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Advances in ACL Surgery and the Impact on Rehabilitation and Return to Activity

DOCTOR OF ATHLETIC TRAINING MORAVIAN UNIVERSITY

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Disclosures

- I have no relevant financial relationships to disclose.
- I will not discuss off-label use or investigational use in my presentation.

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Learning Objectives

1. Evaluate the advantages and disadvantages of various surgical and non-surgical interventions and provide recommendations regarding best treatment outcomes for patients suffering ACL injuries.
2. Design evidence-based rehabilitation programs for patients recovering from ACL injury who have undergone surgical repair, surgical reconstruction, or opted for non-surgical management.
3. Examine the impact of various ACL surgical interventions on patient's rehabilitation program and return-to-activity outcomes.
4. Educate patients about the various treatment options available following ACL injury, including a discussion of the best-available evidence regarding patient outcomes, patient satisfaction, and re-injury rate for surgical and non-surgical interventions based on the patient's age, past medical history, and desired activity level.

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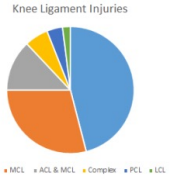
ACL Epidemiology

- Isolated and combined ACL injuries make up ~75% of all knee ligamentous injuries



ACL Incidence by Sex
1 injury : 36 athletes → 2.8% incidence
1 injury : 29 female athletes → 3.4% incidence
1 injury : 50 males athletes → 2% incidence

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ACL Healing Research

- In general, healing potential is believed to be **poor**
- However, some patients who delay surgery demonstrate ACL healing on MRI (Costa-Paz, 2012)
- Up to 50% of patients with delayed surgery demonstrated healing on MRI as early as 3 months after injury (Filbay, 2022)
  - Patients with healing on MRI had better PRO
  - Patients without healing on MRI were more likely to undergo ACLR
- In research where surgery is delayed in favor of rehabilitation, ~50% of patients opt for surgery within 2-5 years (Frobell, et. al., 2013 & Reijman, et. al., 2021)
  - ACLR knees were objectively more stable on testing
  - Better PRO between ACLR and unrepaired knees (Reijman, 2021 & Beard, 2022)
  - No difference in OA in knees between ACLR and unrepaired knees

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ACL Deficiency

- 10-20% can successfully be treated non-operatively
- Usually demonstrate ACL healing on MRI at 3 months
- Longer RTP if non-surgical
- Effects of ACL Deficiency Include:
  - Decreased Proprioception
  - Increased Joint Laxity
  - Increased Functional Knee Instability
  - Increased Risk to Secondary Structures
  - Increased Articular Cartilage Injury (OA)
  - Increase Risk of Ipsilateral Knee Surgery in Future (Ding, et. al., 2022)
- What are key muscular stabilizers of ACL "Copers"?
  - Quadriceps, Hamstrings, Gluteal Muscles, **Gastrocnemius**

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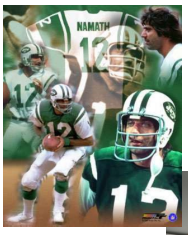
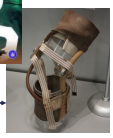
History of ACL Surgery

- First performed in the 1890s
- Surgical techniques have changed over time
  - 1980's- Open Repair
  - Early 1990's- Arthroscopic Repair
  - Late 1990's- Reconstruction
  - 2020's- Repair
- ACL graft of choice has changed over time
  - Gortex (67% failure rate)
  - Allograft
  - Autograft
  - Repair





Namath's Lenox Hill ACL Brace in the Pro Football Hall of Fame

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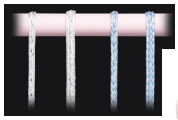
Reconstruct vs. Repair

- Recent discussion regarding repairing ACL as opposed to reconstructing ACL (repair for proximal ACL ruptures only)
- Advantages to repair:
  - Preserve insertion sites
  - Preserve ligament proprioception
  - Preserve cells
  - Good joint stability achieved
- Disadvantages to repair:
  - Poor surgical outcomes
  - Synovial fluid prevents fibrin clot
  - Collagen breaks down and failure rate is higher (10%)



Repair with internal brace augmentation

Wilson, et. al. Anterior cruciate ligament repair with internal brace augmentation: A systematic review. Knee. 2022; 35:192-200.

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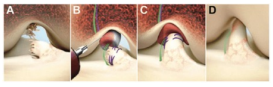
Overall repair techniques show promise, but more research is needed

Other Types of Repair

- Suture Anchor Repair for proximal avulsion injuries
  - Age impacts failure rate due to bony maturity and activity level
  - < 22 years = 37% failure rate
  - 22-35 years = 4.2% failure rate
  - > 35 years = 3.2% failure rate
- Bridge Enhanced ACL Restoration Implant
  - Suture repair and Bioactive scaffold to bridge across the tear
  - Effectively forms a sleeve around injured tissue
  - Early findings show outcomes comparable to ACLR at 2 years s/p repair



Murray, et. al. Bridge-enhanced anterior cruciate ligament repair is not inferior to autograft anterior cruciate ligament reconstruction at 2 years. Am J Sports Med. 2020; 48(6):1305-1315.

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Rehabilitation After BEAR Implant

- Strict bracing guidelines after repair surgery
  - Knee locked in extension for WB activity, Limits on knee flexion ROM
  - In hinged knee brace for ~8 weeks, then into functional ACL brace
- Range of motion limitations during first 6-8 weeks after repair
  - 0-45 degrees first 2 weeks, 0-90 degrees weeks 2-4, 0-110 degrees by week 8
  - Braced locked at 0 degrees for sleeping weeks 0-6
- **No PROM** into knee flexion for 12 weeks after surgery
- Initially rehabilitation is slower than with ACLR
- Later in the rehabilitation process, timelines are identical to ACLR
- RTA is expected at 9-12 months after repair

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Surgical Reconstruction Options

- Patellar Tendon Graft
- Quadriceps Tendon
- Hamstring (Semitendinosis & Gracilis) Graft
- Allograft

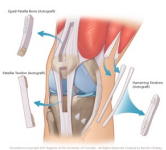
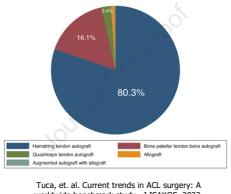


Figure 1: First choice of graft according to the percentage of respondents choice.



Tuca, et. al. Current trends in ACL surgery: A worldwide benchmark study. J ISAKOS. 2023.

ACLR does **NOT** 1) Guarantee return to previous level of participation, 2) Eliminate Pivot Shift, or 3) Prevent TFJ OA.

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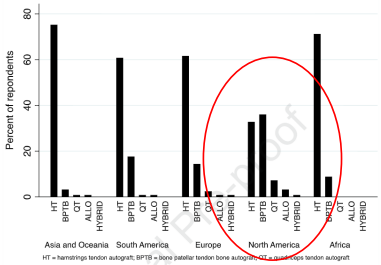
ACLR in North America vs. World

Figure 2: Percent of the respondents first choice of graft preferences by their location.



HT = hamstrings tendon autograft; BPTB = bone patellar tendon bone autograft; QT = quadriceps tendon autograft
ALLO = allograft; HYBRID = augmented autograft with allograft

Tuca, et. al. Current trends in ACL surgery: A worldwide benchmark study. J ISAKOS. 2023.

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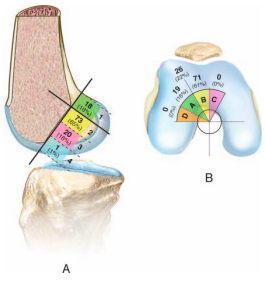
Graft Placement

- Graft placement during surgery is critical to surgical success
  - Primary cause of graft failure is surgical error during graft placement
  - Errors of as little as a few mm can cause graft impingement & failure
- Post-surgical knee ROM is affected based on graft placement
  - Graft placed too anterior on femur will limit knee flexion
  - Graft placed too anterior on tibia will limit knee extension



Marchant BG, et al. Prevalence of non-anatomical graft placement in a series of failed anterior cruciate ligament reconstructions. *Am J Sports Med* 2010; 38(10):1987-1996.

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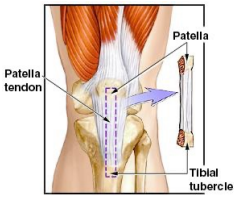
Patellar Tendon Graft (BPTB)

- Advantages
  - Early bone to bone healing at 6 weeks
  - Consistent size & shape of graft
  - Low failure rate
  - No increased risk of OA
- Disadvantages
  - Harvest Site Morbidity
  - Larger Incision / Scar
  - Difficulty Regaining Knee Flexion ROM
  - Patellar Tendinopathy
  - Anterior Knee Pain / PFP (secondary to patellar stiffness & lack of mobility)
  - Late Patellar Fracture
  - Pain with kneeling



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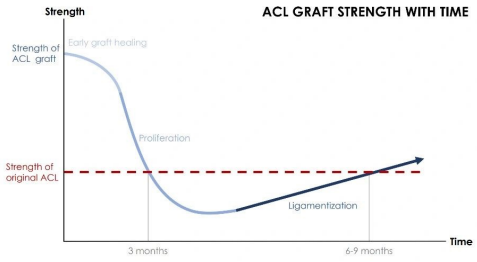
ACLR Graft Healing & Strength



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Henning, CE, et al (1985). An In Vivo Strain Gauge Study of Elongation of the ACL. Am J Sports Med; 13:22-26.
N=2 subjects... One reading indicates only one knee tested, range indicates two knees tested

ACL Strain During Activity

Activity	Relative ACL Strain (%)
Running Downhill at 5 mph	125%
Isometric Quad activity at 22 degrees flexion against 20# force	62-121%
Isometric Quad activity at 0 degrees flexion against 20# force	87-107%
Jogging at 5 mph	62-89%
SLR with knee in 22 degrees flexion	12-79%
Isometric Quad activity at 45 degrees flexion against 20# force	50%
Walking without assistive device	36%
Single leg, Half Squat	21%
Quad Set	18%
Walking with crutches (50# WB)	7%
Stationary Bike	7%
Isometric HS Contraction	-7%

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Rehabilitation After BPTB ACLR

- Focus on knee flexion ROM early in rehab
- Focus on patellar mobility to decrease risk of PFP
- Use caution with OKC and CKC strengthening due to increased risk of PFP
- Use caution when progressing in early stages of functional rehabilitation due to risk of late patellar fracture
- Failure rate at 1 year = 1.16% (Liukkonen, et al, 2022)
- Revision rate at 2+ years s/p ACLR = 2.38% (Hayback, et al, 2022)

Hayback G, Raas G, Rosenberger R. Failure rates of common grafts used in ACL reconstructions: A systematic review of studies published in the last decade. Trauma Surg. 2022; 142:3293-3299.
Liukkonen RJ, Ponkilainen VT, Reito A. Revision rates after primary ACL reconstruction performed between 1969 and 2018: A systematic review and metaregression analysis. Orthop J Sports Med. 2022; 10(8).

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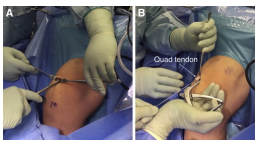
Quadriceps Tendon Graft

- Advantages
  - Minimal harvest site morbidity
  - Minimal acute post-operative pain
  - Little impact on Quad / HS strength
  - More customizable graft
  - More cosmetic scar
  - Lower Patellar Fracture Risk
  - Lower failure rates than HS Graft and BPTB
- Disadvantages
  - No bone plugs
  - Limited data regarding long-term outcomes



Equal Outcomes regarding knee stability, patient satisfaction, and PRO scores to other grafts

Xerogeanes JW. Quadriceps tendon graft for ACL reconstruction: The graft of the future! Arthroscopy. 2019; 35(3):696-697.

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Rehabilitation After QT ACLR

- Hinged ROM brace x 4-6 weeks
- Avoid hyperextension for first 2 weeks s/p repair
- Achieve terminal extension by end of week 2
- Primary focus on regaining quadriceps and hamstring strength
- No specific limitations beyond traditional ACL rehabilitation
- Anticipated RTA 8-12 months
- Failure rate at 1 year = 0.72% (Liukkonen, et al, 2022)

Liukkonen RJ, Ponkilainen VT, Reito A. Revision rates after primary ACL reconstruction performed between 1969 and 2018: A systematic review and metaregression analysis. Orthop J Sports Med. 2022; 10(8).

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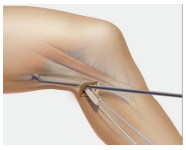
Semitendinosis & Gracilis Graft

- Advantages:
  - Four bundle graft is stronger & stiffer than PT
  - See maximum loads of grafts
  - Less anterior knee pain, no kneeling pain
- Disadvantages:
  - No bone-to-bone graft fixation
  - Higher failure rate
  - Bone to soft tissue healing longer than bone to bone healing (12 weeks vs. 6 weeks)
  - More difficult to harvest graft
  - Higher incidence of tunnel widening than BPTB (3 months after repair 2˚ aggressive rehab)
  - Permanent Loss of HS strength (10%)



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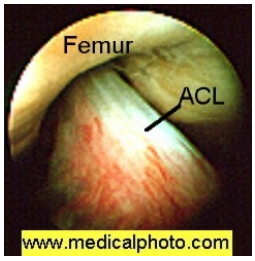
ST vs. BPTB Graft

- Graft Strength Issues
- (ST vs. ACL):
  - One strand = 70%
  - Four bundle =250%
- (ST vs. BPTB)
  - Four bundle = 200%
- Graft fixation
- Donor site morbidity
- Anterior knee pain
- Rehabilitation Outcomes



Single Bundle vs. Double Bundle (n=98, ages 18-52, s/p ACL Reconstruction at 2 years), researchers evaluated several measures to assess subjective & objective outcomes. DB group had 79% normal knee function, while SB group had 67% normal knee function. Authors found no statistically significant difference in outcomes between groups (Ahlden, M, et al 2013) .

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Rehabilitation After ST ACLR

- Slower progression during initial 3 months due to no bone-to-bone fixation
  - 12 weeks vs. 6 weeks for healing
  - Higher incidence of tunnel widening which can increase failure rates
- Delay strengthening of HS for first 6 weeks
- Increased focus on gastrocnemius strengthening due to HS deficit
- Failure rate at 1 year = 1.70% (Liukkonen, et al, 2022)
- Revision rate at 2+ years s/p ACLR = 2.71% (Hayback, et al, 2022)

Hayback G, Raas G, Rosenberger R. Failure rates of common grafts used in ACL reconstructions: A systematic review of studies published in the last decade. Trauma Surg. 2022; 142:3293-3299.
Liukkonen RJ, Ponkilainen VT, Reito A. Revision rates after primary ACL reconstruction performed between 1969 and 2018: A systematic review and metaregression analysis. Orthop J Sports Med. 2022; 10(8).

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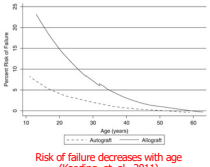
Allograft

- Advantages:
  - No harvest site morbidity
- Disadvantages:
  - Risk of Disease Transmission (HIV / HBV)
  - Weakened Graft secondary to Age / Radiation
  - Longer Graft to Bone Incorporation than BPTB
  - More Expensive
  - Low Risk of Rejection and/or Bacterial infection
  - Higher failure rates in collegiate athletes
  - USMA cadets with allograft were 7.7x more likely to suffer reinjury than BPTB (Pallis, et. al., 2012)
  - 3x failure rate compared to BPTB and worse outcomes for laxity, hop test, activity level, PRO (Kraeutler, et. al., 2013)



Risk of failure decreases with age (Kaeding, et. al., 2011)

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Rehabilitation After Allograft ACLR

- Faster immediate post-operative recovery
- Less post-operative pain
- Clinician may need to caution against patient accelerating rehabilitation process
- Anticipated RTA is 6-12 months
- Failure rate at 1 year = 1.76% (Liukkonen, et al, 2022)
- Revision rate at 2+ years s/p ACLR = 5.24% (Hayback, et al, 2022)

Hayback G, Raas G, Rosenberger R. Failure rates of common grafts used in ACL reconstructions: A systematic review of studies published in the last decade. Trauma Surg. 2022; 142:3293-3299.
Liukkonen RJ, Ponkilainen VT, Reito A. Revision rates after primary ACL reconstruction performed between 1969 and 2018: A systematic review and metaregression analysis. Orthop J Sports Med. 2022; 10(8).

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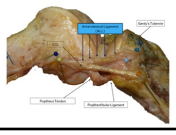
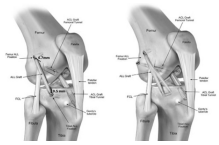
Alan, et. al. Lateral extra-articular tenodesis reduces failure of hamstring tendon autograft anterior cruciate ligament reconstruction: 2-year outcomes from the STABILITY study randomized clinical trial. Am J Sports Med. 2020; 48(2):285-297.

ACLR with Lateral Augmentations

- Common in younger patients (< 25 years)
- Lateral augmentation involves repair of the anterior lateral ligament and lateral capsule to improve knee kinematics and limit graft strain
- Injury to lateral structures results in high grade pivot shift
- High grade pivot shift is associated with higher risk of graft failure
- Clinical outcomes show less rotational laxity, fewer graft failures, no difference in strength or function at 2 years compared to ST graft without lateral augmentation





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ACL Infection Rates

- Infection rate for all ACLR is 0.50% (N=13,472)
- Infection rates are equal with allograft (0.49%, N=5,632) and autograft (0.51%, N=7840)
- Graft type (ST vs. BPTB) has no effect on infection rate

Stucken, C, et al. SportsHealth. 2013; 5(6):553-557.

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ACL Failure Rates

- Initial Reconstruction Failure Rate 1-8%
- Second Reconstruction Failure Rate 14%
- High Risk Sports Failure Rate ~25% (Wiggins, et. al., 2016)
- Causes of Failure
  - Surgical Repair
  - Biomechanics
- When do these occur?
  - Early post-op most likely due to graft fixation issues
  - 2-3 months s/p most likely due to graft strength (< 50% strength)
  - > 6 months s/p most likely due to repeated ACL MOI (plant & cut)

2011 Data from the Multicenter ACL Revision Study, Washington University & from the National Institute of Arthritis & Musculoskeletal & Skin Diseases

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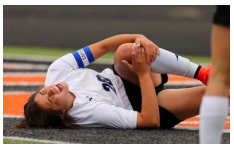
Adolescent ACLR Outcomes & Failure Rates



- 13% failure rate in adolescent ACLR
- 14% risk of contralateral ACL injury
- 80% return to pre-injury level of sport
- 7x increased risk before 9 months s/p
  - Compared to contralateral knee
- 50% decreased risk of ACL failure every month after 6 months s/p
- Passing Return to Sport Testing significantly reduces risk
- At two years s/p ACL risk is equal bilaterally

Saper M. ACL Reconstruction in the Adolescent Patient. Saper Sports Medicine, 2020.

Following ACLR, the risk of a second surgery on ipsilateral or contralateral knee is ~35% (Nestor, et. al., 2022)

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ACL Long-Term Outcomes

- Cleveland Clinic studied 1,592 s/p ACL repair patients over a ten-year period with 80% of patients following-up at 2, 6, and 10 years post-surgery
- Outcomes were measured for self-reported **sport activity**, **pain**, and **overall function**
- Findings showed that patients were statistically the same at each follow-up period in terms of pain and function (no drop off between 2 years and 10 years post-surgery)
- Patients did report decreased sport activity 10 years post-surgery compared to 2 years post-surgery
- Study also found that status between year 1 and year 2 post-surgery was unchanged (meaning rehabilitation in year one is critical to overall outcomes)

Spindler, K. ACL Repair Holds-Up Over Time. 2018.

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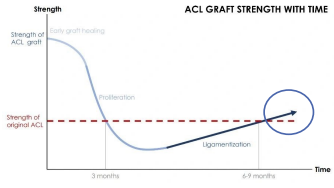
General ACL Return Timeline

- Return to Desk Work / School
  - 2-3 weeks
- Return to Manual Labor
  - 2-5 months
- Return to Sport
  - 8-12 months



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ACL Return to Sport Statistics

- A study of 314 recreational and competitive athletes (Australian Rules Football, Basketball / Netball & Soccer) revealed that at 39-months post-surgery for ACL reconstruction:
  - 44% had returned to sport at the same competitive level
  - 12% reported returning to sport at a decreased performance level
  - 44 % discontinued sport participation
- Common reasons for discontinuing sport participation included **fear of re-injury or less confidence in knee stability**

2011 Data from Arden, C. Research conducted at La Trobe University in Australia

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ACLR Return to American Football

- A systematic review of return to play (RTP) after ACLR in Division I and NFL players revealed:
  - RTP is position-specific
    - 67% of all players return to play
    - 60% of OL/DL return to play
    - 79% of RB and WR return to play
    - 90% of QB return to play
  - Mean time for RTP was 11.6 months
  - Considerable decline in overall performance noted between pre-repair versus post-repair

Ross BJ, Savage-Elliott I, Brown SM, Mulcahey MK. Return to play and performance after primary ACLR in American football players: A systematic review. Review Orthop J Sports Med. 2020; 8(10):29.

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High School & College ACL RTP Statistics

High School ACL Statistics
28% do not RTP
26% RTP but do not RTL
45% RTP and RTL

Collegiate ACL Statistics
33% do not RTP
29% RTP but do not RTL
38% RTP and RTL

RTP= Return to Play
RTL= Return to Level

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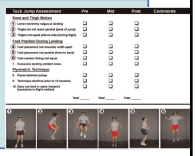
RTP Testing

Isokinetic Testing
Lateral Step Down Test
Y-Balance Test
Single Leg Hop Testing
Tuck Jump Test
Drop Vertical Jump Test



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Isokinetic Testing

Time s/p Surgery	ACL Graft Strength	Quad Strength (%)
0-8 weeks	100% plus	N/A
12 weeks (1st test date)	80%	60%
16 weeks	50%	80%
24 weeks	70%	90%
36 weeks	90%	100%
1 Year	100%	100%

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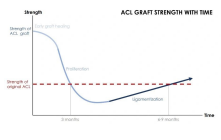
Bracing Philosophies

- Determined by physician & patient
- Factors to consider:
  - Activity level of patient
  - Post-surgical knee stability
  - Secondary structures injured
  - Anatomical predisposition to injury
  - Lower extremity strength
  - Surgical procedure performed
- "One-year rule of thumb"



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