstruction

An 11-Year Follow-up of a Randomized Controlled Trial

Matjaz Sajovic,*† MD, PhD, Andrej Strahovnik,† MD,
Mojca Z. Dernovsek,‡ MD, PhD, and Katja Skaza,§ PT
Investigation performed at General Hospital Celje, Celje, Slovenia

Results: At the 11-year follow-up, no statistically significant differences were seen with respect to the Lysholm score and Short Form-36, KT-1000 arthrometer laxity testing, anterior knee pain, single-legged hop test, or International Knee Documentation Committee (IKDC) classification results. Positive pivot-shift test (1+) was significantly more frequent in the PT group (P = .036). Twenty-two patients (81%) in the STG group and 18 patients (72%) in the PT group were still at their preinjury level of activity. Graft rupture occurred in 2 patients from the STG group (6%) and in 4 patients from the PT (12%). Grade B and C abnormal radiographic findings were seen in 84% (21 of 25) of patients in the PT group and in 63% (17 of 27) of patients in the STG group (P = .008).

Conclusion: Both hamstring and patellar tendon autografts provided good subjective outcomes and objective stability at 11 years. Positive pivot-shift test (1+) was significantly more frequent in the PT group. No significant differences in the rate of graft failure were identified. Patients with patellar tendon graft had a greater prevalence of osteoarthritis at 11 years after surgery.

The American Journal of Sports Medicine, Vol. 39, No. 10
DOI: 10.1177/0363546511411702

Quality of Life and Clinical Outcome Comparison of Semitendinosus and Gracilis Tendon Versus Patellar Tendon Autografts for Anterior Cruciate Ligament Reconstruction

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The American Journal of Sports Medicine, Vol. 39, No. 10
DOI: 10.1177/0363546511411702

Reconstruction of the Anterior Cruciate Ligament: Meta-analysis of Patellar Tendon Versus Hamstring Tendon Autograft

John P. Goldblatt, M.D., Sean E. Fitzsimmons, M.D., Ethan Balk, M.D., M.P.H., and John C. Richmond, M.D.

Conclusions: The data presented in this meta-analysis show that the incidence of instability is not significantly different between the BPTB and HT grafts. However, BPTB was more likely to result in reconstructions with normal Lachman, normal pivot-shift, KT-1000 manual-maximum side-to-side difference <3 mm, and fewer results with significant flexion loss. In contrast, HT grafts had a reduced incidence of patellofemoral crepitance, kneeling pain, and extension loss. The choice of graft by the patient and surgeon must be individualized, and the results of this meta-analysis can aid in the decision by clarifying the risks and benefits of each surgical approach. **Level of Evidence:** Level I. **Key Words:**

Arthroscopy: The Journal of Arthroscopic and Related Surgery, Vol 21, No 7 (July), 2005: pp 791-803

Autograft Versus Allograft Anterior Cruciate Ligament Reconstruction

A Prospective, Randomized Clinical Study With a Minimum 10-Year Follow-up

The American Journal of Sports Medicine, Vol. XX, No. X
DOI: 10.1177/0363546515596406

Craig R. Bottoni,*† MD, Eric L. Smith,‡ MD, CPT James Shaha,† MD, Steven S. Shaha,§ PhD, Sarah G. Raybin,† BA, John M. Tokish,† MD, and CDR(Ret) Douglas J. Rowles,† MD

Conclusion: At a minimum of 10 years after ACL reconstruction in a young athletic population, over 80% of all grafts were intact and had maintained stability. However, those patients who had an allograft failed at a rate over 3 times higher than those with an autograft.

A systematic review of randomized controlled clinical trials comparing hamstring autografts versus bone-patellar tendon-bone autografts for the reconstruction of the anterior cruciate ligament

Shuzhen Li · Yueping Chen · Zonghan Lin · Wei Cui · Jingmin Zhao · Wei Su

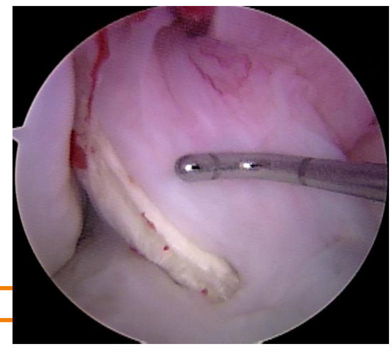
Results Nine RCTs (738 patients) met the inclusion criteria. The combined results of the meta-analysis indicated there was a significantly lower rate of negative Pivot test [relative risk (RR) 0.87, 95 % confidence intervals (CI) 0.79–0.96, $P = 0.004$], anterior knee pain (RR 0.66, 95 % CI 0.45–0.96, $P = 0.03$) and of kneeling pain (RR 0.49, 95 % CI 0.27–0.91, $P = 0.02$) in the HT group than in the BPTB group.

Conclusions ACL reconstruction with HT autografts or BPTB autografts achieved similar postoperative effects in terms of restoring knee joint function. HT autografts were inferior to BPTB autografts for restoring knee joint stability, but were associated with fewer postoperative complications.

Arch Orthop Trauma Surg (2012) 132:1287–1297
DOI 10.1007/s00402-012-1532-5

ARTHROSCOPY AND SPORTS MEDICINE

- The healing process
  - It’s a dead piece of tissue!
  - Graft needs to be re-vascularized
    - “Ligamentization” occurs
  - Vascular synovial layer wraps around graft in 4-6 weeks
- Autologous ACL grafts don’t transition through necrotic stage
- Weakest link fixation 4-6 weeks
- Soft tissue graft to bone: 12 weeks
- Bone autograft to bone: 8 weeks
- Complete re-vascularization of the graft takes ~20 weeks
- Remodeling occurs:
  - By one year histological and biochemical properties of ACLR ≈ native ACL



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Healing Rate of Tissues

- Times affected by age, comorbities, etc

Table 4. Healing Rates of Tissues.*

	0–3 days	4–14 days	3–4 weeks	5–7 weeks	2–3 months	3–6 months	6 months –1 year	Up to 2 years
Tendon								
• Tendinitis			←	→				
• Lacerations				←	—	→		
Muscle								
• Exercise-induced	↔							
• Grade I	←	→						
• Grade II		←	—	—	→			
• Grade III			←	—	—	→		
Ligament								
• Grade I	↔							
• Grade II			←	—	—	→		
• Grade III				←	—	—	→	
Ligament Graft[162]					←	—	—	→
Bone				←	→			
Articular Cartilage Repair[224]					←	—	—	→

*Reprinted with permission from Axe MJ, Snyder-Mackler L.[143] Copyright 2005, Orthopaedic Section, APTA Inc.

Prevention

SPORTSMETRICS™ USA

The Santa Monica Sports Medicine Research Foundation

The PEP Program: Prevent injury and Enhance Performance

Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing the Incidence of Anterior Cruciate Ligament Injuries in Female Athletes

2-Year Follow-up

The American Journal of Sports Medicine, Vol. 33, No. 7

The Santa Monica Orthopaedic and Sports Medicine Research Foundation

The PEP Program: Prevent injury and Enhance Performance

http://www.aclprevent.com/index.htm

Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing the Incidence of Anterior Cruciate Ligament Injuries in Female Athletes

2-Year Follow-up

Methods: In 2000, 1041 female subjects from 52 teams received a sports-specific training intervention in a prospective non-randomized trial. The control group consisted of the remaining 1905 female soccer players from 95 teams participating in the same league who were age and skill matched. In the 2001 season, 844 female athletes from 45 teams were enrolled in the study, with 1913 female athletes (from 112 teams) serving as the age- and skill-matched control. All subjects were female soccer players between the ages of 14 and 18 and participated in either their traditional warm-up or a sports-specific training intervention before athletic activity over a 2-year period. The intervention consisted of education, stretching, strengthening, plyometrics, and sports-specific agility drills designed to replace the traditional warm-up.

Results: During the 2000 season, there was an 88% decrease in anterior cruciate ligament injury in the enrolled subjects compared to the control group. In year 2 , during the 2001 season, there was a 74% reduction in anterior cruciate ligament tears in the intervention group compared to the age- and skill-matched controls.

Preventing ACL Injuries in Team-Sport Athletes: A Systematic Review of Training Interventions

MARKO D. STOJANOVIC and SERGEJ M. OSTOJIC
Center for Health, Exercise and Sport Sciences, Belgrade, Serbia

ing interventions have a preventive effect on ACLI. Collectively, the studies indicate there is moderate evidence to support the use of multifaceted training interventions, which consisted of stretching, proprioception, strength, plyometric and agility drills with additional verbal and/or visual feedback on proper landing technique to decrease the rate of ACLIs in team sport female athletes, while the paucity of data preclude any conclusions for male athletes.

Research in Sports Medicine, 20:223–238, 2012

ISSN: 1543-8627 print/1543-8635 online
DOI: 10.1080/15438627.2012.680988

Interventions Designed to Prevent Anterior Cruciate Ligament Injuries in Adolescents and Adults

The American Journal of Sports Medicine, Vol. 41, No. 8
DOI: 10.1177/0363546512458227

A Systematic Review and Meta-analysis

Joel J. Gagnier,*†‡ ND, MSc, PhD, Hal Morgenstern,‡ PhD, and Laura Chess,§ MPH
Investigation performed at the University of Michigan, Ann Arbor, Michigan

Results: Eight cohort (observational) studies and 6 randomized trials were included, involving a total of approximately 27,000 participants. The random-effects meta-analysis yielded a pooled rate-ratio estimate of 0.485 (95% confidence interval [CI], 0.299-0.788; $P = .003$), indicating a lower ACL rate in the intervention groups, but there was appreciable heterogeneity of the estimated effect across studies ($I^2 = 64\%$; $P = .001$). In the meta-regressions, the estimated effect was stronger for studies that were not randomized, performed in the United States, conducted in soccer players, had a longer duration of follow-up (more than 1 season), and had more hours of training per week in the intervention group, better compliance, and no dropouts. Nevertheless, residual heterogeneity was still observed within subgroups of those variables ($I^2 > 50\%$; $P < .10$).

Conclusion: The authors found that various types of neuromuscular and educational interventions appear to reduce the incidence rate of ACL injuries by approximately 50%, but the estimated effect varied appreciably among studies and was not able to explain most of that variability.

Clinical Relevance: Neuromuscular and educational interventions appear to reduce the incidence rate of ACL injuries by approximately 50%.

Prevention and Screening Programs for Anterior Cruciate Ligament Injuries in Young Athletes

A Cost-Effectiveness Analysis

Eric Swart, MD, Lauren Redler, MD, Peter D. Fabricant, MD, MPH, Bert R. Mandelbaum, MD, Christopher S. Ahmad, MD, and Y. Claire Wang, MD, ScD

J Bone Joint Surg Am. 2014;96:705-11

Results: Universal neuromuscular training of all athletes was the dominant strategy, with better outcomes and lower costs compared with screening. On average, the implementation of a universal training program would save $100 per player per season, and would reduce the incidence of ACL injury from 3% to 1.1% per season. Screening was not cost-effective within the range of reported sensitivity and specificity values.

Degenerative Changes in the Knee 2 Years After Anterior Cruciate Ligament Rupture and Related Risk Factors

A Prospective Observational Follow-up Study

Belle L. van Meer,[*†‡] MD, PhD, Edwin H.G. Oei,[§] MD, PhD,
Duncan E. Meuffels,[†] MD, PhD, Ewoud R.A. van Arkel,[||] MD, PhD,
Jan A.N. Verhaar,[†] MD, PhD, Sita M.A. Bierma-Zeinstra,[†¶] PhD, and Max Reijman,[†] PhD

Results: The median time between MRI at baseline and MRI at 2-year follow-up was 25.9 months (interquartile range, 24.7-26.9 months). Progression of cartilage defects in the medial and lateral tibiofemoral compartments was present in 12% and 27% of patients, and progression of osteophytes in tibiofemoral and patellofemoral compartments was present in 10% and 8% of patients, respectively. The following determinants were positively significantly associated with early degenerative changes: male sex (odds ratio [OR], 4.43; 95% CI, 1.43-13.66; $P = .010$), cartilage defect in the medial tibiofemoral compartment at baseline (OR, 3.66; 95% CI, 1.04-12.95; $P = .044$), presence of bone marrow lesions in the medial tibiofemoral compartment 1 year after trauma (OR, 5.19; 95% CI, 1.56-17.25; $P = .007$), joint effusion 1 year after trauma (OR, 4.19; 95% CI, 1.05-16.72; $P = .042$), and presence of meniscal tears (OR, 6.37; 95% CI, 1.94-20.88; $P = .002$). When the patients were categorized into 3 treatment groups (nonoperative, reconstruction <6 months after ACL rupture, and reconstruction ≥6 months after ACL rupture), there was no significant relationship between the treatment options and the development of early degenerative changes.

Conclusion: Two years after ACL rupture, early degenerative changes were assessed on MRI. Concomitant medial cartilage defect and meniscal injury, male sex, persistent bone marrow lesions in the medial tibiofemoral compartment, and joint effusion are risk factors for degenerative changes.

The American Journal of Sports Medicine, Vol. XX, No. X
DOI: 10.1177/0363546516631936

Increased Risk of Osteoarthritis After Anterior Cruciate Ligament Reconstruction

A 14-Year Follow-up Study of a Randomized Controlled Trial

- Investigated 14 years after ACL Repair
- Control was contralateral healthy knee
- Risk factors investigated for OA:
  - Weight
  - Other injuries
  - Sex
  - Age
  - Time between injury and repair
  - Graft type
- Graft type and time between injury and repair were not factors
- Meniscal resection was a significant risk factor
- ***3 fold increase in OA in surgical knee vs control***
  - Mostly medial compartment

Am J Sports Med published online March 18, 2014
DOI: 10.1177/0363546514526139

Björn Barenius,[*†] MD, PhD, Sari Ponzer,[†] MD, PhD, Adel Shalabi,[‡] MD, PhD,
Robert Bujak,[§] MD, PhD, Louise Norlén,[||] MD, and Karl Eriksson,[†] MD, PhD

Which determinants predict tibiofemoral and patellofemoral osteoarthritis after anterior cruciate ligament injury? A systematic review

Belle L van Meer,[1] Duncan E Meuffels,[1] Wilbert A van Eijsden,[1] Jan A N Verhaar,[1] Sita M A Bierma-Zeinstra,[1,2] Max Reijman[1]
van Meer BL, et al. Br J Sports Med 2015;0:1–11. doi:10.1136/bjsports-2013-093258

Conclusions Medial meniscal injury/meniscectomy after ACL rupture increased the risk of OA development. In contrast, it seems that lateral meniscal injury/meniscectomy has no relationship with OA development. Our results suggest that time between injury and reconstruction does not influence patellofemoral and tibiofemoral OA development. Many determinants showed conflicting and limited evidence and no determinant showed strong evidence.

Is Anterior Cruciate Ligament Reconstruction Effective in Preventing Secondary Meniscal Tears and Osteoarthritis?

Thomas L. Sanders,*† MD, Hilal Maradit Kremers,†‡ MD, MSc, Andrew J. Bryan,† MD, Kristin M. Fruth,‡ BS, Dirk R. Larson,‡ MS, Ayoosh Pareek,† BS, Bruce A. Levy,† MD, Michael J. Stuart,† MD, Diane L. Dahm,† MD, and Aaron J. Krych,† MD
The American Journal of Sports Medicine, Vol. 44, No. 7
DOI: 10.1177/0363546516634325

Conclusion: Patients treated with ACLR have a significantly lower risk of secondary meniscal tears, symptomatic arthritis, and TKA when compared with patients treated nonoperatively after ACL tears. Similarly, early ACLR significantly reduces the risk of subsequent meniscal tears and arthritis compared with delayed ACLR.

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INTERVENTIONS – NEUROMUSCULAR ELECTRICAL STIMULATION

A Neuromuscular electrical stimulation should be used for 6 to 8 weeks to augment muscle strengthening exercises in patients after ACL reconstruction to increase quadriceps muscle strength and enhance short-term functional outcomes.

INTERVENTIONS – NEUROMUSCULAR RE-EDUCATION

A Neuromuscular re-education training should be incorporated with muscle strengthening exercises in patients with knee stability and movement coordination impairments.

INTERVENTIONS – THERAPEUTIC EXERCISES

A Weight-bearing and non–weight-bearing concentric and eccentric exercises should be implemented within 4 to 6 weeks, 2 to 3 times per week for 6 to 10 months, to increase thigh muscle strength and functional performance after ACL reconstruction.

KYUNG-MIN KIM, MS, ATC[1] • TED CROY, PT, OCS[2] • JAY HERTEL, PhD, ATC[3] • SUSAN SALIBA, PT, PhD, ATC[3]

J Orthop Sports Phys Ther 2010;40(7):383-391.

Effects of Neuromuscular Electrical Stimulation After Anterior Cruciate Ligament Reconstruction on Quadriceps Strength, Function, and Patient-Oriented Outcomes: A Systematic Review

• CONCLUSION: NMES combined with exercise may be more effective in improving quadriceps strength than exercise alone, whereas its effect on functional performance and patient-oriented outcomes is inconclusive. Inconsistencies were noted in the NMES parameters and application of NMES.

Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus

Nicky van Melick,[1,2] Robert E H van Cingel,[3,4] Frans Brooijmans,[5] Camille Neeter,[6] Tony van Tienen,[7] Wim Hullegie,[8] Maria W G Nijhuis-van der Sanden[1]

Br J Sports Med 2016;**0**:1–13. doi:10.1136/bjsports-2015-095898

Summary Ninety studies were included as the basis for the evidence statement. Rehabilitation after ACL injury should include a prehabilitation phase and 3 criterion-based postoperative phases: (1) impairment-based, (2) sport-specific training and (3) return to play. A battery of strength and hop tests, quality of movement and psychological tests should be used to guide progression from one rehabilitation stage to the next. Postoperative rehabilitation should continue for 9–12 months. To assess readiness to return to play and the risk for reinjury, a test battery, including strength tests, hop tests and measurement of movement quality, should be used.

Rehabilitation Principles of the Anterior Cruciate Ligament Reconstructed Knee

Twelve Steps for Successful Progression and Return to Play

Kevin E. Wilk, PT, DPT[a,b,*], Christopher A. Arrigo, MS, PT, ATC[c]

Clin Sports Med 36 (2017) 189–232
http://dx.doi.org/10.1016/j.csm.2016.08.012
0278-5919/17/

Box 1
Twelve steps critical to successful anterior cruciate ligament rehabilitation

1. Preparation of both the patient and their knee for surgery
2. Restore full passive knee extension
3. Reduce postoperative inflammation
4. Gradual restoration of full knee flexion
5. Restore complete patellar mobility
6. Individualize and adjust the rehabilitation program based on the status of the knee
7. Reestablish quadriceps activation
8. Restoration of dynamic functional stability of the knee complex
9. Knee stability and dynamic control must be provided from both above and below
10. Protect the knee both now and later
11. Objective return to running
12. Objective progressing beyond running and back to sport

Box 2
Rehabilitation phases, program goals and criteria for progression after anterior cruciate ligament reconstruction

1. Preparative phase
   a. Goals: Diminish inflammation, swelling and pain
      i. Restore normal ROM (especially knee extension)
      ii. Restore voluntary muscle activation
      iii. Provide patient education to prepare for surgery

2. Immediate postoperative phase (days 1–7)
   a. Goals: Restore full passive knee extension
      i. Diminish joint swelling and pain
      ii. Restore patellar mobility
      iii. Gradually improve knee flexion
      iv. Reestablish quadriceps control
      v. Restore independent ambulation
   b. Criteria to progress to early rehabilitation phase
      i. Quadriceps control (ability to perform good quadriceps set and straight leg raises)
      ii. Full passive knee extension
      iii. PROM: 0° to 90°
      iv. Good patellar mobility
      v. Minimal joint effusion
      vi. Independent ambulation

3. Early rehabilitation phase (weeks 2–4)
   a. Goals: maintain full passive knee extension (≥0 to 5–7 hyperextension)
      i. Gradually increase knee flexion
      ii. Diminish remaining swelling and pain
      iii. Improve muscle control and activation
      iv. Restore proprioception/neuromuscular control
      v. Normalize patellar mobility
   b. Criteria to progress to strengthening/neuromuscular control phase
      i. Active ROM 0≥ to 115°
      ii. Quadriceps strength 60% greater than the contralateral side (isometric test at 60° o knee flexion)
      iii. Unchanged KT test bilateral values (≤1)
      iv. Minimal to no knee joint effusion
      v. No joint line or patellofemoral pain

4. Progressive strengthening/neuromuscular control phase (Weeks 4–10)
   a. Goals: restore full knee ROM (0°–125°)
      i. Improve lower extremity strength
      ii. Enhance proprioception, balance and neuromuscular control
      iii. Improve muscular endurance
      iv. Restore limb confidence and function
   b. Criteria to progress to advanced activity phase
      i. AROM 0° to 125° or greater
      ii. Quadriceps strength 75% of contralateral side
      iii. Knee extension flexor: extensor ratio 70% to 75%
      iv. No change in KT values (comparable with contralateral side, within 2 mm)
      v. No pain or effusion
      vi. Satisfactory clinical examination
      vii. Satisfactory isokinetic test (values at 180°/s)
         1. Quadriceps bilateral comparison 75%
         2. Hamstring strength equal bilaterally
         3. Quadriceps peak torque/body weight ratios
            a. 65% males
            b. 55% females
         4. Single leg hop test 80% of contralateral leg
         5. Subjective knee scoring (modified Noyes system) 80 points or better

5. Advanced activity phase (weeks 10–16)
   a. Goals: normalize lower extremity strength
   b. Enhance muscular poser and endurance
   c. Improve neuromuscular control
   d. Perform selected sport-specific drills
   e. Criteria to enter return to activity phase
      i. Full ROM
      ii. Unchanged KT test (within 2.5 mm of opposite side)
      iii. Isokinetic test that fulfills criteria
         1. Quadriceps bilateral comparison 80% or greater
         2. Hamstring bilateral comparison 110% or greater
         3. Quadriceps torque/body weight ratio 55% or greater
         4. Hamstring/quadriceps ratio 70% or greater
      iv. Proprioceptive test 100% of contralateral leg
      v. Functional test 85% or greater of contralateral side
      vi. Satisfactory clinical examination
      vii. Subjective knee scoring (modified Noyes system) 90 points or better

6. Return to activity phase (Weeks 16–22)
   a. Goals: gradual return to full unrestricted sports
   b. Achieve maximal strength and endurance
   c. Normalize neuromuscular control
      i. Progress skill training

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LONNIE PAULOS, MD[4] • JAMES R. ANDREWS, MD[5]

Anterior Cruciate Ligament Strain and Tensile Forces for Weight-Bearing and Non–Weight-Bearing Exercises: A Guide to Exercise Selection

- Seated Knee Extension
  - Peak strain 3.2%-4.4% occurring at 10-30deg of knee flexion
  - Increases ~1% with 10lb weight
  - Increases 2x if weight placed at ankle vs prox tibia
- Seated Knee Flexion
  - No strain
- Single or Double Knee Squats
  - Minimal or no strain
  - No change with weight
  - If squat on toes is over 3x more loading through ACL
  - With trunk flexion of 30-40deg decreased load on ACL vs upright posture

| MARCH 2012 | VOLUME 42 | NUMBER 3 | JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY

- Forward/Side Lunges
  - ACL loading is minimal
- Leg Press
  - Minimal to no loading
  - No change with increased weight or different foot positions (high or low/wide or narrow)
- Bicycling
  - Peak strain 1.2%-2.1%
    - Lachman produced 3-3.5% strain
- Plyometric
  - 250N force with double leg jump from 60cm platform
    - Similar to load from seated knee extension

- For both NWB and WB greater loading occurs at lower knee flexion angles (10-30deg)
  - Decreases from 30-60deg of knee flexion
  - None at above 60deg of knee flexion
- NWB exercises produce significantly more load on ACL than WB in same range of motion
- Use a forward trunk lean of 30-40deg with all WB therex
  - Increases HS recruitment to unload ACL
- Anterior knee translation beyond toes (>8cm) increases ACL load

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JEFFREY R. DUGAS, MD[4] • JAMES R. ANDREWS, MD[5]

Recent Advances in the Rehabilitation of Anterior Cruciate Ligament Injuries

JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY | VOLUME 42 | NUMBER 3 | MARCH 2012 | 153

Goals:

Full knee extension immediately
- Hyperextension returned equal to other side by week 2

Restore Patellar Mobility
Reduce post op inflammation
Range of Motion
- 0-90deg 5-7days post op
- 0-100deg 7-10 days post op

Reestablish voluntary quad control
- NMES

Restore Neuromuscular control
- Proprioceptive training by week 2

By Graft Type:

Less aggressive with soft tissue grafts
- Return to running,plyo and sports is slower

Slower to aggressive activities for allograft vs autograft
- Increased healing time due to longer for fixation of soft tissue as it heals in bone tunnel

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MICHAEL J. AXE, MD[4] • LYNN SNYDER-MACKLER, PT, ATC, ScD, SCS, FAPTA[5]

Current Concepts for Anterior Cruciate Ligament Reconstruction: A Criterion-Based Rehabilitation Progression

JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY | VOLUME 42 | NUMBER 7 | JULY 2012 | 601

- With this protocol
  - 75% of patients had knee function w/i normal ranges at 6mo
    - 87% by 1 year
  - 40% of preoperative "non copers" passed return to sport by 6mo
    - 73% by 12mo
  - 90% or above on self report outcome questionnaires
    - 70% at 3mo
    - 92.5% at 6mo
  - Quad strength ~90% by 6mo post op
    - Typically 80% at 6 mo

- Running Progression
  - Starts at 8 weeks if
    - Quad strength 80% of uninvolved side
    - Trace effusion
    - Understanding of soreness rules
    - Full AROM
    - Normal gait

TABLE 4 RUNNING PROGRESSION*

Level	Treadmill	Track
Level 1	0.1-mi walk/0.1-mi jog, repeat 10 times	Jog straights/walk curves (2 mi)
Level 2	Alternate 0.1-mi walk/0.2-mi jog (2 mi)	Jog straights/jog 1 curve every other lap (2 mi)
Level 3	Alternate 0.1-mi walk/0.3-mi jog (2 mi)	Jog straights/jog 1 curve every lap (2 mi)
Level 4	Alternate 0.1-mi walk/0.4-mi jog (2 mi)	Jog 1.75 laps/walk curve (2 mi)
Level 5	Jog full 2 mi	Jog all laps (2 mi)
Level 6	Increase workout to 2.5 mi	Increase workout to 2.5 mi
Level 7	Increase workout to 3 mi	Increase workout to 3 mi
Level 8	Alternate between running/jogging every 0.25 mi	Increase speed on straights/jog curves

**Progress to next level when patient is able to perform activity for 2 mi without increased effusion or pain. Perform no more than 4 times in 1 week and no more frequently than every other day. Do not progress more than 2 levels in a 7-day period. Conversion: 1 mi = 1.6 km. Reprinted with permission from Tara Manal, University of Delaware Physical Therapy Clinic.*

TABLE 2 — Effusion Grading Scale of the Knee Joint Based on the Stroke Test

Grade	Test Result
Zero	No wave produced on downstroke
Trace	Small wave on medial side with downstroke
1+	Larger bulge on medial side with downstroke
2+	Effusion spontaneously returns to medial side after upstroke (no downstroke necessary)
3+	So much fluid that it is not possible to move the effusion out of the medial aspect of the knee

Reproduced from Sturgill et al.[95]

TABLE 3 — Soreness Rules*

Criterion	Action
Soreness during warm-up that continues	2 days off, drop down 1 level
Soreness during warm-up that goes away	Stay at level that led to soreness
Soreness during warm-up that goes away but redevelops during session	2 days off, drop down 1 level
Soreness the day after lifting (not muscle soreness)	1 day off, do not advance program to the next level
No soreness	Advance 1 level per week or as instructed by healthcare professional

**Reprinted with permission from SAGE Publications: Fees M, Decker T, Snyder-Mackler L, Axe MJ. Upper extremity weight-training modifications for the injured athlete. A clinical perspective. Am J Sports Med. 1998;26(5):735. Copyright ©1998 SAGE Publications.*

- More specific goals for each phase of rehab and specific return to sport guidelines
- Addition of guidelines for concomitant injuries
  - Ligamentous, meniscal or chondral

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RETURN TO SPORT

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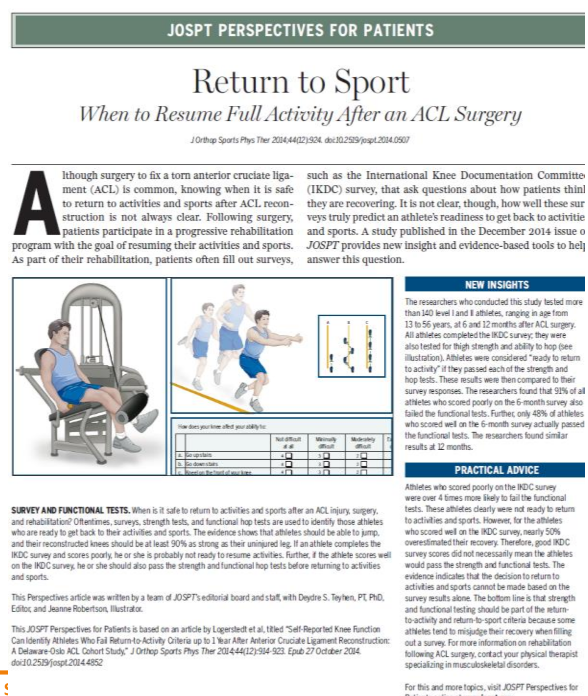
- JOSPT Patient Perspective
  - December 2014



JOSPT PERSPECTIVES FOR PATIENTS

Return to Sport

When to Resume Full Activity After an ACL Surgery

J Orthop Sports Phys Ther 2014;44(12):924. doi:10.2519/jospt.2014.0507

Although surgery to fix a torn anterior cruciate ligament (ACL) is common, knowing when it is safe to return to activities and sports after ACL reconstruction is not always clear. Following surgery, patients participate in a progressive rehabilitation program with the goal of resuming their activities and sports. As part of their rehabilitation, patients often fill out surveys, such as the International Knee Documentation Committe (IKDC) survey, that ask questions about how patients thinl they are recovering. It is not clear, though, how well these sur veys truly predict an athlete's readiness to get back to activitie and sports. A study published in the December 2014 issue o *JOSPT* provides new insight and evidence-based tools to hel answer this question.

SURVEY AND FUNCTIONAL TESTS. When is it safe to return to activities and sports after an ACL injury, surgery, and rehabilitation? Oftentimes, surveys, strength tests, and functional hop tests are used to identify those athletes who are ready to get back to their activities and sports. The evidence shows that athletes should be able to jump, and their reconstructed knees should be at least 90% as strong as their uninjured leg. If an athlete completes the IKDC survey and scores poorly, he or she is probably not ready to resume activities. Further, if the athlete scores well on the IKDC survey, he or she should also pass the strength and functional hop tests before returning to activities and sports.

This Perspectives article was written by a team of *JOSPT*'s editorial board and staff, with Deydre S. Teyhen, PT, PhD, Editor, and Jeanne Robertson, Illustrator.

This JOSPT Perspectives for Patients is based on an article by Logerstedt et al, titled "Self-Reported Knee Function Can Identify Athletes Who Fail Return-to-Activity Criteria up to 1 Year After Anterior Cruciate Ligament Reconstruction: A Delaware-Oslo ACL Cohort Study," *J Orthop Sports Phys Ther 2014;44(12):914-923. Epub 27 October 2014. doi:10.2519/jospt.2014.4852*

NEW INSIGHTS

The researchers who conducted this study tested more than 140 level I and II athletes, ranging in age from 13 to 56 years, at 6 and 12 months after ACL surgery. All athletes completed the IKDC survey; they were also tested for thigh strength and ability to hop (see illustration). Athletes were considered "ready to return to activity" if they passed each of the strength and hop tests. These results were then compared to their survey responses. The researchers found that 91% of all athletes who scored poorly on the 6-month survey also failed the functional tests. Further, only 48% of athletes who scored well on the 6-month survey actually passed the functional tests. The researchers found similar results at 12 months.

PRACTICAL ADVICE

Athletes who scored poorly on the IKDC survey were over 4 times more likely to fail the functional tests. These athletes clearly were not ready to return to activities and sports. However, for the athletes who scored well on the IKDC survey, nearly 50% overestimated their recovery. Therefore, good IKDC survey scores did not necessarily mean the athletes would pass the strength and functional tests. The evidence indicates that the decision to return to activities and sports cannot be made based on the survey results alone. The bottom line is that strength and functional testing should be part of the return-to-activity and return-to-sport criteria because some athletes tend to misjudge their recovery when filling out a survey. For more information on rehabilitation following ACL surgery, contact your physical therapist specializing in musculoskeletal disorders.

For this and more topics, visit JOSPT Perspectives for Patients online at **www.jospt.org**.

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Factors Used to Determine Return to Unrestricted Sports Activities After Anterior Cruciate Ligament Reconstruction

Sue D. Barber-Westin, B.S., and Frank R. Noyes, M.D.

months' follow-up. **Results:** Of 716 studies identified, 264 met the inclusion criteria. Of these, 105 (40%) failed to provide any criteria for return to sports after ACL reconstruction. In 84 studies (32%) the amount of time postoperatively was the only criterion provided. In 40 studies (15%) the amount of time along with subjective criteria were given. Only 35 studies (13%) noted objective criteria required for return to athletics. These criteria included muscle strength or thigh circumference (28 studies), general knee examination (15 studies), single-leg hop tests (10 studies), Lachman rating (1 study), and validated questionnaires (1 study). **Conclusions:** The results of this systematic review show noteworthy problems and a lack of objective assessment before release to unrestricted sports activities. General recommendations are made for quantification of muscle strength, stability, neuromuscular control, and function in patients who desire to return to athletics after ACL reconstruction, with acknowledgment of the need for continued research in this area. **Level of Evidence:** Level IV, systematic review of Level I to IV studies.

Arthroscopy: The Journal of Arthroscopic and Related Surgery, Vol 27, No 12 (December), 2011: pp 1697-1705

Factors Used to Determine Return to Unrestricted Sports Activities After Anterior Cruciate Ligament Reconstruction

Sue D. Barber-Westin, B.S., and Frank R. Noyes, M.D.

- Recommendations:
  - Less than 10% deficit in strength of QS vs HS on isokinetic at 180 and 300deg/sec
  - Less than 15% deficit in symmetry on single leg hop testing
    - Single hop, triple hop, crossover hop, timed hop
  - Less than 3mm increased A-P tibial displacement on Lachman or arthrometer testing
  - Greater than 60% knee separation distance on video drop-jump test
  - No effusion
  - Normal ROM/patellar mobility
  - No or slight patellar crepitus
  - No pain or swelling with all activities

TABLE 5 — **Return-to-Sport Criteria***

- Minimum 12 wk postoperative
- 90% or greater on quadriceps index
- 90% or greater on all hop tests
- 90% or greater on KOS-ADL
- 90% or greater on global rating score of knee function

Abbreviation: KOS-ADL, Knee Outcome Survey-activities of daily living.
**All criteria must be met prior to beginning a return-to-sport progression.*

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MICHAEL J. AXE, MD[4] • LYNN SNYDER-MACKLER, PT, ATC, ScD, SCS, FAPTA[5]

Current Concepts for Anterior Cruciate Ligament Reconstruction: A Criterion-Based Rehabilitation Progression

JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY | VOLUME 42 | NUMBER 7 | JULY 2012 | 601

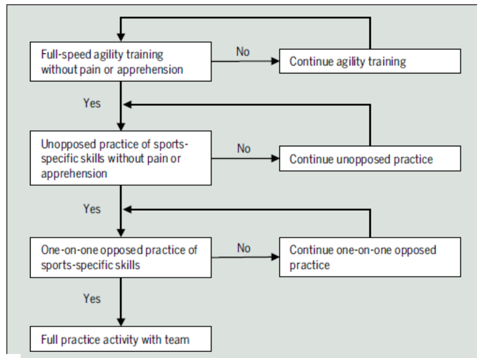

FIGURE 6. Progression to sports-related activities (adapted from Fitzgerald et al[25]).

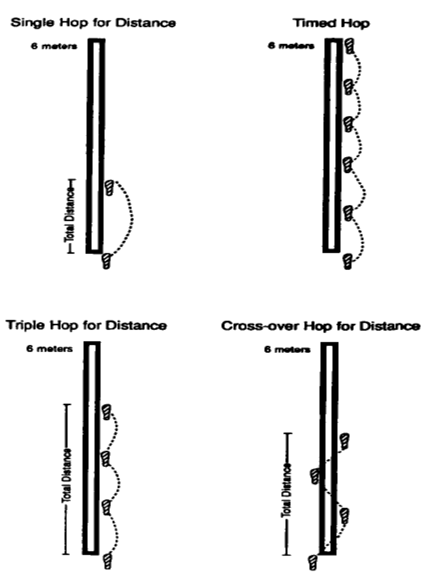

Figure 1. The courses for the four function tests.

Testing
- Patient performs 2 practice trials on each leg for each hop sequence
- Patient performs 2 timed or measured trials on each leg for each hop sequence
- Measured trials are averaged and compared (involved to uninvolved) for single, triple, and crossover hop
- Measured trials are averaged and compared (uninvolved to involved) for timed hop

Passing criteria for return to sport
- Greater than or equal to 90% on quadriceps MVIC, hop testing, KOS-ADL score, and global rating of knee function score

Suggestions From the Field for Return to Sports Participation Following Anterior Cruciate Ligament Reconstruction: American Football

Mark Verstegen, Susan Falsone, Russell Orr, Steve Smith

J Orthop Sports Phys Ther 2012;42(4):337-344. doi:10.2519/jospt.2012.4031

[Abstract] [Full Text] [Videos]

Suggestions From the Field for Return to Sports Participation Following Anterior Cruciate Ligament Reconstruction: Basketball

Eric Waters

J Orthop Sports Phys Ther 2012;42(4):326-336. doi:10.2519/jospt.2012.4030

[Abstract] [Full Text] [Videos]

Suggestions From the Field for Return-to-Sport Rehabilitation Following Anterior Cruciate Ligament Reconstruction: Alpine Skiing

Dirk Kokmeyer, Michael Wahoff, Matt Mymern

J Orthop Sports Phys Ther 2012;42(4):313-325. doi:10.2519/jospt.2012.4024

[Abstract] [Full Text] [Videos] [Slides]

Suggestions From the Field for Return to Sports Participation Following Anterior Cruciate Ligament Reconstruction: Soccer

Mario Bizzini, Dave Hancock, Franco Impellizzeri

J Orthop Sports Phys Ther 2012;42(4):304-312. doi:10.2519/jospt.2012.4005

[Abstract] [Full Text] [Videos] [Slides]

The Challenge of Return to Sports for Patients Post–ACL Reconstruction

Guy G. Simoneau, Kevin E. Wilk

J Orthop Sports Phys Ther 2012;42(4):300-301. doi:10.2519/jospt.2012.0106

Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture

Polyvios Kyritsis,[1] Roald Bahr,[1,2] Philippe Landreau,[1] Riadh Miladi,[1] Erik Witvrouw[1,3]

Br J Sports Med 2016;**50**:946–951. doi:10.1136/bjsports-2015-095908

Conclusions Athletes who did not meet the discharge criteria before returning to professional sport had a four times greater risk of sustaining an ACL graft rupture compared with those who met all six RTS criteria. In addition, hamstring to quadriceps strength ratio deficits were associated with an increased risk of an ACL graft rupture.

Neuromuscular Training to Target Deficits Associated With Second Anterior Cruciate Ligament Injury

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JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY | VOLUME 43 | NUMBER 11 | NOVEMBER 2013

TABLE 1 Proposed Methods to Assess Neuromuscular Impairments After ACLR

Assessment Method	Impairments Assessed	Clinically Important Cutoff Criteria	Evidence for Clinical Applicability
Thigh muscle dynamometry	Quadriceps and hamstrings side-to-side symmetry; hamstrings-quadriceps ratio	90% or greater[1,134]	1. Athletes who underwent ACLR and had at least 90% quadriceps strength index (side-to-side symmetry) demonstrated functional performance similar to uninjured control subjects[134] 2. Female athletes who went on to sustain a primary ACL rupture had decreased hamstrings-quadriceps ratios compared to male controls[96]
Single-leg hop tests	Dynamic, sports-related knee function side-to-side symmetry	90% or greater[1,147]	1. Limb-symmetry indexes on single-leg hop for distance, triple hop for distance, and crossover hop for distance differed between controls and athletes who had ACLR[108] 2. Symmetry on the triple hop for distance was the most strongly correlated to self-reported function of the 4 hop tests[128]
Tuck jump	Trunk and lower extremity asymmetry and quality of mechanics	Perfect score of 80 points (no asymmetries or abnormalities)[107]	1. Feedback provided on tuck jump technique reduces knee abduction motion during the drop-vertical jump[109]
Drop-vertical jump	Sagittal and frontal plane knee mechanics	Greater than 60% normalized knee separation distance[7]	1. Sagittal and frontal plane knee motion during a drop-vertical jump is part of a clinical algorithm that accurately predicts high external knee abduction loads[101]
Patient-reported outcomes	Patient perception of function, symptoms, sport-related disability	90% or greater[1]	1. IKDC scores were lower in athletes who underwent ACLR compared to controls, and lowest in the athletes with strength asymmetries greater than 15%[134] 2. Use of self-reported outcomes is advised as part of a battery of tests to determine functional status following acute ACL injury[36,44] and readiness to return to sport following ACLR[1]

Abbreviations: ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; IKDC, International Knee Documentation Committee Subjective Knee Evaluation Form.

TABLE 2 Evidence for Selected Exercises

Exercise/Task	Key Muscles Targeted	Key Motions/ Elements Targeted	Direct Evidence for Targeted Effect	Indirect Evidence for Targeted Effect
Single-leg anterior progression	Gluteals; quadriceps and hamstrings	Sagittal plane trunk and LE joint motion; plyometric	1. Single-leg squat activated gluteus medius and maximus similarly and elicited greatest gluteus maximus activation[40]	1. Athletes with ACL deficiency shifted moments away from knee during hopping and their center of mass was more anterior versus controls[117]
Single-leg lateral progression	Gluteals; trunk musculature; quadriceps and hamstrings	Frontal plane trunk and LE joint motion; unstable surface; plyometric	1. Single-leg squat activated gluteus medius and maximus similarly and elicited greatest gluteus maximus activation[40] 2. High hamstrings-quadriceps co-activation ratios occurred with lateral hopping[10]	1. Athletes with ACL deficiency shifted moments away from knee during hopping versus controls[117] 2. Healthy athletes with increased knee valgus demonstrated higher hip adductor, gastrocnemius, and tibialis anterior activation[122] 3. Unstable surface shifted joint moments proximally[14]
Lunge progression	Gluteals; quadriceps and hamstrings	3-D trunk and LE joint motion; plyometric	1. Forward lunge elicited high hamstrings-quadriceps coactivation ratios[10] 2. Lunge elicited greater than 75% vastus medialis muscle activity[40]	1. Quadriceps strength was significantly correlated with external sagittal plane knee moments[117] and dynamic knee function in athletes following ACLR[67,78,80]
Tuck jump progression	Gluteals; trunk musculature	Symmetry of LE movement; frontal plane trunk and LE joint motion; plyometric	1. Female athletes who received feedback on their tuck jump mechanics demonstrated a 38% (up to 6.9°) reduction in the peak frontal plane angle on the drop-vertical jump task[109]	None
Lateral jumping progression	Gluteals; quadriceps and hamstrings	3-D LE joint motion; plyometric	1. High hamstrings-quadriceps coactivation ratios occurred with lateral hopping[10]	1. Athletes with ACL deficiency shifted moments away from knee during hopping versus controls[117] 2. Increased lateral trunk motion increased external knee abduction moments[66]
Lateral trunk progression	Trunk musculature	Frontal and transverse plane trunk motion	1. External obliques demonstrated high levels of muscle activity in sidelying flexion exercises[73]	1. Increased early lateral trunk displacement with secured lower extremities predicted knee ligament injury[162] 2. Maximum lateral trunk displacement with secured lower extremities predicted ligament injury in females only[162]
Prone trunk stability	Gluteals; trunk musculature	Sagittal and transverse plane trunk motion	1. Prone bridge elicited high abdominal muscle activity[40] 2. Trunk extension combined with hip extension elicited trunk extensor activation up to 50%[73]	None

TABLE 2 EVIDENCE FOR SELECTED EXERCISES (CONTINUED)

Exercise/Task	Key Muscles Targeted	Key Motions/ Elements Targeted	Direct Evidence for Targeted Effect	Indirect Evidence for Targeted Effect
Kneeling trunk stability	Gluteals; trunk musculature	3-D trunk motion; unstable surface	None	1. Unstable surface shifted joint moments proximally[34] 2. Increased lateral trunk motion increased external knee abduction moments[66] 3. Increased early lateral trunk displacement with secured lower extremities predicted knee ligament injury[162] 4. Maximum lateral trunk displacement with secured lower extremities predicted ligament injury in females only[162]
Posterior chain progression	Gluteals; trunk musculature; hamstrings	Transverse plane trunk and hip motion	1. Single-leg bridge elicited high gluteus medius, hamstrings, longissimus thoracis, and multifidi activity[40]	None
Single-leg dead lift progression	Gluteals; trunk musculature; hamstrings	3-D trunk and LE joint motion; unstable surface	1. Single-leg dead lift activated gluteus medius and maximus similarly and elicited greatest gluteus maximus activation[40] 2. High hamstrings-quadriceps activation ratios with Romanian dead lift[10]	1. Unstable surface shifted joint moments proximally[129]
Lunge jump progression	Gluteals; trunk musculature; quadriceps and hamstrings	3-D trunk and LE joint motion; plyometric	1. Forward lunge elicited low hamstrings-quadriceps coactivation ratios[10] 2. Lunge elicited greater than 75% vastus medialis muscle activity[40]	1. Long-axis neuromuscular training increased propulsive jumping forces, reduced joint velocities during landing phase, and early stabilization[136] 2. Long-axis neuromuscular training increased knee flexion, increased gluteal muscle efficiency, changed timing of frontal plane peaks[136] 3. Athletes with ACL deficiency shifted moments away from knee during hopping versus controls[138] 4. Quadriceps strength was significantly correlated with external sagittal plane knee moments[137] and dynamic knee function in athletes following ACLR[67,78,80]

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POSTERIOR CRUCIATE LIGAMENT

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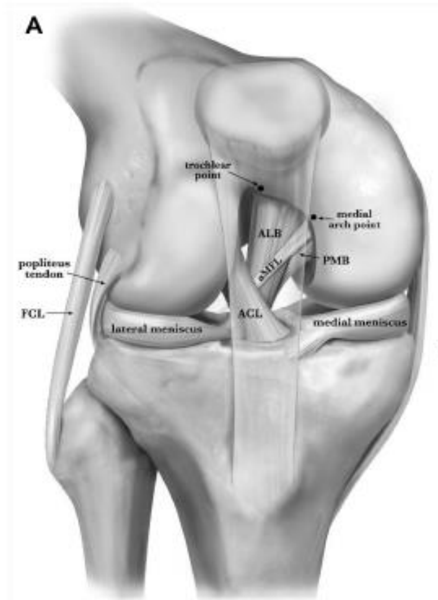
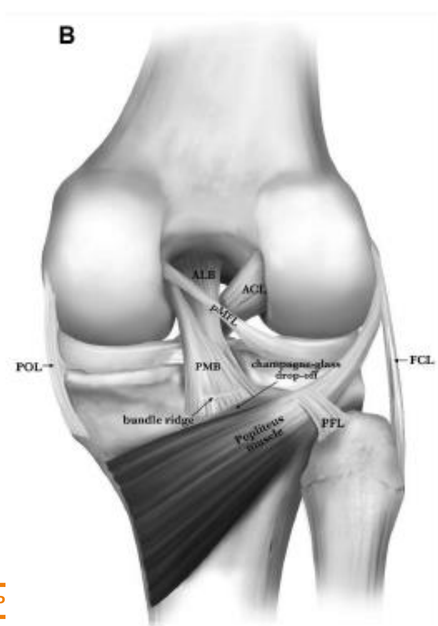
Anatomy

- Lateral aspect of medial femoral condyle to posterior tibial spine
- Anterolateral bundle and Posteromedial bundle
  - Anterolateral
    - Larger (95%)
    - Tight in flexion
  - Posteromedial
    - Smaller (5%)
    - Tight in extension

Anterior View



Posterior View

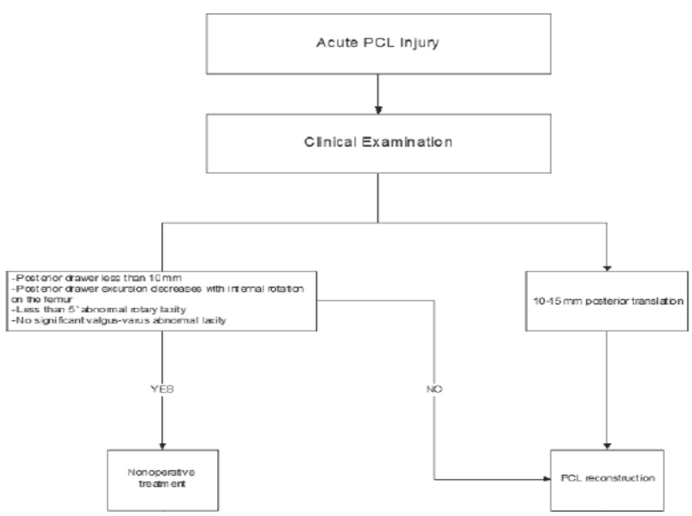


- Function: Limits….
  - Posterior Tibial translation (primary – 90%)
    - In full extension bears ~93%of posterior directed force
    - Most important at 70-90deg of flexion due to laxity of secondary restraints (MCL, popliteus, capsule)
  - Ext Rot tibia (secondary)
  - 90% multi lig injury

Injury Mechanism

- **MVA**
  - "Dashboard injury"
- **Contact sports**
  - Fall on a bent knee with their foot plantar flexed. The tibia hits the ground first and it translates posteriorly.
  - Hyper flexion in external rotation

Evaluation and Treatment of Posterior Cruciate Ligament Injuries : Revisited
William M. Wind, Jr, John A. Bergfeld and Richard D. Parker
Am J Sports Med 2004 32: 1765



Treatment

- Non Operative
  - Indicated for:
    - Grade I-II isolated tears
    - Non displaced grade II avulsion from tibia
  - Brace immobilization x2-4weeks
  - Focus on ROM, quad activation and limiting HS overactivity initially progressing to closed chain strengthening/proprioception/quad strength
  - Slow progression compared to ACL

Treatment

- Operative
  - Indicated for:
    - All grade III injuries; either isolated or with combined instability
    - Bony avulsion that requires ORIF
    - Some isolated grade II lesions in high demand athletes

Table 1. *PCL Postoperative Rehabilitation Program*

Postoperative Period	Program
Weeks 1 through 3	Non–weight-bearing with crutches; long leg brace locked in full extension.
Weeks 4 through 6	Non–weight-bearing with crutches continues until the end of postoperative week 6. The long leg brace is unlocked, and progressive range of motion begins during postoperative weeks 4 through 6.
Weeks 7 through 10	Progressive weight-bearing with crutches at 25% of body weight per week over a period of 4 weeks to full weight-bearing at the end of postoperative week 10.
Weeks 11 through 24	Progressive range of motion and strength training, avoiding resisted hamstring exercises.
Weeks 25 through 52	Continue strength and agility training. Return to sports or heavy labor when strength, range of motion, and proprioceptive skills are symmetric to the uninjured lower extremity.

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MEDIAL COLLATERAL LIGAMENT

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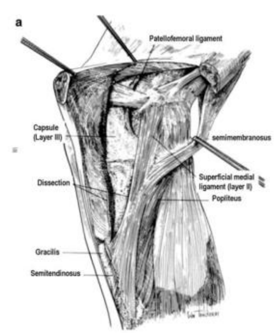
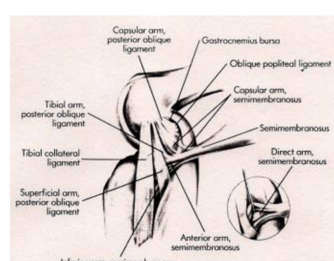
Anatomy

- Medial aspect femur (proximal-posterior to medial femoral epicondyle) courses distal and attaches anterior to posteriomedial tibial crest, distal to medial tibial plateau
- 3 tissue layers
  - Superficial
  - Deep
  - Posterior Oblique
- Multiple connections to joint capsule, med meniscus, muscle-tendon units





Anatomy

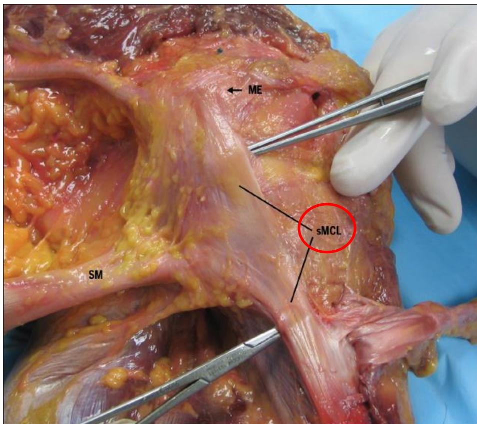


FIGURE 2. Photograph of a left knee demonstrating the course of the superficial medial collateral ligament. Abbreviations: ME, medial epicondyle; SM, semimembranosus tendon; sMCL, superficial medial collateral ligament.

Superficial

Deep

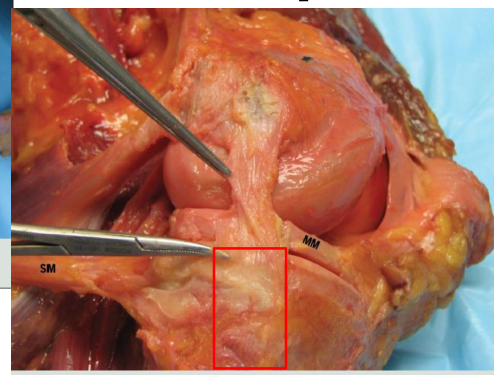


FIGURE 3. Photograph of the deep medial collateral ligament of a left knee. The superficial medial collateral ligament and the joint capsule anterior and posterior to the deep medial collateral ligament have been removed. The hemostat (bottom) is deep to the meniscofemoral portion of the deep medial collateral ligament, while the forceps (top) is holding the meniscotibial portion of the deep medial collateral ligament. Abbreviations: MM, medial meniscus; SM, semimembranosus tendon (anterior arm).

Anatomy

Posterior Oblique

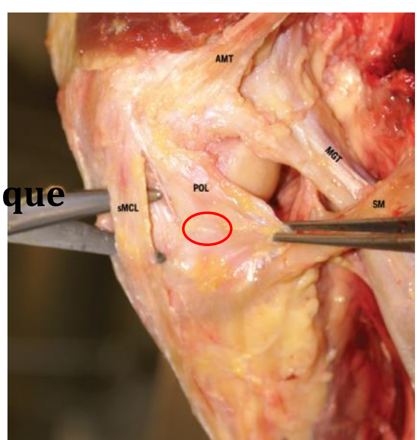


FIGURE 4. Photograph of a right knee demonstrating the central arm of the posterior oblique ligament. Abbreviations: AMT, adductor magnus tendon; MGT, medial gastrocnemius tendon; POL, posterior oblique ligament; SM, semimembranosus tendon; sMCL, superficial medial collateral ligament.

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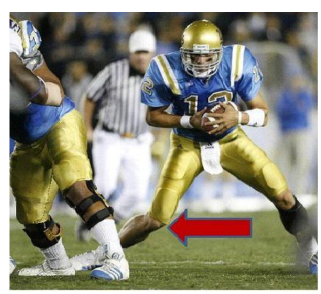
MCL Function

- 57% Valgus stability at 5 degrees knee flexion
- 78% Valgus stability at 25 degrees knee flexion
  - Due to decreased contribution from posterior capsule

MCL



- Valgus blow
- CKC - plant/cut valgus stress
- 7.9% of all athletic injuries
  - Most common NFL/alpine skiing
  - Second in collegiate hockey, women's rugby
- Grade III injury ~80% concomitant lig injury
  - 95% of the time ACL

MCL

- Treatment guidelines
  - Grade I/II
  - Non operative
    - Rest/ice
    - Hinged brace
    - Early ROM – Strength/Proprioception
    - Early weightbearing
    - Avg. return to football 20 days (grade II)
    - 74% return to pre injury activity level at 3mo
- Grade III
  - Rx – controversial
    - Most treated non operatively
      - Indications for surgery
        - » Avulsion fx with bony fragment
        - » Laxity affecting sports performance/daily activities
        - » Consistently positive stress radiographs for MCL
    - ACL + MCL (standard of care reconstruct ACL, not MCL)

MCL Bracing

V

The New Zealand Guideline Group[5] believe that bracing is beneficial for severe grade II and grade III ruptures of the MCL for the first 4 to 6 weeks to stabilize the knee to allow ligament healing to occur. Following surgery to the MCL, a long hinged brace allowing 30° to 90° of knee motion for the first 3 weeks followed by progressive weaning off the brace starting at week 6 is recommended.[123]

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LATERAL COLLATERAL LIGAMENT

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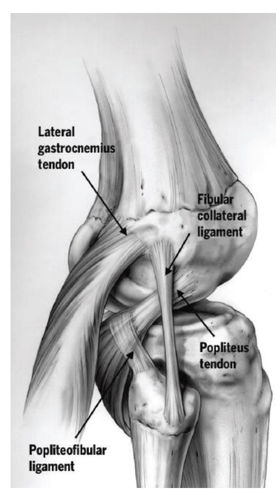
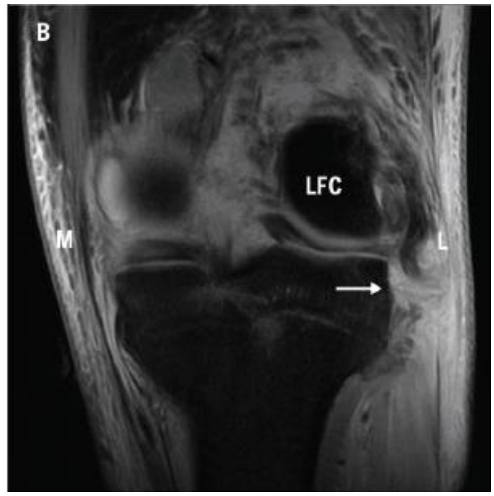
Anatomy

- Attaches equidistant from posterior and distal border of lateral femoral condyle and distally to superior and lateral facing V-shaped plateau on the fibular head
- Function
  - Resists varus force @ 0 and 30 degrees
    - 55% of varus load at 5deg
      - Posterior lateral capsule 13% ,ITB 5%, cruciate ligs the remaining amount
    - 69% of varus load at 25deg
      - Posterior structures on slack in flexion-preferred test
  - Secondary: limit ER of a flexed knee



LCL

- Injury Mechanism:
  - Least commonly injured knee ligament
  - Incidence of 4%
  - Usually with a soft tissue avulsion off prox femur or bony avulsion off fibular head
  - Typically with more extensive PLC injury



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Posterolateral Corner (PLC)

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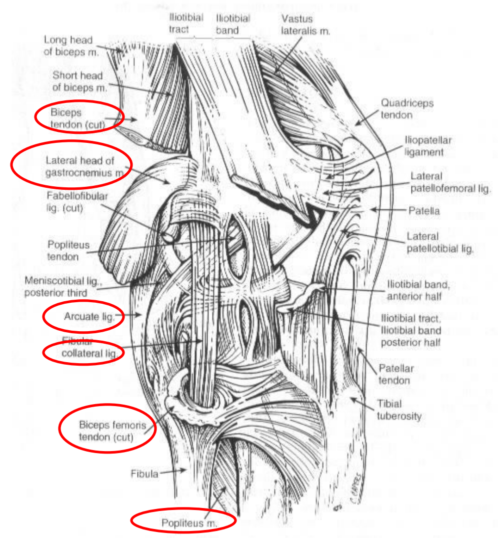
Anatomy

- *Muscles:*
  - Popliteus
  - Lateral Head of Gastrocnemius
  - Short head of Biceps Femoris
- *Ligaments:*
  - Fibular Collateral Lig
  - Arcuate Ligament
- *Misc:*
  - Lateral Meniscus
  - Lateral Retinaculum



- One of the most common multi-ligament injuries
- Isolated injuries to PLC 1.6% of all ligament injuries
- Concomitant PLC and other ligament injury: 43-80%
  - Vehicular Trauma: 64%
  - Athletic Injury: 46%
- Commonly missed with failed ACL
- Prevents:
  - Primary:
    - Varus
    - Tibial ER
  - Secondary
    - Assists PCL with posterior tibial translation (30 degrees)
    - Hyperextension

PLC

- Injury Mechanism:
  - Blow to anteromedial aspect tibia near or at full extension
  - Forced hyperextension/varus
  - Valgus force on flexed knee
  - Severe tibial ER in flex or extension

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Treatment

- Grade I and II
  - Good results non-operatively
- Grade III
  - Good results operatively if performed within 3weeks of injury

- Better success operatively of acute vs chronic injuries

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Non Operative Treatment

- Phase I
  - Edema management
  - QS activation
  - ROM return
- Phase II
  - Gait mechanics
  - Increase strength
    - QS, HS, GS, Popliteus, Hip, Lumbopelvic
- Phase III
  - Neuromuscular control
  - Control of varus and tibial ER at increased angles of knee flexion
- Phase IV
  - Sport specific training

Post Operative Treatment

- NWB x6weeks
  - Immobilizer locked out for 1-2 weeks
- ROM
  - 0-90 in 2 weeks
  - Full in 6weeks
- Full body squats permitted at 12weeks
- Until 4 months, no….
  - CKC therex at greater than 70deg knee flexion
  - Tibial ER
  - Resisted or repetitive HS in knee flexion

PROTOCOL FOR REHABILITATION OF A POSTEROLATERAL KNEE RECONSTRUCTION

Procedure

The popliteus tendon, the popliteofibular ligament, and fibular collateral ligament are reconstructed.

This protocol can be combined with cruciate reconstruction protocols adhering to all restrictions for each protocol.

Postoperative Restrictions

1. Patient remains in the knee immobilizer in full-knee extension at all times during the first 6 weeks postoperatively other than when working on knee range of motion (ROM) or performing quadriceps exercises.
2. Patient remains non-weight bearing for 6 weeks.
3. Patient to avoid tibial external rotation, and external rotation of the foot/ankle, especially in sitting for the first 4 months postoperatively.
4. Patient avoids open-chain hamstring exercises until 4 months postoperatively.

Postoperative Red Flags

Signs and symptoms of infection (excessive swelling, body temperature [fever] greater than 101°, increasing redness around the surgical incisions) calf swelling or tenderness, lack of full knee extension, complaints of knee instability, complaints of catching or locking, and increased effusion following activity/therapy.

Phase 1

Weeks 1-2

1. Edema management: ice, compression, elevation.
2. Quadriceps sets and straight leg raises (SLRs) performed in the knee immobilizer. Quadriceps sets can be performed hourly up to 30 repetitions and SLR up to 30 repetitions 4 to 5 times per day.
3. Four times a day gentle passive and active assisted ROM exercises. Goal is 90° of knee flexion by the end of 2 weeks, and 0° of knee extension.
4. Core (lumbopelvic and hip) stabilization exercises in knee immobilizer that do not increase knee forces in varus, hyperextension, or tibial external rotation.

Weeks 3-6

1. Continue with passive and active assisted ROM exercises 4 to 6 times per day. Patient should achieve full extension at this time, and 120° of flexion.
2. Continue with quadriceps sets and SLRs.

Phase 2

Weeks 7-12

1. Start partial weight bearing using crutches. Goal is to ambulate full weight bearing without crutches within 2 weeks. Patient must be walking without a limp to discharge crutches. Discontinue knee immobilizer if able to perform SLR without a knee extension lag.
2. Initiate use of stationary exercise bike if 105° of knee flexion ROM is achieved. Working on motion, beginning with 5 minutes every other day and increasing to 20 minutes daily, based on the knee's response to increased activity. If soreness or effusion is evident reduce time or days utilizing the bike.

Weeks 13-16

At this time the patient should have a normal gait pattern, without the presence of a limp or Trendelenburg sign.

The physician should be notified if patient is lacking 5° or more of extension or has less than 110° of flexion.

1. Leg press up to 25% of the patient's body weight to fatigue. Knee flexion allowed to a maximum of 70°.
2. Squat rack/squat machine: using weight up to 50%, body weight 10 repetitions, again not exceeding 70° of knee flexion. Slow progression to full body weight.
3. Closed kinetic chain exercise progression: double-limb squatting, lunges, single-limb squatting, etc. All exercises performed with less than 70° of knee flexion.
4. Daily biking or swimming. If swimming, no whipkicks or flip turns.

Phase 3

Months 4-6 (Weeks 16-24)

Physical therapy goals: improve quadriceps strength and function, increase endurance, improve coordination, improve proprioception.

1. Walking program: 20 to 30 minutes daily with a medium to brisk pace. Add 5 minutes per week.
2. Resistance can be added to bicycling as tolerated. Biking done 3 to 5 times per week for 20 minutes, and the lower extremities should feel fatigued post biking.
3. Advanced closed kinetic chain exercise progression: addition of unstable surface, movement patterns, resistance, etc.
4. Return to run program once patient is able to perform 20 repetitions of involved lower extremity single-limb squatting to greater than 60°of knee flexion with good control.
5. Plyometric progression: supported jumping, jumping, leaping, hopping, etc.

Month 7 and Beyond (Week 28)

Goals: achieve maximum strength of operative extremity.

1. Maintenance of home exercise program 3 to 5 times per week.

Note: Physician will give clearance for cutting and pivoting and sports simulation activities as appropriate. Physician clearance is based on favorable outcomes with imaging studies, clinical exam findings, and functional progression with therapy. The coordination of care between the surgeon and physical therapy staff is critical for a complete assessment of patient function and a complete recovery from the surgery.

Functional testing often performed at this time. A progressive return-to-play program is initiated if the limb symmetry index is greater than 85% with functional testing and satisfactory varus stress radiographs.

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MENISCUS

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DAVID S. LOGERSTEDT, PT, MA • LYNN SNYDER-MACKLER, PT, ScD • RICHARD C. RITTER, DPT • MICHAEL J. AXE, MD

Knee Pain and Mobility Impairments: Meniscal and Articular Cartilage Lesions

Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association

J Orthop Sports Phys Ther. 2010;40(6):A1-A35. doi:10.2519/jospt.2010.0304

CLINICAL GUIDELINES

Summary of Recommendations

C CLINICAL COURSE

Knee pain and mobility impairments associated with meniscal and articular cartilage tears can be the result of a contact or noncontact incident, which can result in damage to 1 or more structures. Clinicians should assess for impairments in range of motion, motor control, strength, and endurance of the limb associated with the identified meniscal or articular cartilage pathology or following meniscal or chondral surgery.

C RISK FACTORS – MENISCUS

Clinicians should consider age and greater time from injury as predisposing factors for having a meniscal injury. Patients who participated in high-level sports or had increased knee laxity after an ACL injury are more likely to have late meniscal surgery.

C RISK FACTORS – ARTICULAR CARTILAGE

Clinicians should consider the patients' age and presence of a meniscal tear for the odds of having a chondral lesion subsequent to having an ACL injury. The greater a patient's age and longer time from initial ACL injury are predictive factors of the severity of chondral lesions and time from initial ACL injury is significantly associated with the number of chondral lesions.

C DIAGNOSIS/CLASSIFICATION

Knee pain, mobility impairments, and effusion are useful clinical findings for classifying a patient with knee pain and mobility disorders into the following International Statistical Classification of Diseases and Related Health Problems (ICD) categories: tear of the meniscus and tear of the articular cartilage; and the associated International Classification of Functioning, Disability, and Health (ICF) impairment-based category knee pain (b28016 Pain in joint) and mobility impairments (b7100 Mobility of a single joint).

C DIFFERENTIAL DIAGNOSIS

Clinicians should consider diagnostic classifications associated with serious pathological conditions or psychosocial factors when the patient's reported activity limitations or impairments of body function and structure are not consistent with those presented in the diagnosis/classification section of this guideline, or, when the patient's symptoms are not resolving with interventions aimed at normalization of the patient's impairments of body function.

C EXAMINATION – OUTCOME MEASURES

Clinicians should use a validated patient-reported outcome measure, a general health questionnaire, and a validated activity scale for patients with knee pain and mobility impairments. These tools are useful for identifying a patient's baseline status relative to pain, function, and disability and for monitoring changes in the patient's status throughout the course of treatment.

C EXAMINATION – ACTIVITY LIMITATION MEASURES

Clinicians should utilize easily reproducible physical performance measures, such as single-limb hop tests, 6-minute walk test, or timed up-and-go test, to assess activity limitation and participation restrictions associated with their patient's knee pain or mobility impairments and to assess the changes in the patient's level of function over the episode of care.

C INTERVENTIONS – PROGRESSIVE KNEE MOTION

Clinicians may utilize early progressive knee motion following knee meniscal and articular cartilage surgery.

D INTERVENTIONS – PROGRESSIVE WEIGHT BEARING

There are conflicting opinions regarding the best use of progressive weight bearing for patients with meniscal repairs or chondral lesions.

C INTERVENTIONS – PROGRESSIVE RETURN TO ACTIVITY – MENISCUS

Clinicians may utilize early progressive return to activity following knee meniscal repair surgery.

E INTERVENTIONS – PROGRESSIVE RETURN TO ACTIVITY – ARTICULAR CARTILAGE

Clinicians may need to delay return to activity depending on the type of articular cartilage surgery.

D INTERVENTIONS – SUPERVISED REHABILITATION

There are conflicting opinions regarding the best use of clinic-based programs for patients following arthroscopic meniscectomy to increase quadriceps strength and functional performance.

B INTERVENTIONS – THERAPEUTIC EXERCISES

Clinicians should consider strength training and functional exercise to increase quadriceps and hamstrings strength, quadriceps endurance, and functional performance following meniscectomy.

B INTERVENTIONS – NEUROMUSCULAR ELECTRICAL STIMULATION

Neuromuscular electrical stimulation can be used with patients following meniscal or chondral injuries to increase quadriceps muscle strength.

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DIAGNOSIS/CLASSIFICATION

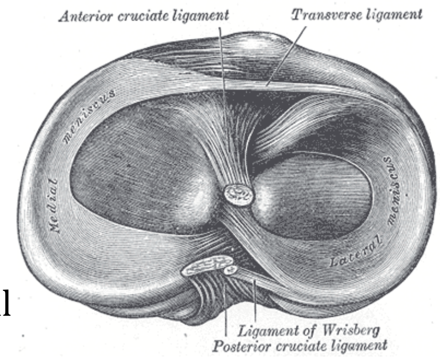
II The ICD diagnosis of a meniscal tear and the associated ICF diagnosis of joint pain and mobility impairments are made with a fair level of certainty when the patient presents with the following clinical findings[3,6,51,78,95,115]:

- Twisting injury
- Tearing sensation at time of injury
- Delayed effusion (6-24 hours postinjury)
- History of "catching" or "locking"
- Pain with forced hyperextension
- Pain with maximum flexion
- Pain or audible click with McMurray's maneuver
- Joint line tenderness
- Discomfort or a sense of locking or catching in the knee over either the medial or lateral joint line during the Thessaly Test when performed at 5° or 20° of knee flexion

Meniscus

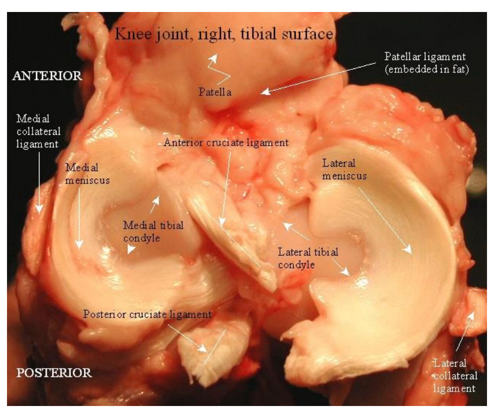
- Second most common knee injury
  - Incidence of 12-14%
- 10-20% of all orthopaedic surgeries in US involve meniscus
  - 850000 patients a year

Anatomy



- Lateral
  - Circular
  - More mobile than medial
  - Connected to:
    - medial meniscus anteriorly by transverse lig
    - patella by patellomeniscal lig
    - posteriorly to popliteus mm and PCL
    - medial femoral condyle by meniscofemoral lig (Ligament of Wrisberg)

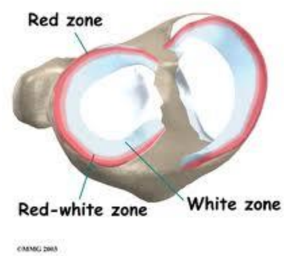
Anatomy



- Medial
  - C shaped
  - Less mobile
  - Connected to
    - transverse and meniscofemoral ligs like lateral
    - semimembranosus mm
    - anterior horn attached to ACL
    - posterior horn to PCL

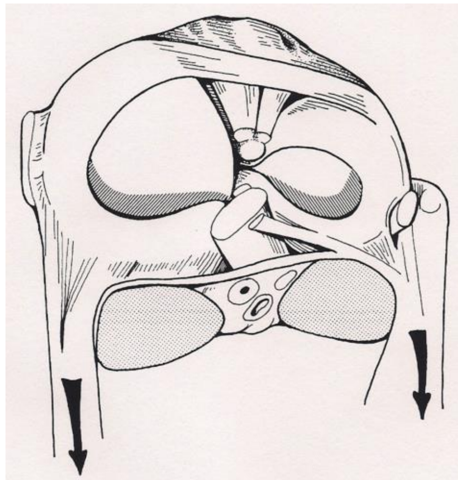
Anatomy

- Cover 2/3 of tibial plateau
- Red Zone: lateral 1/3
  - Good blood supply from capsular arteries
- White Zone: remaining 2/3
  - Poor blood supply

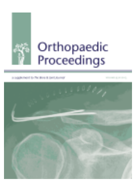


Function

- Load transmission
  - Manage 70% of load across knee during activities
- Shock absorption
- Stability
- Congruence
- Proprioceptive
- Transmit joint compressive forces
  - 50% EXT
  - 85% @ 90 degrees
- During flexion move posteriorly, extension move anteriorly
- During rotation, follow motion of femur
  - Most likely due to meniscofemoral ligs



- Semimembranosus and Popliteus pull on medial and lateral meniscus during flexion of the knee



THE ACCURACY OF MAGNETIC RESONANCE IMAGING IN DETECTING MENISCAL PATHOLOGY

S Chambers, M Jones, Y Michla, and D Kader
J Bone Joint Surg Br 2012 94-B: (SUPP XXIX) 61.

We looked at whether the MRI report showed a tear, and this was graded Y/N. The arthroscopic report was graded for tear: Y/N. 66 patients had a positive scan. 64 of these were found to have a tear at surgery. 37 scans were reported as "no tear", of which 4 were found to have a tear at surgery. Nine scans were not easy to classify as they were descriptive.

In our series of 112 knees, MRI was 90.5% sensitive, 89.5% specific and 90.1% accurate.

When a definite diagnosis of "tear", or "no tear" was made at scan, there were two false positives and four false negatives. False positives may be unnecessarily exposed to the risks of surgery. Patients with negative scans had a mean delay to surgery of 33 weeks compared to 18 weeks for patients with positive scans. False negatives may wait longer for their surgery. Two of the false negative scans clearly showed meniscus tears which were missed by the reporting radiographer. In our series the scan itself was more accurate than the reporting. It is important to have an experienced musculoskeletal radiologist to minimise the number of missed tears. It is also important for surgeon to check the scan as well as the report.

Meniscal Repair

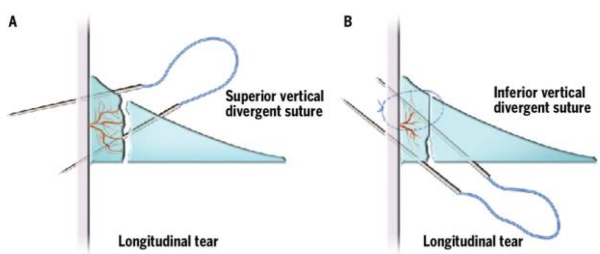
FRANK R. NOYES, MD[1] • TIMOTHY P. HECKMANN, PT, ATC[2] • SUE D. BARBER-WESTIN, BS[3]

Meniscus Repair and Transplantation: A Comprehensive Update

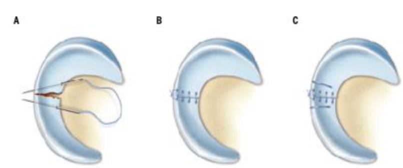
TABLE 1 INDICATIONS AND CONTRAINDICATIONS FOR MENISCUS REPAIR

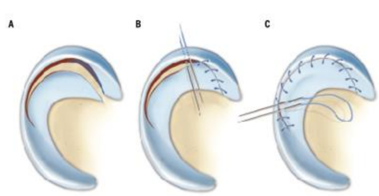
Indications
- Meniscus tear with tibiofemoral joint line pain
- Patients younger than 50 years of age or patients in their fifties who are athletically active
- Concurrent knee ligament reconstruction or osteotomy
- Meniscus tear reducible, good tissue integrity, normal position in the joint once repaired
- Peripheral single longitudinal tears: red-red, 1 plane; reparable in all cases, high success rates
- Middle-third region: red-white (vascular supply present) or white-white (no blood supply); often reparable with reasonable success rates
- Outer-third and middle-third regions, longitudinal, radial, horizontal tears: red-white, 1 plane; often reparable

Contraindications
- Meniscus tears located in inner-third region
- Chronic degenerative tears in which the tissue is of poor quality and not amenable to suture repair
- Longitudinal tears less than 10 mm in length
- Incomplete radial tears that do not extend into the outer-third region
- Patients older than 60 years of age
- Patients unwilling to follow postoperative rehabilitation program



Radial Tear Repair





Flap Tear Repair

Meniscal Transplantation

TABLE 2 — **Indications and Contraindications for Meniscus Transplantation**

Indications
- Prior meniscectomy
- Patients 50 years of age or younger
- Pain in the meniscectomized tibiofemoral compartment
- No radiographic evidence of advanced joint deterioration, ≥2 mm of tibiofemoral joint space on 45° weight-bearing posteroanterior radiographs
- No or only minimal bone exposed on tibiofemoral surfaces
- Normal axial alignment

Contraindications
- Advanced knee joint arthrosis with flattening of the femoral condyles, concavity of the tibial plateau, and osteophytes that prevent anatomic seating of the meniscus transplant
- Uncorrected varus or valgus axial malalignment
- Uncorrected knee joint instability, anterior cruciate ligament deficiency
- Knee arthrofibrosis
- Significant muscular atrophy
- Prior joint infection with subsequent arthrosis
- Symptomatic, noteworthy patellofemoral articular cartilage deterioration
- Obesity (body mass index >30 kg/m^2)
- Prophylactic procedure (asymptomatic patients with no articular cartilage damage)

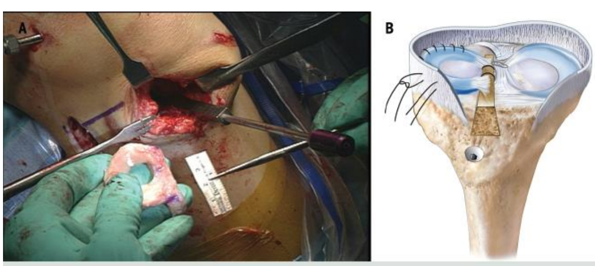


FIGURE 7. (A) A lateral meniscus transplant is ready to be placed into the tibial slot using the central bone bridge technique. Reprinted with permission from Noyes FR, Barber-Westin SD, Rankin M. Meniscal transplantation in symptomatic patients less than fifty years old. *J Bone Joint Surg Am.* 2005;87 suppl 1 pt 2:149-165.[47] (B) A lateral meniscus graft in place and sutured. This figure was published in *Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes*, Noyes FR, Barber-Westin SD, Meniscus transplantation: diagnosis, operative techniques, clinical outcomes, 772-805, Copyright Saunders, 2009.[41]

FIGURE 9. Final anterior and posterior tunnel fixation appearance of medial meniscus transplant and vertical divergent sutures. This figure was published in *Noyes' Knee Disorders: Surgery, Rehabilitation, Clinical Outcomes*, Noyes FR, Barber-Westin SD, Meniscus transplantation: diagnosis, operative techniques, clinical outcomes, 772-805, Copyright Saunders, 2009.[41]

TABLE 3 — Rehabilitation Protocol Summary for Meniscus Repairs and Transplants*

	Postoperative Weeks					Postoperative Months			
	1-2	3-4	5-6	7-8	9-12	4	5	6	7-12
Brace									
Long-leg postoperative	C, A, T	C, A, T	C, T						
Range-of-motion minimum goals									
0° to 90°	X								
0° to 120°		X							
0° to 135°			X						
Weight bearing									
Toe touch: half body weight	P								
Three-quarters to full		P							
Toe touch: one-quarter body weight	C, T, A								
Half to three-quarters body weight		C, T, A	C, A						
Full			T	C, A					
Patellar mobilization	X	X	X						
Stretching									
Hamstring, gastroc-soleus, iliotibial band, quadriceps	X	X	X	X	X	X	X	X	X
Strengthening									
Quadriceps isometrics, straight leg raises, active knee extension	X	X	X	X	X	X	X	X	X
Closed-chain: gait retraining, toe raises, wall sits, minisquats		P	C	X	X	X	X	X	
Knee flexion hamstring curls (90°)			P	C	X	X	X	X	X
Knee extension quadriceps (90°-30°)			X	X	X	X	X	X	X
Hip abduction-adduction, multihip			X	X	X	X	X	X	X
Leg press (70°-10°)			P	P	X	X	X	X	X
Balance/proprioceptive training									
Weight shifting, minitrampoline, BAPS, BBS, plyometrics	P	X	X	X	X	X	X	X	X
Conditioning									
Upper-body ergometer		X	X	X					
Bike (stationary)				X	X	X	X	X	X
Aquatic program					X	X	X	X	X
Swimming (kicking)					P, C	X	X	X	X
Walking					X	X	X	X	X
Stair-climbing machine					P, C	P, C	P, C	P, C	X
Ski machine					P	P	P	C	X
Running									
Straight†						P	P	C	X
Cutting									
Lateral carioca, figure-of-eight†							P	P	X
Full sports†							P	P	X

Abbreviations: A, all-inside meniscus repairs; BAPS, Biomechanical Ankle Platform System; BBS, Biodex Balance System; C, complex inside-out meniscus repairs extending into middle third region; P, peripheral meniscus repairs; T, transplants; X, all meniscus repairs and transplants.
**Modified from Heckmann et al, with permission.*
†Return to running, cutting, and full sports based on multiple criteria. Patients with noteworthy articular cartilage damage are advised to return to light recreational activities only.

Rehab

- Dependent on type and location of repair/transplant
  - Physician directed
- Generally
  - Long leg brace x6 weeks
  - Restricted weight bearing atleast 3 weeks
  - Flexion ROM restricted to 90 week 1, 120 week 4, 135 week 6
  - Biking week 7, straight running month 4, cutting month 5, return to sport month 5

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ARTICULAR CARTILAGE

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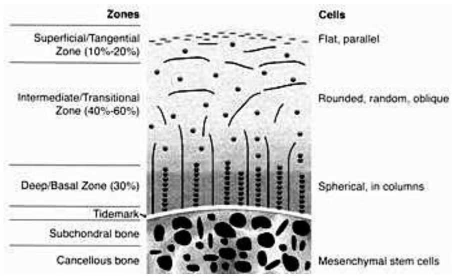
Articular Cartilage

- Incidence
  - 60-70%
    - Isolated 30%
    - Non isolated 70%
- Most commonly at medial femoral condyle and patella articular surface
- Medial meniscus tears and ACL rupture most common concomitant injuries
  - 37% and 36%

Anatomy



V The ICD diagnosis of an articular cartilage defect and the associated ICF diagnosis of joint pain and mobility impairments is made with a low level of certainty when the patient presents with the following clinical findings[16]:

- Acute trauma with hemarthrosis (0-2 hours) (associated with osteochondral fracture)
- Insidious onset aggravated by repetitive impact
- Intermittent pain and swelling
- History of "catching" or "locking"
- Joint line tenderness

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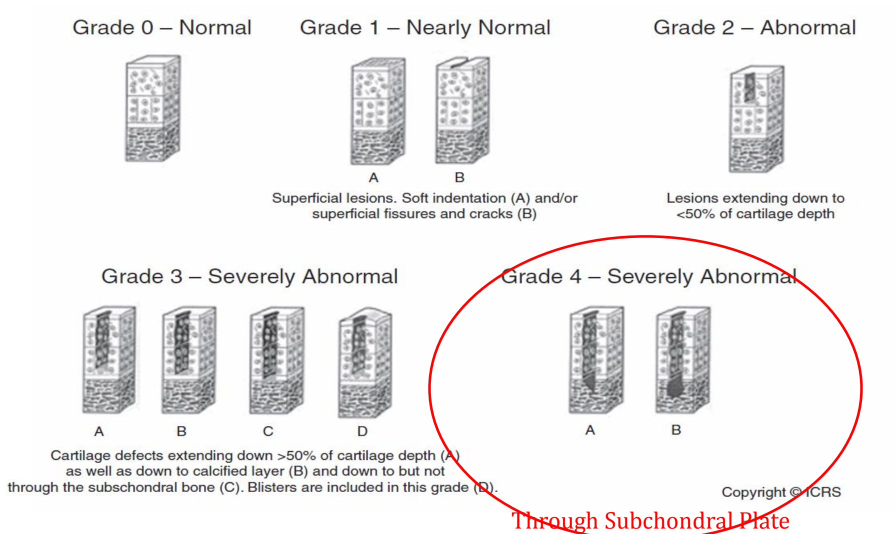


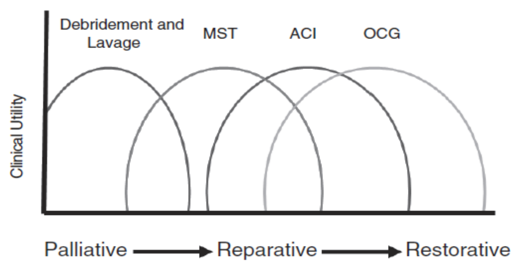
FIGURE 2. ICRS Grading. The International Cartilage Repair Society grading system for normal and abnormal articular cartilage. Pri with kind permission from the International Cartilage Repair Society.

Treatment Options

- Conservative/Palliative
  - Debridement/Lavage
- Reparative
  - Subchondral Drilling
  - Microfracture
- Restorative
  - OATS
  - ACI/MACI

Treatment Options

- Debridement/Lavage
- Marrow Stimulating
- Autologous Chondrocyte Implantation
- Osteochondral Grafting



Treatment Selection in Articular Cartilage Lesions of the Knee

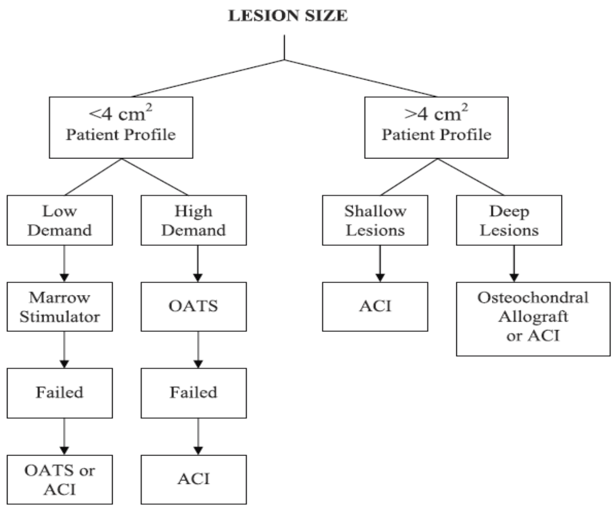
A Systematic Review

Joris E. J. Bekkers, MD, Melanie Inklaar, MD, and Daniël B. F. Saris,* MD, PhD

Results: Lesion size, activity level, and age were the influencing parameters for the outcome of articular cartilage repair surgery. Lesions greater than 2.5 cm^2 should be treated with sophisticated techniques, such as autologous chondrocyte implantation or osteochondral autologous transplantation, while microfracture is a good first-line treatment option for smaller (<2.5 cm^2) lesions. Patients who are active show better results after autologous chondrocyte implantation or osteochondral autologous transplantation when compared with microfracture. Younger patients (<30 years) seem to benefit more from any form of cartilage repair surgery compared with those over 30 years of age.

Conclusion: Lesion size, activity level, and patient age are factors that should be considered in selecting treatment of articular cartilage lesions of the knee. In addition, these factors are a step toward evidence-based, instead of surgeon-preferred, treatment of articular cartilage lesions of the knee.

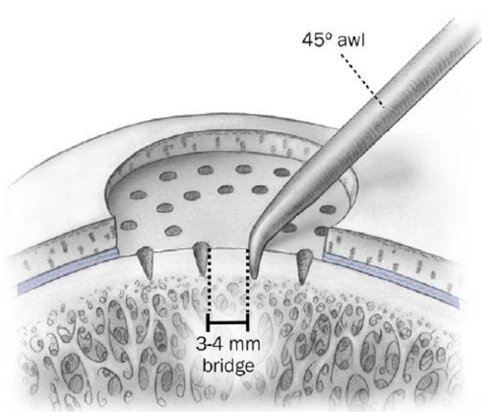
Am J Sports Med 2009 37: 148S



Bulletin of the NYU Hospital for Joint Diseases 2007;65(1):51-60

Micro fracture

- Marrow stimulation technique
- Most common
- Simple, safe, cheap
- Injury/inflammatory response
- Fibrous Clot formed
- < 2-4 cm lesion



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Successful Outcome

1. Remove calcified cartilage layer – Do not abrade subchondral bone
2. Penetrate Subchondral bone (awl) with 1-2 mm between to allow soft tissue in growth to adhere
3. Maintain post op ROM (CPM)
4. Post op – partial weight bearing (50% x 6 weeks)
5. Realignment/stabilizing procedure concurrently – DJD, Patellar tracking, ligt repair/reconstruction

OATS/Mosaicplasty

TABLE 1. Indications for mosaicplasty.

- Focal chondral and osteochondral defects of weight-bearing articular surfaces of the knee
- Defects of other diarthrodial surfaces of the talus, humeral capitulum, and femoral head
- Patient less than 50 years of age
- The ideal diameter of the defect is between 1 and 4 cm^2
- Concurrent treatment of instability, malalignment, and meniscal and ligament tears is essential
- Patient compliance is critical (ie, weight-bearing limitation)

J Orthop Sports Phys Ther • Volume 36 • Number 10 • October 2006

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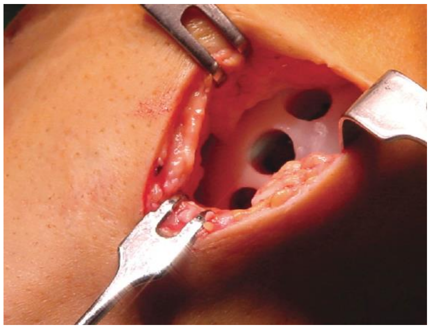
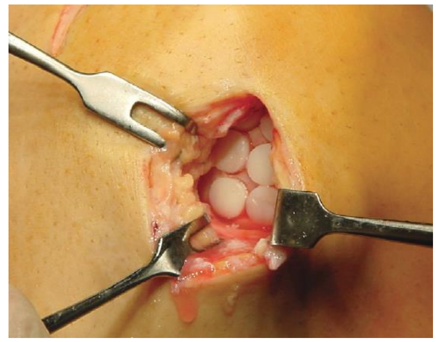
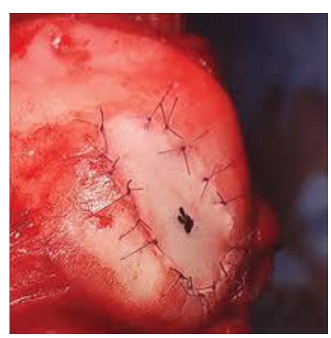
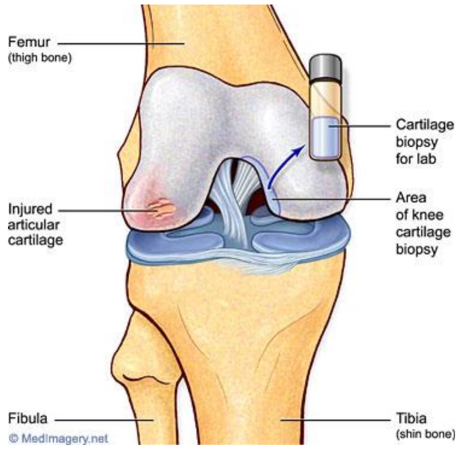




Autologous Chondrocyte Implantation (ACI)



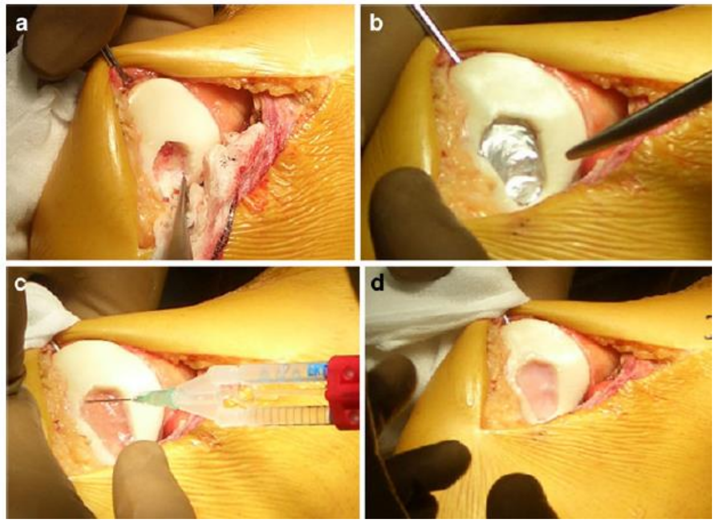
- 2 surgical stages:
  - Chondral biopsy
  - Implantation of cells into lesion
- Full thickness lesions – Femoral condyle, trochlear groove
- Unipolar lesions
- <50 yrs old
- Larger lesions 2-8 cm
- Normal alignment/stability
- Hyaline cartilage = Better Outcomes?



Matrix Induced ACI

- ACI surgery but without periosteum harvest
- 2 stage surgery
  - Harvest of cells
  - Implantation of membrane
- Use fibrin glue to adhere membrane

Fig. 3 Surgical stage of matrix-induced autologous chondrocyte implantation (MACI) in patellar chondral lesion. **a** Debridement and shaping of chondral lesion. **b** Sizing of lesion for preparing of the membrane. **c** Filling the crater with fibrin glue. **d** Pressing the membrane and looking for air bubbles and glue leak before moving the knee



- Graft Healing Course Following MACI

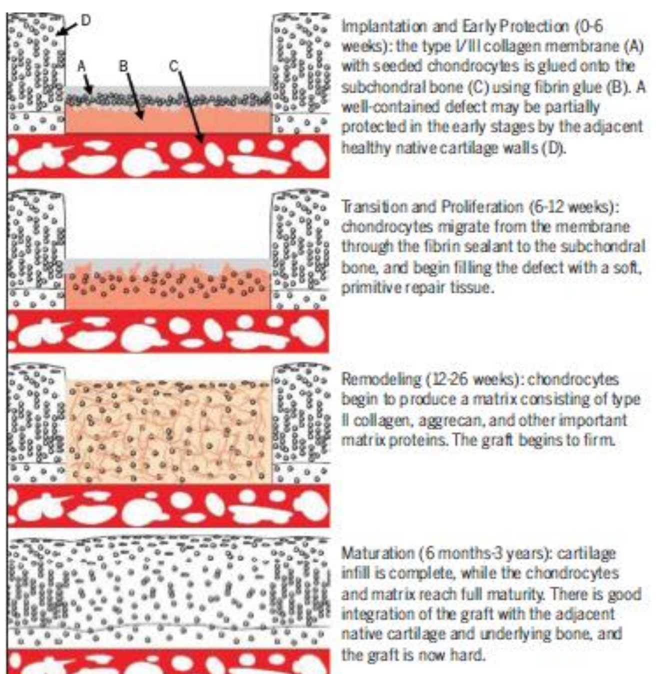


FIGURE 1. Graft-maturation paradigm: the postoperative timeline of tissue maturation will dictate the progression of physical activity.

Summary

- Improved outcomes for <30yo
- Improved outcomes for more active individuals
- For lesions >4cm, better outcomes with ACI or MACI
- All surgical interventions showed improved outcome measures short and long term
- Return to sport fastest with OATS (7mo), longest with ACI (18-25mo)
- Lack of conclusive research on best approach

Management of Articular Cartilage Defects of the Knee

Asheesh Bedi, Brian T. Feeley and Riley J. Williams, III
J Bone Joint Surg Am. 2010;92:994-1009. doi:10.2106/JBJS.I.00895

TABLE E-1 Outcomes Following Microfracture for Isolated Articular Cartilage Lesions

Study	No. of Patients	Average Age *(yr)*	Average Duration of Follow-up *(yr)*	Average Size of Lesion *(cm²)*	Outcome*
Steadman et al.[20] (2003)	71	30.4	11.3	2.774	Lysholm score[27,28]: 59→89; Tegner score[27,28]: 3→6
Steadman et al.[15] (2003)	25	28.2	4.5	Not recorded	Lysholm score[27,28]: 68→90; 76% returned to NFL in 1 yr
Knutsen et al.[23] (2004)	40	32.2	2	4.80	Lysholm score[27,28]: 53→76; SF-36 physical score: 36→46
Mithoefer et al.[22] (2005)	48	41.7	3.6	4.82	Good to excellent: 67%
Gudas et al.[24] (2005)	29	24.3	3.1	2.80	Good to excellent: 52%
Gobbi et al.[25] (2005)	53	38	6	4.00	Lysholm score[27,28]: 56→87; Tegner score[27,28]: 3.2→5; IKDC score[26]: 70% nearly normal

*The values before and after the arrows indicate the preoperative and follow-up scores (in points), respectively.

Management of Articular Cartilage Defects of the Knee

Asheesh Bedi, Brian T. Feeley and Riley J. Williams, III
J Bone Joint Surg Am. 2010;92:994-1009. doi:10.2106/JBJS.I.00895

TABLE E-2 Outcomes Following Osteochondral Autograft Transplantation for Isolated Articular Cartilage Lesions

Study	No. of Patients	Average Age *(yr)*	Average Duration of Follow-up *(yr)*	Average Size of Lesion *(cm²)*	Outcome*
Hangody and Füles[58] (2003)	831	Unknown	10	Unknown	Good to excellent: 92% of femoral lesions, 87% of tibial lesions, 79% of patellofemoral lesions
Marcacci et al.[125] (2007)	30	29.3	7	<2.5	Good to excellent: 77%; IKDC score[26]: 35→72
Oztürk et al.[59] (2006)	19	33.1	2.7	1-2.5	Good to excellent: 85%; Lysholm score[27,28]: 46→88
Chow et al.[126] (2004)	30	44.6	3.7	1-2.5	Good to excellent: 83%; Lysholm score[27,28]: 44→88
Miniaci and Tytherleigh-Strong[61] (2007)	20	14.3	3.4	Unknown (osteochondritis dissecans)	Clinically normal by 18 mo; healing of osteochondritis dissecans lesions by 6 mo
Nho et al.[62] (2008)	22	30	2.1	1.7	IKDC score[26]: 47→74 for isolated patellar lesions; 71% with complete incorporation on magnetic resonance imaging

*The values before and after the arrows indicate the preoperative and follow-up scores (in points), respectively.

Management of Articular Cartilage Defects of the Knee

Asheesh Bedi, Brian T. Feeley and Riley J. Williams, III
J Bone Joint Surg Am. 2010;92:994-1009. doi:10.2106/JBJS.I.00895

TABLE E-4 Outcomes Following Autologous Chondrocyte Implantation for Isolated Articular Cartilage Lesions

Study	No. of Patients	Average Age *(yr)*	Average Duration of Follow-up *(yr)*	Average Size of Lesion *(cm²)*	Outcome*
Brittberg et al.[93] (1994)	23	27	3.7	1.6-6.5	Good to excellent: 14/16
Peterson et al.[101] (2000)	25	32.2	4.2	4.2	Good to excellent for femoral condyles: 92%
Peterson et al.[128] (2002)	18	40.8	7.4	1.3-12	Tegner score[27,28]: 6→9.8; good to excellent: 17/18
Bentley et al.[99] (2003)	50	31	1.5	4.7	Good to excellent: 88%
Zaslav et al.[96] (2009)	126	34.5	3.9	4.6	Treatment success: 76%; modified Cincinnati score[27,28]: 3.3→6.3

*The values before and after the arrows indicate the preoperative and follow-up scores (in points), respectively.

Systematic Review

Treatment of Chondral Defects in the Athlete's Knee

Joshua D. Harris, M.D., Robert H. Brophy, M.D., Robert A. Siston, Ph.D., and David C. Flanigan, M.D.

Arthroscopy: The Journal of Arthroscopic and Related Surgery, Vol 26, No 6 (June), 2010: pp 841-852

Improved outcomes after cartilage repair or restoration in athletes were observed in smaller defects in younger patients with a shorter preoperative duration of symptoms, without any prior surgical intervention, and higher preinjury and postoperative levels of sports. Results of microfracture appeared inferior in rate of return and performance on return relative to ACI or OATS, and clinical outcomes in this patient population may deteriorate with time after microfracture. Although the literature suggests that ACI and OATS may provide better results for athletes compared with microfracture, only further randomized prospective clinical trials will elucidate the optimal surgical treatment for focal chondral injury in the athlete's knee.

Systematic Review

Treatment of Chondral Defects in the Athlete's Knee

Joshua D. Harris, M.D., Robert H. Brophy, M.D., Robert A. Siston, Ph.D., and David C. Flanigan, M.D.

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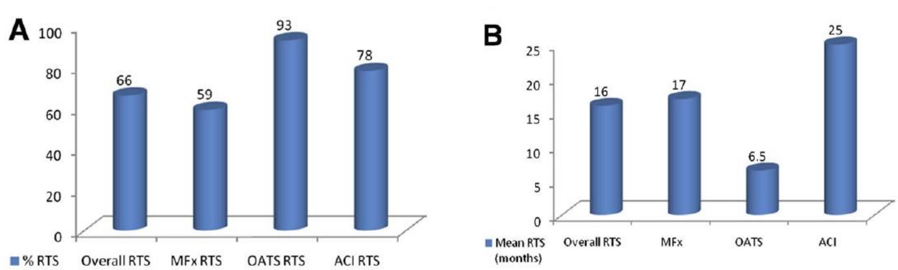

KAI MITHOEFER, MD[1] • KAREN HAMBLY, PT, PhD, MCSP[2] • DAVID LOGERSTEDT, PT, PhD, MPT, SCS[3]
MARGHERITA RICCI, MD[4] • HOLLY SILVERS, MPT[5] • STEFANO DELLA VILLA, MD[4]

Current Concepts for Rehabilitation and Return to Sport After Knee Articular Cartilage Repair in the Athlete

| MARCH 2012 | VOLUME 42 | NUMBER 3 | JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY

TABLE 1 **Factors to Consider During Individualized Cartilage Repair Rehabilitation**

Considerations/Specific Factors	Implications
Individual	
Athlete's age	Slower cartilage repair with increased age
Body mass index	More gradual rehabilitation progression with body mass index greater than 30 kg/m^2
Type of sport	Higher demand on repair tissue in impact sports
Competitive level	Competitive athletes have better outcomes
Psychological	Less fear of reinjury and higher self-efficacy are associated with better outcomes
Lesion/defect	
Defect size	Smaller defects frequently improve faster with rehabilitation
Repair technique	More rapid rehabilitation progression with restorative techniques
Defect location	Immediate weight bearing for patellofemoral defect (knee brace locked in full extension)
Duration of symptoms	Longer recovery if symptoms persist longer than 12 months (deconditioning)
Cartilage quality	Slower rehabilitation progression with generalized joint chondropenia
Concomitant injuries	
Concomitant procedures	Modified protocols for anterior cruciate ligament reconstruction, meniscal repair, osteotomy, etc
Meniscus status	Slower rehabilitation progression after meniscectomy (especially lateral meniscus)

.com

Phases of Healing and Rehab

- Biologic Phase
  - Phase I
    - Graft integration and stimulation
  - Phase II
    - Matrix production and organization
  - Phase III
    - Repair cartilage maturation and adaptation
- Rehab Phase
  - Phase I
    - Protection and joint activation
  - Phase II
    - Progressive loading and functional joint restoration
  - Phase III
    - Activity restoration

Rehabilitation

- Phase I
  - Protection and Joint Activation
    - Weeks 1-6
    - Effusion control
    - Partial weightbearing
    - NMES/Quad activation therex
    - Gradual improving ROM

Rehabilitation

- Phase II
  - Progressive loading and functional joint restoration
    - Week 6-6month
    - Full ROM/weightbearing
    - Progress proprioceptive training
    - Progress concentric to eccentric and static to dynamic strengthening and neuromuscular control
    - Introduce progressive plyometrics /loading activities

Rehabilitation

- Phase III
  - Activity restoration
    - Sport specific/on field rehab
    - 6-18 months (depending procedure, graft size, healing via imaging)

TABLE 4 **Weight-Bearing Guidelines and Criteria for Progression After Articular Cartilage Repair**

Phase 1. Weight-Bearing Guidelines

- Femoral defects
  - Restorative techniques (OATS/allograft): touch-down loading for 2 wk, then progress to full weight bearing by 4 to 6 wk
  - Reparative techniques (microfracture/ACI): touch-down loading for 2 wk, then progress by 25% body weight per wk
- Patellar/trochlear defects
  - Immediate weight bearing with brace locked in 0° to 10° of knee flexion

Progression Criteria to Go from Phase 1 to Phase 2

- Full passive ROM equal to the nonoperated knee
- Minimal or absent pain (VAS less than 3/10)
- Minimal or no effusion (grade 0 or 1+)
- Recovery of muscular activation
- Recovery of normal gait cycle (equal stride length and stance time between limbs, no limp)

Progression Criteria to Go from Phase 2 to Phase 3

- Full and painless ROM
- No or minimal pain (VAS less than 3/10)
- No or minimal effusion (grade 0 or 1+)
- Maximum peak torque difference of less than 20% between limbs on isokinetic test
- Hop performance difference of less than 10% between limbs
- Self-report outcomes greater than 90%
- Ability to run on a treadmill at 8 km/h for more than 10 min
- MRI evaluation of the repaired cartilage to evaluate repair tissue

Abbreviations: ACI, autologous chondrocyte implantation; MRI, magnetic resonance imaging; OATS, osteochondral autograft transplantation system; ROM, range of motion; VAS, visual analog scale

Clinical Rehabilitation Guidelines for Matrix-Induced Autologous Chondrocyte Implantation on the Tibiofemoral Joint

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Postoperative Rehabilitation Phases	Stages of Repair Tissue Maturation
1. Phase 1: Inpatient hospital rehabilitation 2. Phase 2: 2-3 weeks postsurgery	Implantation and protection (0-6 weeks)
3. Phase 3: 4-6 weeks postsurgery	Transition and proliferation (6-12 weeks)
4. Phase 4: 7-12 weeks postsurgery	Remodeling (12-26 weeks)
5. Phase 5: 3-6 months postsurgery 6. Phase 6: 6-9 months postsurgery 7. Phase 7: 9-18 months postsurgery and the return to sport	Maturation (26 weeks onward)

FIGURE 3. Phases of postoperative rehabilitation and the associated graft-maturation timeline.

- Excellent resource for rehabilitation protocol and progression