Evaluation and Treatment of Pediatric ACL Injuries

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- July 18, 2018

Disclosures

- No disclosures

Outline

- Epidemiology
- Anatomy
- Skeletal Maturity
- Alignment
- Growth Arrest
- Basic Science
- Non-operative Treatment
- Operative Treatment Techniques
- New Technology on the Horizon

Reasons for Increased Incidence

- Increased participation at higher levels of competition at younger ages.
- Effects of Title IX (effectively doubled denominator)
- Societal/Parental Pressures
- College Scholarship drive
- Single Sport Emphasis
- Increased awareness, higher index of suspicion, improved recognition

20 Yr History Pediatric ACL Reconstruction in NY

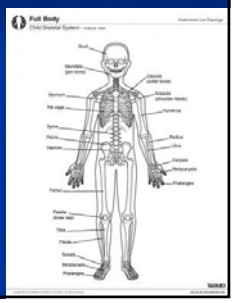
- Dodwell et al, AJSM 42, 2014
  - SPARCS Database Review 1990 – 2009
  - Rate of ACLr ages 3-20
  - 1990 = 17.6/100,000 population
  - 2009 = 50.9/100,000 population
  - Steadily increasing rate of ACLr in the young population

Injury by Sport

- Highest rate ACL injury: ♀ soccer players
  - Incidence 14.08/100,000
- Second highest: ♂ football players
  - Incidence 13.87/100,000 exposures

Comstock et al.: Summary Report: National High School Sports-related Injury Surveillance Study. 2009-2010 School Year. Available at: http://www.nationwidechildrens.org/Document/Get/103353.

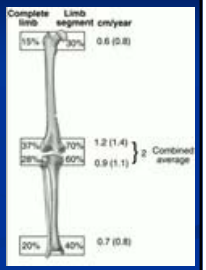
Pediatric Anatomy



Anatomy

Physeal Facts about the Knee

- Distal Femoral Physis
  - 70% total length of femur
  - 37% total length of leg
  - 1 cm (0.375 in) growth per year
- Proximal Tibial Physis
  - 55% total length of tibia
  - 25% total length of leg
  - 0.64 cm (0.25 in) growth per year



Stanitski CL: Correlation of arthroscopic and clinical examinations with magnetic resonance imaging findings of injured knees in children and adolescents. *Am J Sports Med* 1998;26:2-6

Skeletal Maturity

- Concern for physeal injury in ACL reconstruction
- Growth Spurt initiation
  - 12.5 years in boys
  - 10.5 years in girls
- Peak Growth Velocity
  - 1 year later
  - Precedes menarche in girls
- Tanner Staging
- Bone Age
  - Hand Xray

Corey R. Troxell, D.O., Pediatric ACL injuries, OMED 2012

Skeletal Maturity

Tanner Stages of Physiologic Maturity

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Boys					
Growth	5–6 cm/y	5–6 cm/y	7–8 cm/y	10 cm/y	None
Testes, penis	Testes: <4 mL or <2.5 cm	Testes: 4 mL or 2.5–3.5 cm; penis usually not yet enlarged	Testes: 12 mL or 3.6 cm; enlargement, lengthening of penis	Testes: 4.1–4.5 cm; increased size and breadth of penis	Testes fully mature in shape and size
Pubic hair	None	Sparse, at base of penis	Pubic hair over pubis; darker, coarser, and more curled	Adult-like, but over a smaller area	Fully mature in type and quantity, extending to the thighs
Girls					
Growth	5–6 cm/y	7–8 cm/y	8 cm/y	7 cm/y	None
Breasts	No development	Buds	Elevation and areolar enlargement	Areolae and papillae form secondary mound	Mature
Pubic hair	None	Sparse, on labia; slightly pigmented	On mons pubis; darker, coarser, and more curled	Adult-like, but over a smaller area	Fully mature in type and quantity, extending to the thighs

Frank & Gambacorta. JAAOS 2013.

Basic Science Growth Plates

THE EFFECT OF INTRA-ARTICULAR ACL RECONSTRUCTION ON THE GROWTH PLATES OF RABBITS

V. GUZZANTI, F. FALCIGLIA, A. GIGANTE, C. FABBRICIANI

From the Catholic University of the Sacred Heart and the Children's Hospital 'Bambino Gesu' Institute of Scientific Research, Rome, Italy

- Rabbit Model
- Risk of Growth Arrest
  - related to size of drill hole
- > 7% total physeal volume yields arrest
- Tibial side
  - 12% frontal plane
  - 4% cross-sectional area
- Femoral Side
  - 11% frontal plane
  - 3% cross-sectional area

Other Drilling Effects

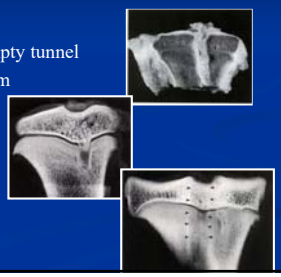
- Graft Radius
  - May be most important factor affecting physeal volume
  - Increase in hole diameter from 6 mm to 11mm increases volume % removed from 2.3% to 7.8%
- Drill Angle
  - Increased drill angle = decreased volume removed
  - 45º angle to 70º angle reduces volume removed from 4.1% to 3.1%
  - 0.2% decrease in volume removed for each 5º angle increase

Histological changes of semitendinosus autograft after anterior cruciate ligament reconstruction in an immature rabbit model.
Giordano M, Falciglia F, Poggiaroni A, Aulisa AG, Savignoni P, **Guzzanti** V. J Exp Orthop. 2015 Dec;2(1):17. doi: 10.1186/s40634-015-0033-1. Epub 2015 Aug 28.

Effect of Drilling and Soft Tissue Grafting Across Open Growth Plates

Ross et al, AJSM 23, 1995

- Dog Model Study
  - fascia lata graft vs empty tunnel
  - sacrificed at 2 wks/4 m
  - Non-grafted animals
    - 100% bone bridges
  - Grafted animals
    - 0% bone bridges
    - no limb length



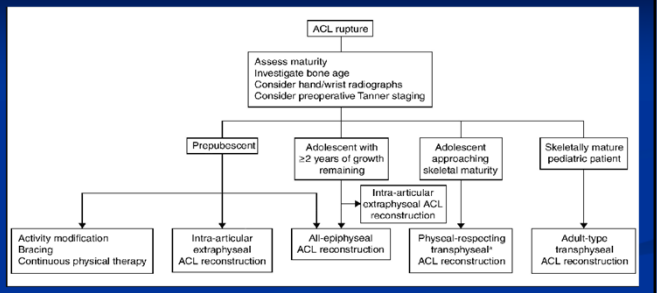
Basic Science

- Factors Found to Increase Physeal Injury=
  - Large Tunnel diameter (>12mm)
  - Oblique Tunnel Positioning
  - Inteference Screw Fixation
  - High-speed Tunnel Reaming
  - Lateral Extra-Articular Tenodesis
  - Dissection Close to Perichondral Ring of LaCroix
  - Suturing Near Tibial Tubercle

Pediatric ACL Tx Options

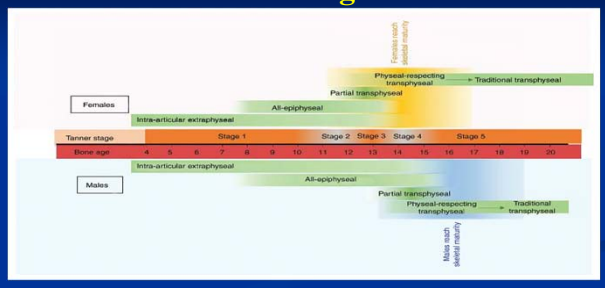
- Non-operative
- Physeal-sparing Recon
- Partial Transphyseal Recon
- Complete Transphyseal Recon

Treatment Algorithm



Frank & Gambacorta. JAAOS 2013.

Treatment Algorithm



Conservative Management

- Conservative management of skeletally immature patients with complete ACL injuries
  - Low success rate
- High noncompliance rate
  - Associated with secondary damage of menisci and/or articular cartilage
- Large percentage of patients eventually require surgical reconstruction

McCarroll JR, Rettig AC, Shelbourne KD. Anterior cruciate ligament injuries in the young athlete with open physes. Am J Sports Med 1988;16(1): 44–7.
Mizuta H, Kubota K, Shiraishi M, et al. The conservative treatment of complete tears of the anterior cruciate ligament in skeletally immature patients. J Bone Joint Surg Br 1995;77(6):890–4

Non-Operative

- Activity modification
  - Prohibit team sports
  - Prohibit jumping/pivoting
- Functional bracing
- Strengthening and Physical rehabilitation
- Wait for physes to close/nearly close

- **Ideal candidate**: highly compliant, low-demand patient without additional intra-articular pathologies or pt with partial ACL tear.

Frank & Gambacorta. JAAOS 2013.
Corey R. Troxell, D.O., Pediatric ACL injuries, OMED 2012

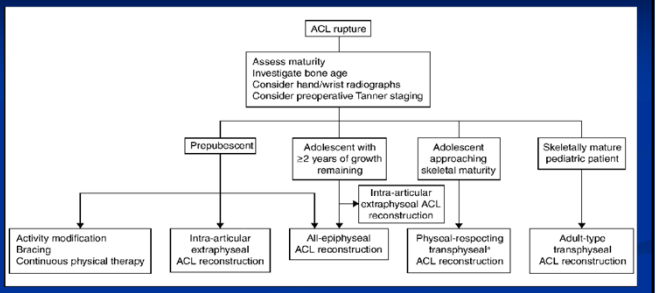
Natural History

- Graf et al, Arthroscopy 8, 1992
- Janarv et al, J Ped Orthop 16, 1996
- Mizuta et al, JBJS 77, 1995
  - Instability symptoms, decreased activity level
  - Resulting meniscal tears
  - Subsequent need for ACL reconstruction
- McCarroll et al, AJSM 1988, 1994
  - 38 Tanner stage 1,2 treated non-op
    - 27/38 developed meniscal tears

Effects of Treatment Delay

- Guenther et al, CORR 472, 2014
  - 112 adolescent ACLs treated non-op
  - Bucket handel MMT more common if Rx delayed > 1 yr (p <0.013)
  - Medial meniscus "survival" declined sharply greater then 1 yr after injury

Treatment Algorithm



Frank & Gambacorta. JAAOS 2013.

Partial Tears

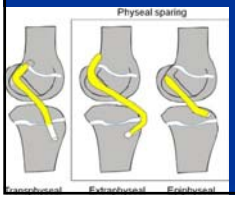
- Difficult to diagnose
- Typical diagnostic maneuvers may be negative with up to 75% disruption/tear
  - Hole et al. AJSM 1996.
- Oblique coronal MRI images helpful in determining percentage of intact fibers

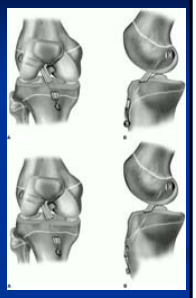
Partial Tears

- Kocher et al. AJSM 2002.
  - 45 pts <18yo treated non-op for partial tear
  - Diagnosed via PE, MRI, and arthroscopy
  - Partial tears occur in 61% of adolescents
  - Minimum 2 yr F/U, 31% underwent ACL recon
  - Risk factors for failure:
    - >50% of the midsubstance ligament width
    - Tears predominantly involving the posterolateral bundle
    - Mildly positive pivot shift test
    - Older chronologic and skeletal age
- Conclusion: Partial ACL tears in children and adolescents aged ≤14 years with near normal Lachman and pivot shift tests may be managed nonsurgically

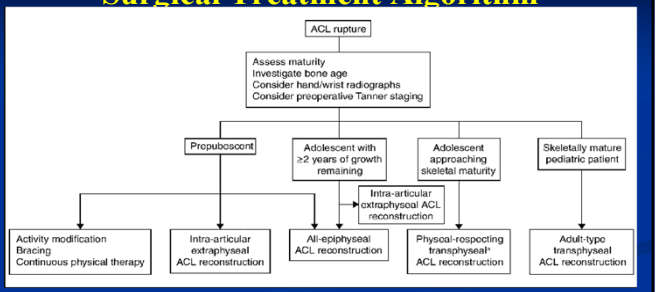
Surgical

- Physeal sparing
- Partial transphyseal
- Transphyseal.





Surgical Treatment Algorithm

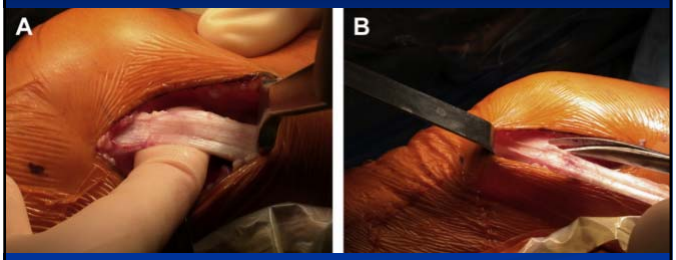


Physeal-Sparing

- Indications
  - Prepubescent Child
  - Tanner stage 1-2
  - Skeletal Age <11 Female, <12 Male

- Micheli LJ, Rask B, Gerberg L. Anterior cruciate ligament reconstruction in patients who are prepubescent. Clin Orthop Relat Res 1999;(364):40–7.
- Kocher MS, Garg S, Micheli LJ. Physeal sparing reconstruction of the anterior cruciate ligament in skeletally immature prepubescent children and adolescents. J Bone Joint Surg Am 2005;87(11):2371–9

Surgical



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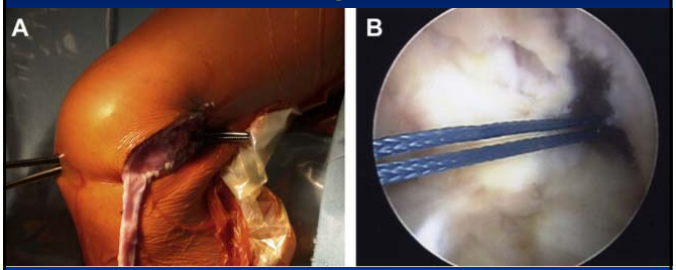
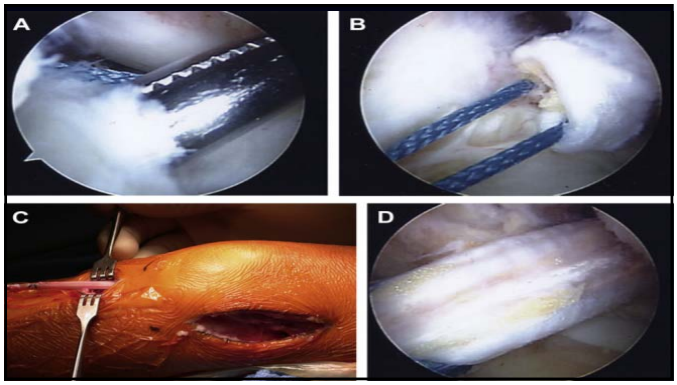
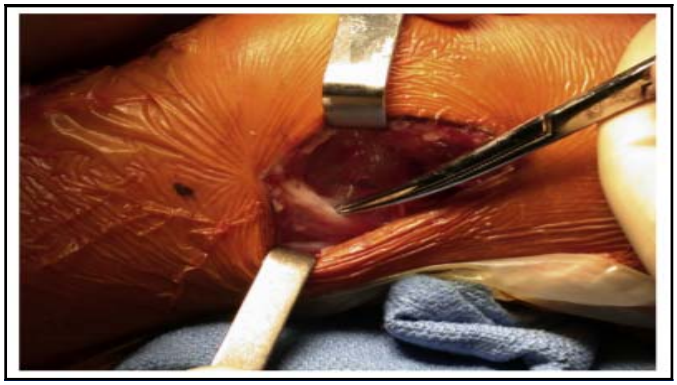
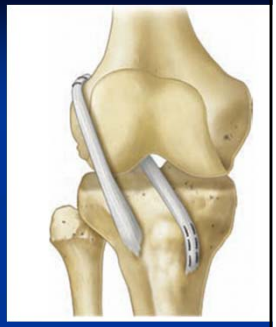






Results

Retear rate=4.5%
Arthrofibrosis=2%
IKDC=96.7
Lysholm score=95.7
No growth disturbances.



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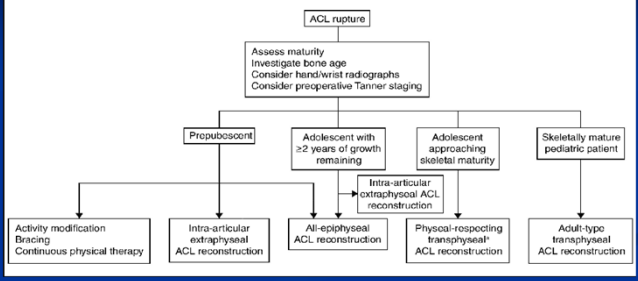
Surgical Treatment Algorithm



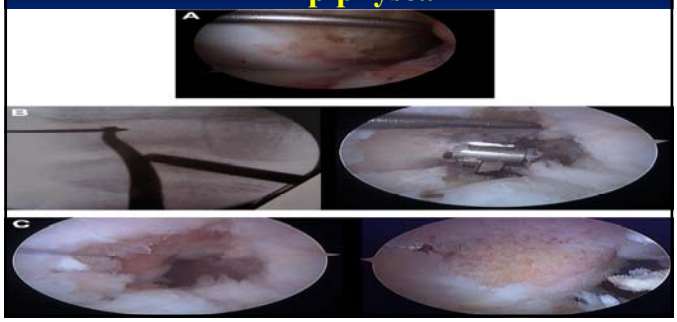
All Epiphyseal

- Indications
  - Adolescent with >2 years growth remaining
  - Tanner stage 2-3
  - Skeletal Age 10-12 Female, 11-13 Male

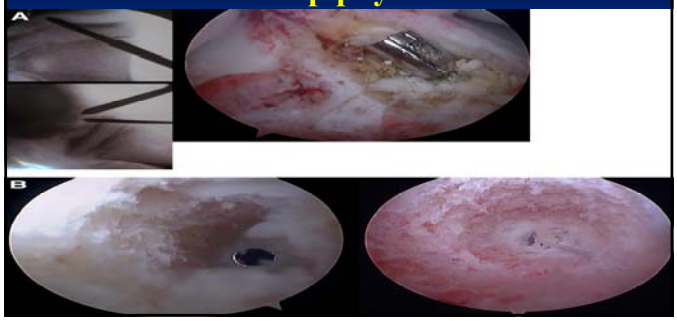
- Micheli LJ, Rask B, Gerberg L. Anterior cruciate ligament reconstruction in patients who are prepubescent. Clin Orthop Relat Res 1999;(364):40–7.
- Kocher MS, Garg S, Micheli LJ. Physeal sparing reconstruction of the anterior cruciate ligament in skeletally immature prepubescent children and adolescents. J Bone Joint Surg Am 2005;87(11):2371–9

All Epiphyseal

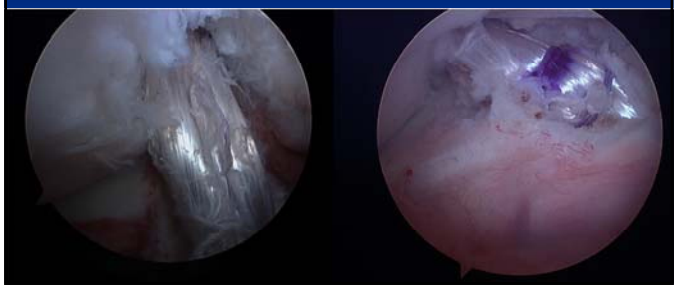
All Epiphyseal



All Epiphyseal



All Epiphyseal

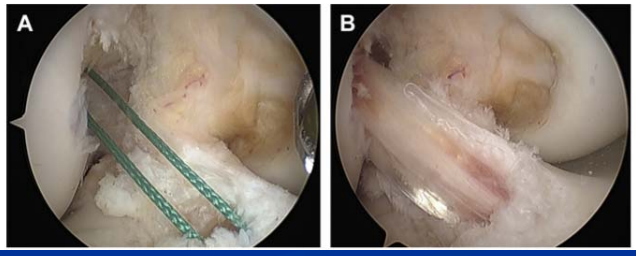


All Epiphyseal

Surgical

- Pubescent Patient
  - Tanner Stage 3-4
  - Skeletal age Females 12-14, males 14-16

Surgical

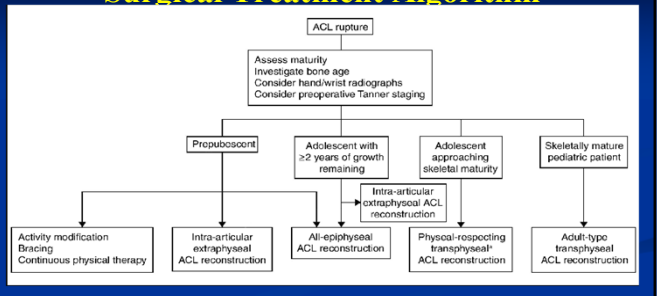


Results

- Retear Rate=3%
- IDKC Score=90
- Lysholm Score=91
- No limb length or angular deformities

Kocher MS, Smith JT, Zoric BJ, et al. Transphyseal anterior cruciate ligament reconstruction in skeletally immature pubescent adolescents. J Bone Joint Surg Am 2007;89(12):2632–9.

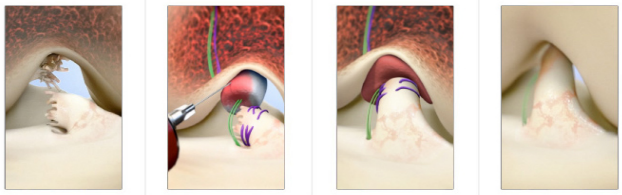
Surgical Treatment Algorithm



ACL Repair

BEAR

Fig. 1	Fig. 2	Fig. 3	Fig. 4
Torn ACL	Place BEAR™ implant between torn ACL ends. Add blood.	Pull torn ACL ends into imlplant with stitches.	Healing ACL tissue replaces BEAR™ implant.



The End

Rehabilitation Protocols

Anderson et al. Sports Health 2009

- Phase 1:
  - POD 0- isometric quad contraction and straight leg raises
  - POD 1- Begin ROM, prone hamstring stretches, WBAT with crutches
  - Week 1 goal- ROM 0-90 degrees
- Phase 2: (weeks 2-11)
  - AROM, patellar mobilization, electrical muscle stimulation
  - Goal- Full ROM at 6 weeks
- Phase 3: (12-20 weeks)
  - Jogging in line, plyometric exercises, sport cord. Exercises
- Phase 4: (16-20 weeks)
  - Full running
- Goal is full sport participation at 28 weeks

Protocols

- Lawrence et al. CORR 2010
  - Cryotherapy and CPM x 2 w
  - Partial weight bearing in locked brace x 6 weeks
  - Goal is return to sport in 6-9m
  - Recommend functional bracing for 2years

Rehab

- Greenberg et al. Sports Health 2014
  - Retrospective review of all patients 7 to 15 yo who underwent AE ACLR by a single surgeon (TJG)
  - 47 patients eligible, 16 patients had complete data
  - Isokinetic strength testing, functional hop test
  - Avg age 12.2 (all tanner stage 2 or lower)
  - Autologous hamstring used for all patients

- Evaluation at 7.1m post-surgery
  - 9/16 (56.25%) patients had satisfactory quadriceps strength
  - 15/16 (94%) patients had satisfactory hamstring strength
- At mean 12.8m post-op
  - 6/16 (38%) were able to achieve satisfactory performance of >90% on all functional tests
- At mean 15.4m post-op
  - only 4/16(25%) had >90% on all testing parameters (functional and strength)

- Conclusions
  - Significant quadriceps strength and functional performance deficits may exist within this population
  - More difficult to regain quadriceps strength than hamstring strength, despite use of hamstring autograft

If using isokinetic strength and unilateral hop testing performance of at least 85 to 90% to return to sport then they would only have 25% meet that criteria at 15 months

Rehab

- Proper rehabilitation after ACL reconstruction in the skeletally immature patient is extremely important to ensure an excellent outcome and a successful and timely return to sports
- Important to have therapists who are experienced working with young patients to make therapy sessions engaging and beneficial.
- Activity restrictions and compliance with graduated activity levels are critical to successful outcomes.
- Must have full cooperation from parent, teachers, and caregivers.

Rehab

- ROM brace for 6 weeks post-op
- IT band ACL reconstruction restricted to TTWB for 6 weeks
- Transphyseal technique restricted to TTWB for 2 weeks
- Progressive rehabilitation first 3 months:
  - ROM
  - Closed- chain quadriceps and hamstring strengthening
  - Patellar mobilization
- At 3 months:
  - Straight-line jogging
  - Plyometrics
- Full return to cutting and pivoting activities and sports allowed at approximately 6 months postoperatively
- ACL brace is advised during sports activities for the first 2 years postoperatively

Frank & Gambacorta. JAAOS 2013.

Rehab