**About the procedures:** Cartilage reconstruction and joint preservation is used when a patient has an isolated area of cartilage damage. Several procedures can be used to reconstruct the damaged area. Some of these reconstruction options include – microfracture, Autologous Cultured Chondrocytes, Osteochondral autograft and osteochondral allograft.

- **Microfracture:** After removing any loose or unstable flaps of cartilage, drill holes are placed within the cartilage defect to allow bone marrow and stem cell elements to fill the area of wear with a blood clot. Over time, this clot transforms into scar cartilage. This is best for small lesions, most patients report improvement in the short term, though there is concern about how long the scar cartilage will last.

- **Osteochondral Autograft (OATS):** Also used for small lesions, a cylinder of the patient’s own bone and cartilage with associated sub-chondral bone is moved from a less important area to a more important area. A benefit is that it utilizes the patient’s own tissue, but can result in pain at the donor site in larger lesions. Typical size of autografts is 6-10 mm, up to 3-4 plugs can be taken from donor sites in the knee.

- **Osteochondral Allograft (OCA):** A concept similar to osteochondral autografts as described above, osteochondral allografts utilize a fresh cadaver graft as the source of the donor tissue. This is typically used for lesions >15 mm. Rejection medicines are NOT necessary following the surgery.

- **Autologous Cultured Chondrocytes on a porcine membrane (ACC):** This is a staged reconstruction where a small piece of the patient’s own cartilage is harvested during an initial arthroscopy. The tissue is taken to a lab where the cells are grown and embedded within a collagen matrix. This matrix can then be implanted at the time of a second surgery (6 weeks minimum, 5 years maximum from initial arthroscopy).

Regardless of specific cartilage reconstruction technique, the graft or cells are most vulnerable in the first several months following the procedure, while it is undergoing the biologic steps of healing and integration. While compression is generally a healthy process for normal joint cartilage, excessive compressive forces early in the recovery period can be detrimental to the early healing organization processes, thus limited weight bearing precautions are often used.

Cartilage reconstruction procedures are commonly coupled with an osteotomy procedure to aid in unloading the affected region of the joint. An osteotomy procedure requires its own specific post-operative precautions to allow for bony healing, which typically involves protected WB and modified quadriceps strengthening activities during the first 6-8 weeks post-operatively (please refer to specific rehabilitation protocol reflecting concomitant procedure, if done).
Supervised recovery from a cartilage reconstruction procedure commonly ranges from 9-12 months postoperatively; however, the implant may continue to undergo maturation for as long as 18-24 months postoperatively. Patients and clinicians should be thoughtful about the length of this recovery process with rehabilitation progressions, return to activity guidelines, and general post-operative expectations.

**Surgery Specific Precautions & Pearls:**

- **At any time during/after rehabilitation process, if sharp pain with locking or swelling is experienced, notify surgeon**
- **Avoid excessive graft shear and compression** (site specific, tibiofemoral vs patellofemoral)
- **Address quadriceps muscle inhibition or dysfunction**
  - Close observation for co-contraction with hip/hamstrings or TFL (patient should feel balanced quad activation at distal thigh)
  - NMES to minimize post-surgical deactivation (in PFJ-safe positions)
- **Avoid excessive scar/adhesion formation**
  - Tissue & joint mobilizations, targeted muscle stretching
- **Minimize destructive forces on implant**
  - Excessive compression
    - Excessive compression can displace immature cartilage cells (MACI)
    - Weight bearing restriction (TF – crutch use)
  - Shear
    - Avoid pushing through a bent knee which combines compressive load & joint translation, causing “shear” stresses over the healing graft
  - Swelling
    - Increased joint swelling detrimental to quadriceps muscle activation
- **Address joint nutrition & early joint mobility**
  - High frequency joint ROM through instructed range to maximize circulation of synovial fluid for joint nutrition
  - Respectful progression with ROM
  - Targeted joint and/or soft tissue mobilization techniques around the joint
- **Respect the graft healing & integration process**
  - Avoid premature re-introduction of load/impact
- **Frequency/duration of physical therapy**
  - The recovery process to full activities s/p cartilage reconstruction procedure is >9-12 months
  - Frequency of visits early in the post-operative recovery is typically 2x/week for Phase I, decreasing to 1x/week dependent upon the patient’s progress
  - Frequency of visits remains an individualized item that is to be determined through the PT’s clinical discretion
- **Activity goal setting with the patient**
  - Running and other high impact activities s/p cartilage reconstruction procedure is often ill-advised. This is somewhat size and location dependent.
  - Collaboration between surgeon, PT and patient will be essential in determining the best goals for activity for chondral health of the knee unique to each patient
### Phase 1: Weeks 1-6

**Precautions:** Tibiofemoral compartment (TF) TTWB; Patellofemoral compartment (PF) WBAT brace locked in extension; Careful monitoring of signs of joint intolerance; Range of motion ≤90°KF

<table>
<thead>
<tr>
<th>Weight Bearing</th>
<th>Brace</th>
<th>ROM – Timeframes: Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>• TF: TTWB with 2 crutches</td>
<td>• TF: 0-30°</td>
<td>• CPM: 0-30° day 1; increase 5-10° per day as tolerated</td>
</tr>
<tr>
<td>• PF: WBAT with 2 crutches → no AD</td>
<td>• PF: locked in extension when up; unlocked when sitting</td>
<td>• TF: no restrictions – to tolerance (do not push ROM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• PF: 0-90°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Start stationary bike for ROM at week 5-6 (0-90°)</td>
</tr>
</tbody>
</table>

### Therapeutic Exercise and Activity

- Manual therapy – (STM, edema massage) at the peripatellar region, infrapatellar fat pad, suprapatellar pouch, medial & lateral gutters
  - Persistent swelling = quadriceps muscle inhibition, limitation to end range of motion & compromised joint healing environment
  - Incision & soft tissue mobilizations
  - Repetitive, protected joint ROM (CPM 6-8 hours/day)
  - Manual patellar glides (superior/inferior)
  - Repetitive reciprocal joint ROM through comfortable range (honoring surgical ROM restrictions)
  - Muscle stretches: HS, gastroc, adductors, lateral hip (NO end range quad stretching x 8+ weeks post-op for PF)
- Restore proper, volitional quadriceps contraction
  - Quad activation coupled with reciprocal active motion) quad set at full extension phase with heel slides or exercise ball knee flexion reps)
  - NMES in full extension
  - Strong effective quad isometric prior to SLR – begin in standing → progress to reclined standing → supine
  - PF – weight shifting in bilateral stance, brace on
- General strength & fitness maintenance
  - Multi-direction hip strengthening in NWB at involved limb (TF)
  - Early mat-based core muscle activation
  - Toe raises for PF

**Goals:** No resting pain, pain with activity 3/10 or less; Gr. 2+ effusion or less at knee; Full hyperextension ROM; Knee flexion to 90°; Strong volitional quad contraction; Able to perform SLR flexion in supine with no extensor lag
## Phase II: Weeks 7-12

**Precautions:** Monitor for signs of joint intolerance (locking, catching, clicking, increase in swelling – notify MD of such symptoms); Emphasize importance of normal gait mechanics prior to discharge of AD

<table>
<thead>
<tr>
<th>Weight Bearing</th>
<th>Brace</th>
<th>ROM</th>
</tr>
</thead>
</table>
| • TF & PF: WBAT  
  - Utilize crutches (2→1) to facilitate normal gait pattern until patient able to demonstrate normal mechanics with no AD | • TF: Wean out of brace when quad control sufficient  
  • PF: utilize brace to help facilitate KF during swing phase of gait - open brace 0-30˚, 0-50˚ KF, etc. as tolerated to facilitate normal gait – wean out of brace when able | • TF & PF: symmetrical ROM  
  • Stationary bike  
  • Progression with AROM drills into end range |

### Therapeutic Exercise and Activity

- Perform cryotherapy, compression and elevation as required
- Continue manual therapy techniques as needed to facilitated normal ROM, edema control
- Continue phase I stretching exercises, mindful of end range quad stretching with PF until 8+ weeks
- OKC strength training
  - Quadriceps: flexed knee isometric for TF  
  - SLR x 4
- CKC strength training: *(Instruct normal trunk & limb kinematics)*
  - Weight shifting in bilateral stance → marching into SLS  
  - Calf raises in bilateral support  
  - Introduce weighted KF at **Week 8:** 2 legged shallow depth squatting (0-45˚ KF) or isometric leg press, isometric weight shift over step progressing to step-up/down (1st from behind → 2nd lateral)
- Neuromotor control
  - Proprioceptive training (i.e. 2 legged BOSU stance, marching in place)
  - Core progressions in TF safe positions

**Goals:** No pain with activity; no pain >3 hours post-exercise/activity; Effusion 1+ or less – no increased effusion post-exercise/activity; Full knee hyperextension and flexion; tolerate full reps/sets of quadriceps strengthening; Normal gait pattern with AD and/or brace for community distances; Normal gait pattern without AD and brace for short distances.
Phase III: Weeks 13-18

**Precautions:** Continue monitoring of signs of joint intolerance; Preserve symptom management (pain & swelling); Preserve normal ROM

<table>
<thead>
<tr>
<th>Functional Mobility</th>
<th>Proprioception/Balance</th>
<th>Cardiovascular Fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reinforce good trunk &amp; limb mechanics</td>
<td>• 1 legged BOSU</td>
<td>• Fast walking x 15 min</td>
</tr>
<tr>
<td>• Increasing gait speed &amp; distance</td>
<td>• Directional reaching, stepping drills</td>
<td>• Stationary bike with increasing resistance</td>
</tr>
<tr>
<td>• Ascend &amp; descend stairs reciprocally</td>
<td>• Surface, perturbation challenges</td>
<td>• Elliptical</td>
</tr>
</tbody>
</table>

**Strengthening & Core Stability**

- Initiate bridging, progress with difficulty as tolerated

- Progress core stability challenge with dynamic elements

- OKC Strength Progression Options:
  - Quadriceps isolation: SLR reps, flexed knee quad isometric
  - Increase speed and/or resistance with OKC hip strength drills (do NOT add ankle weights at distal limb for SLR flexion)
  - Add HS curls through arc of motion

- CKC Strength Progression Options: **Reinforce** good trunk & limb kinematics
  - 2 legged squats: add resistance or greater depth per symptoms
  - Step drills: Increase depth and/or speed
  - Reverse “slider” lunges: 1st posterior → 2nd posterolateral → 3rd lateral

**Goals:** No pain with activity or soreness >3 hours post-exercise/activity; Trace effusion or less – no increased effusion post-exercise/activity; Full active knee ROM; Tolerate full reps/sets of OKC & CKC strength exercises; Normal gait for moderate distances, reciprocal (non-compensating) stairs; Demonstrate normal trunk & limb kinematics with CKC activity; Maintain SLS >45 sec; Hold core stability poses x 60 seconds; SL Bridges >20 reps
### Phase IV: Weeks 19-24

**Precautions:** Continue monitoring of signs of joint intolerance; Preserve symptom management (pain & swelling); Preserve normal ROM

<table>
<thead>
<tr>
<th>Functional Mobility</th>
<th>Proprioception/Balance</th>
<th>Cardiovascular Fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td>• DEMAND good trunk &amp; limb kinematics</td>
<td>• 1 legged BOSU</td>
<td>• Add intensity intervals to low impact cardio sessions</td>
</tr>
<tr>
<td>• Gradually increase walking speed &amp; distance – variable terrain</td>
<td>• Directional reaching, stepping drills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Surface, perturbation challenges</td>
<td></td>
</tr>
</tbody>
</table>

**Strengthening**

- Squatting:
  - 2 legged: increase depth and/or resistance
  - 1 legged: shallow depth
  - Add proprioceptive challenge with drills (BOSU, etc.)
- Step Drills: increase step height OR speed OR add resistance

- Walking lunges
- Return to sport preparation: band resisted directional stepping

**Goals:** No pain with activity or soreness >3 hours post-exercise/activity; No baseline effusion; Full ROM preserved; Normal quad activation preserved; Single leg squat max depth ≤15% side to side difference; Tolerate 25+ min moderate intensity low impact workout with no symptom increase; Demonstrate normal trunk & limb kinematics with CKC progressions; Maintain SLS >60 sec; Hold core stability poses x 60 sec

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### Phase V: Weeks 25+

**Precautions:** Continue monitoring of signs of joint intolerance; Preserve symptom management (pain & swelling); Preserve normal ROM

<table>
<thead>
<tr>
<th>Functional Mobility</th>
<th>Proprioception/Balance</th>
<th>Cardiovascular Fitness</th>
</tr>
</thead>
<tbody>
<tr>
<td>• DEMAND good trunk &amp; limb kinematics</td>
<td>• Reaction &amp; external perturbation drills</td>
<td>• Initiate interval running progression – see Return to Run for criteria and progressions**</td>
</tr>
<tr>
<td>• Gradually increase walking speed &amp; distance – variable terrain</td>
<td></td>
<td>• Increase one intensity variable at a time (dur, int, freq)</td>
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</tbody>
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Cartilage Reconstruction of the Knee  
M Health
**Phase V continued: Strengthening**

- Increase speed and/or resistance with previous strengthening exercises
- Weight room resistance training program
- Directional lunges
- Core stability – integrate core & strength drills
- Return to sport preparation at 9 months:
  - 2 legged basic plyometric drills – 2 legged vertical, box or broad jumping drills
  - Shuffling → directional footwork/foot speed drills → pivoting
  - Plyometric progressions – 2→1 leg, travel, direction change, intensity
  - 1st acceleration drills, 2nd deceleration drills
  - Target sport basic training elements

**Goals:** No pain with activity or soreness >3 hours post-exercise/activity; No baseline effusion; Full ROM preserved; Symmetrical quad girth side to side; Tolerate full reps and sets of 2 legged squat to 90° KF and 1 legged squat to 60° KF with normal kinematics, no symptoms; Tolerate 20 min continuous run workout, no symptom increase; LSI:>85% difference side to side with hop testing.
**Criteria to be met prior to initiation of return to run program (typically 6-9 months post operatively)**

- Clearance by MD to initiate return to run program (depending on lesion, may be up to 9 months prior to clearance to run)
- Trace to no effusion
- Normal ROM
- Sufficient chondral health of tibiofemoral and patellofemoral joints
- Previous history of regular running
- No increased knee pain or effusion with progression of therapeutic activities to date
- ≥90% LSI with single leg squat (max depth) and/or star excursion balance test (anterior reach)
- Able to perform 20 reps off 6” box with ≤2 breaks/pauses
- Able to tolerate 20 minutes of walking at a brisk, continuous pace without symptom provocation

<table>
<thead>
<tr>
<th>Week</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Run 1 min; walk 4 min</td>
<td>Run 1 min; walk 4 min</td>
<td>Run 1 min; walk 4 min</td>
</tr>
<tr>
<td></td>
<td>25 min total*</td>
<td>25 min total</td>
<td>30 min total</td>
</tr>
<tr>
<td>2</td>
<td>Run 2 min; walk 3 min</td>
<td>Run 2 min; walk 3 min</td>
<td>Run 2 min; walk 3 min</td>
</tr>
<tr>
<td></td>
<td>25 min total</td>
<td>25 min total</td>
<td>30 min total</td>
</tr>
<tr>
<td>3</td>
<td>Run 3 min; walk 2 min</td>
<td>Run 3 min; walk 2 min</td>
<td>Run 3 min; walk 2 min</td>
</tr>
<tr>
<td></td>
<td>25 min total</td>
<td>25 min total</td>
<td>30 min total</td>
</tr>
<tr>
<td>4</td>
<td>Run 4 min; walk 1 min</td>
<td>Run 4 min; walk 1 min</td>
<td>Run 20 min continuously</td>
</tr>
<tr>
<td></td>
<td>25 min total</td>
<td>25 min total</td>
<td></td>
</tr>
</tbody>
</table>

- *If 1 min of jogging is too tenuous, begin with less time, e.g. 30 seconds
- Do not run on consecutive days
- Focus on strengthening and proprioception exercises on non-running days
- Discontinue return to run program and consult PT if:
  - Sharp pain exists in the knee
  - Swelling in the knee
  - Pain worsens as the run progresses
  - Pain is worse later or the following day
  - Pain does not make you limp
- At end of progression, increase slowly with mileage, speed and frequency of running (increase one interval at a time, no more than 10% per week)
- Change footwear every 300-400 miles; base footwear choice primarily on comfort

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