Background

ACI is a two stage surgical procedure indicated for medium to large (>2 cm\(^2\) but ≤12 cm\(^2\)) symptomatic full thickness chondral lesions. During stage one, a small sample of healthy cartilage is harvested from a non-weight bearing or limited weight-bearing portion of the knee. Harvested chondrocytes are cultured with a combination of growth factors, and incubated to allow for proliferation. During stage two, the articular defect is debrided back to an area with vertical margins. The area of defect is covered with a collagen flap and the harvested chondrocytes are implanted under the flap.

Distal patellar realignment is a generic term used to describe an osteotomy of the tibial tubercle in which the tubercle is moved anteriorly (anteriorization), anteriorly and medially (anterioromedialization aka "Fulkerson Procedure"), or anteriorly and laterally (anteriorlateralization). Distal patellar realignments are performed to achieve optimal PF alignment in cases where a malalignment exists. A combination of an anteriorization may be performed even in the absence of malalignments in order to decrease contact forces across the PF joint and increase the longevity and efficacy of the ACI.

Disclaimer

Progression is time and criterion-based, dependent on soft tissue healing, patient demographics, and clinician evaluation. Contact Ohio State Sports Medicine at 614-293-2385 if questions arise.

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### Summary of Recommendations

#### Risk Factors
- ACI requires extensive rehabilitation and can often exhaust insurance approved PT visits. Consider decreasing initial visit frequency with use of home NMES and daily self-ROM.
- Long-term quadriceps strength deficits typically present >1 year post operatively.

#### Precautions

<table>
<thead>
<tr>
<th>Weight Bearing</th>
<th>Brace</th>
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<tr>
<td>0-2 wks: Non-weight bearing (NWB), brace locked in extension</td>
<td>0-4 wks: locked in full extension while sleeping 4-6 wks: unlocked while sleeping</td>
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<td>2-4 wks: 20% weight bearing (WB), brace locked in extension</td>
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<tr>
<td>4-5 wks: 50% WB, brace locked in extension</td>
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<tr>
<td>5-6 wks : 75% WB, brace locked in extension</td>
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<tr>
<td>6-8 wks: WBAT (weight bearing as tolerated) (per MD), brace unlocked if adequate quad control. Gradually wean from brace.</td>
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<tr>
<th>Range of Motion</th>
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<tr>
<td>Day 1 post-ACI: 0°- 40/60° with CPM</td>
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<tr>
<td>3-4 wks: 0-60°</td>
</tr>
<tr>
<td>4-5wks: 0-105°</td>
</tr>
<tr>
<td>6-8wks: 0-120°</td>
</tr>
<tr>
<td>8-10 wks: 0-135°</td>
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**Know the location of the defect:** during loaded and strengthening activities, protect the ROM that places greatest stress on the graft for 4-6 months (Refer to Appendix A)

#### Manual Therapy
- Patellar mobilization in all planes
- Tibiofemoral joint mobilizations
- Knee extension/flexion ROM
- Scar massage
- Soft tissue mobilization

#### Corrective Interventions
- Early NMES (neuromuscular electrical stimulation) for quadriceps activation (recommend home unit purchase/rental)
- Aquatic therapy for gait and exercise
- Neuromuscular re-education for balance and correction of faulty mechanics
- Therapeutic exercise and neuromuscular re-education for LE strength (focus on quadriceps)
- Long-term precautions for high risk activities

#### Outcome Testing
- Isometric quadriceps and hamstring testing at 60° flexion at 6 months
- Isokinetic quadriceps and hamstring testing at 60°/sec and 300°/sec at 9 months
- Functional testing (when appropriate):
  - Forward step down
  - SL hop testing
    - Hop for distance
    - Triple Crossover
    - 6 meter timed
- Patient reported outcome measures:
  - KOOS (Knee Injury and Osteoarthritis Outcome Score)
  - IKDC (International Knee Documentation Committee)
Criteria for discharge with return to sport (9-24 months)

1) Functional Test
   a. 90% limb symmetry with SL hop for distance, SL triple crossover hop, and SL 6-meter timed hop
2) Isokinetic Test
   a. 90% quadriceps and hamstring limb symmetry
3) Patient reported outcome measures
   a. Score ≥90% on KOOS and IKDC
4) Ability to complete sport-specific drills with correct mechanics, no pain, and no reactive effusion.

Criteria for discharge from PT are less rigorous for those not returning to sport. Ensure the PT is able to perform all ADLs and recreational activities without pain, reactive effusion, and with appropriate functional mechanics.
### Phase I: Protection (Post-ACI – 0-6 weeks)

#### ROM
- Initiate CPM (continuous passive motion machine) day 1 post-ACI for 8-12 hour/day
  - PF lesion <6.0 cm²: 0°-60°
  - PF lesion >6.0 cm²: 0°-40°
- Progress CPM ROM 5°-10° per day
- May continue CPM up to 6 wks for total of 6-8 hours/day
- Patellar mobilization in all planes 4-7 times/day
- PF lesions: knee ROM
  - Achieve/maintain full passive knee extension immediately
  - 3-4 wks: 0-90°
  - 4-6 wks: 0-105°
- Stationary bike ½ revolutions without resistance (maintain ROM restrictions)
- Hamstring and calf stretching

#### Weight Bearing / Gait
- 0-2 wks: NWB with brace locked in extension
- 2-4 wks: TTWB brace locked in extension
- 4-5 wks: 50% WB brace locked in extension
- 5-6 wks: 75% WB brace locked in extension
- Weight shifts, multidirectional

#### Strength
- Quad sets
- TKE: prone or partial WB
- SLR: multiple planes (emphasis of no extensor lag) | Use brace if inadequate quad control
- Multi-angle hamstring isometrics
- No open chain knee extension
- No squatting

#### Neuromuscular Control
- NMES to quad in full extension 5-7 times/week (refer to Table 2)
- Glute activation
- Lower abdominal activation (i.e. transverse abdominis)
- Double leg balance/proprioception within WB restrictions

#### Goals to Progress to Next Phase
- ROM: 0-120°
- Strength:
  - Quad set with superior patellar translation
  - 20 SLR with minimal to no extensor lag
- Effusion: 2+ or less with Modified sweep test
- No symptom exacerbation with PWB activities
## Phase II: Mobility (Weeks 6-12)

### ROM
- 6 weeks: 0-120°
- 8 weeks: 0-135°
- Soft tissue mobilization
- Patellar mobilization in all planes
- Stationary Bike: full revolutions (progressively add resistance)

### Weight Bearing / Gait
- 6-8 wks: WBAT with brace unlocked (per MD)
- Pool walking/aquatic exercises
- Weight shifts: multidirectional
- Focus on normalization of gait pattern
- 10-12 wks: initiate treadmill walking program

### Neuromuscular Control
- Continue NMES to quad in full extension 5-7 times/week (refer to Table 2)
- Progress into single leg balance/proprioception
- Correct mechanics with functional tasks (i.e. step ups, heel taps, squats)

### Strengthening
- Progress WB exercises
- 6 wks: calf raises
- 6 wks: Isometric leg press (multiple angles)
- 7-8 wks: PWB leg press
- 7-9 wks: initiate active open chain knee extension 90°-0° | Slowly add resistance; pay close attention to the presence of pain and/or reactive effusion
- 7-8 wks: PF lesion: initiate active open chain knee extension 90°-45° (or in a ROM that does not allow for articulation of the lesion) without resistance (refer to Appendix A)
- 8 wks: mini-squats 0°-45°
- 9-10 wks: initiate double and single leg weight bearing squat progression (i.e. wall squats, step ups/downs, etc.) | only perform if able to demonstrate correct mechanics
- Progress glute strengthening (i.e. side steps, clamshells, bridges)
- Progress hamstring strengthening (i.e. HS curls, HS bridges)
- Stationary bike: progress resistance as tolerated

### Goals to Progress to Next Phase
- ROM: 0-135°
- Gait:
  - Non-antalgic gait without use of assistive devise
  - Able to walk 1-2 miles or bike for 30 min without pain or reactive effusion
- Strength: Single leg heel tap repetitions 20-30% of contralateral extremity in 30 seconds with good form
- Balance: Single leg stance on stable surface ≥ 30 seconds
- Effusion:
  - 1+ or less with Modified stroke test
  - No reactive effusion with WB exercises
# Phase III: Remodeling (Weeks 12-24)

### ROM
- Continue ROM interventions as needed

### Gait / Cardiovascular
- Bicycle
- Elliptical
- Stairmaster
- Swimming

### Neuromuscular Control
- Continue NMES if still demonstrating poor quad control (refer to Table 2)
- Progress balance/proprioception activities as tolerated

### Strengthening
- Progress WB exercises (i.e. single leg closed chain activities, step ups, step downs/heel taps)
- Leg press (0°-90°)
- Bilateral FWB squats (0°-60°)
- 12 wks: Progress active open chain knee extension 90°-0°
  - Progress resistance every 2 wks beginning at wk 20 if no pain or crepitation; pay close attention to pain and reactive effusion
  - Resisted walking (i.e. forward, lateral, retro)
  - Progress HS strengthening (i.e. single leg dead lifts, HS curls, HS bridges)

### Maintenance program: (independently performed)
- Initiate at weeks 16-20 and perform 2-3 times a wk (use to progress strength independently and conserve available PT visits until patient is appropriate to progress to more advanced activities)
- Cardiovascular (i.e. elliptical, bike, stair stepper, swimming)
- Progressive walking program
- Aquatic exercises for entire lower extremity
- Leg press (i.e. SL, DL, concentric, eccentric, isometric holds)
- Squats: SL and DL
- Knee extension
- Glute strengthening
- Functional activities: step ups, heel taps
- Stretching: quadriceps, hamstrings, calf

### Goals to Progress to Next Phase
- ROM: full pain free ROM
- Strength: Isometric testing at 60° flexion
  - Hamstrings 80% limb symmetry of contralateral extremity
  - Quadriceps: 80% limb symmetry of contralateral extremity
- Functional Performance:
  - Perform 5 forward step downs from 20 cm step with ≤1 error (refer to Appendix B)
- Effusion:
  - Trace or less with Modified stroke test
  - No reactive effusion with WB exercises
Phase IV: Return to Sport/Activity (Months 6-24)

### ROM
- Continue ROM interventions as needed

### Gait / Cardiovascular
- 6 months: treadmill/level ground walking with incline
- 9-12 months: initiate walk-jog program with progression to running program
- Initiate walk-jog progression **only if** the patient demonstrates:
  - Quadriceps and hamstring strength ≥ 80% of contralateral extremity
  - Full pain free ROM
  - Normal landing mechanics and single leg squat pattern
  - Audible rhythmic strike patterns and no gross visual antalgic pattern
- 9-12 months: initiate walk-jog program with progression to running program

### Neuromuscular Control
- Continue NMES if quad strength is less than 80% of contralateral extremity
- Emphasis on correct landing mechanics with DL and SL tasks
- Good balance when landing on unstable surfaces

### Strengthening
- Continue to progress open and closed chain LE strengthening with emphasis on quadriceps and hamstring
- 8 months: initiate light PWB plyometrics on Shuttle and slowly progress (i.e. DL, DL rotational, alternating jogging, SL)
- 9 months: initiate light FBW plyometrics and slowly progress (i.e. DL vertical jumps, SL vertical jumps, tuck jumps, split jumps)
  - Avoid box plyometrics for first 12 months

### Functional Performance
- 10 months: initiate light agility drills and slowly progress (i.e. agility ladder, DL line jumps, side shuffle, SL line jumps)
  - Progress agility as tolerated and begin to tailor to sport specific demands
- 11-12 months: Multidirectional running with cutting

### Goals to Return to Sport/Discharge (9-24 months)
- Strength: Isokinetic test at 300°/sec and 60°/sec
  - 90% limb symmetry for quadriceps and hamstring strength
- Functional Performance:
  - 90% limb symmetry with SL hop for distance, SL triple crossover hop and SL 6-meter timed hop
  - Ability to complete sport-specific drills with correct mechanics, no pain and full confidence
- Effusion: Zero to trace effusion with Modified stroke test
  - No reactive effusion with sports specific drills

### Suggested Return to Sport Timelines
- **Low-impact sports**: swimming, skating, rollerblading and cycling; 8 months
- **High-impact sports**: jogging, running and aerobics
  - 9-11 months for smaller lesions (≤4 cm²)
  - 10-12 months for larger lesions (≥4 cm²)
- **Higher-impact sports**: soccer, tennis, basketball, football, gymnastics, volleyball and baseball; 16-24 months

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**THE OHIO STATE UNIVERSITY**
WEXNER MEDICAL CENTER
Appendix A: Patellofemoral Articulations

During strengthening and WB activities avoid/limit articulation of the defect/graft site for the first 4-6 months in order to limit sheer and compressive forces which, in excess, are detrimental to the proliferation and differentiation of chondrocytes.

- 0-40° flexion: avoid if graft site is inferior patella or superior trochlea
- >45° flexion: avoid if graft site is middle/superior patella or inferior trochlea

Table 1: Patellofemoral Articulations Throughout Range of Motion

<table>
<thead>
<tr>
<th>Distal Femur/Trochlea</th>
<th>Patella</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram of Distal Femur/Trochlea" /></td>
<td><img src="image2" alt="Diagram of Patella" /></td>
</tr>
</tbody>
</table>

Table 2: Parameters for Neuromuscular Electrical Stimulation of the Quadriceps

<table>
<thead>
<tr>
<th>Pad Placement</th>
<th>NMES Parameters</th>
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<tbody>
<tr>
<td>Pulse duration/width (microseconds)</td>
<td>300</td>
</tr>
<tr>
<td>Frequency (Hz or pps)</td>
<td>55</td>
</tr>
<tr>
<td>On/off time (seconds)</td>
<td>12-15 on/50 off</td>
</tr>
<tr>
<td>Ramp time (seconds)</td>
<td>2-3</td>
</tr>
<tr>
<td>Treatment time (minutes)</td>
<td>15-20 minutes</td>
</tr>
</tbody>
</table>
Appendix B: Forward Step Down Test

Instructions:
- Have the patient stand with involved limb at the end of a 20 cm box (height), with hands on hips.
- Patient should achieve 60° of knee flexion on extremity being tested (raise or lower step height accordingly)
- Ask the subject to lower on involved limb so that their contralateral heel taps the ground.
- Perform 5 repetitions
- Observe hip, knee and ankle position and score according to errors listed below.

Table 3: Forward Step Down Test Scoring

<table>
<thead>
<tr>
<th>Definition of Errors</th>
<th>Interpretation of Errors</th>
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<tbody>
<tr>
<td><strong>Arm strategy:</strong> PT uses an arm strategy in an attempt to recover balance (1 point)</td>
<td>0-1 errors</td>
</tr>
<tr>
<td><strong>Trunk movement:</strong> trunk leans right or left (1 point)</td>
<td>2-3 errors</td>
</tr>
<tr>
<td><strong>Pelvic plane:</strong> Pelvis rotates or elevates on one side compared to the other (1 point)</td>
<td>4+ errors</td>
</tr>
<tr>
<td><strong>Knee position:</strong> knee deviates medially and the tibial tuberosity crosses an imaginary vertical line over the second toe (1 point); knee deviates medially and the tibial tuberosity crosses an imaginary vertical line over the medial border of the foot (2 points)</td>
<td></td>
</tr>
<tr>
<td><strong>Balance:</strong> subject steps down on the uninvolved side or the subject’s tested leg becomes unsteady (1 point)</td>
<td></td>
</tr>
</tbody>
</table>

References


