RETURN TO PLAY AFTER ARTICULAR CARTILAGE REPAIR OF THE KNEE

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THE ‘PROBLEM’

Damage to the articular cartilage of the knee in athletes presents one of the most difficult challenges in the care of elite and recreational athletes. Unlike bone or muscle, articular cartilage lacks any intrinsic repair mechanism. It has no nerve or blood vessel supply and has a very slow metabolic rate, relying on the extracellular matrix produced by its chondrocytes to provide the multi-purpose and essential functions of cartilage. These unique characteristics of cartilage and its lack of response to injury has led surgeons to seek alternate ways of triggering an acceptable repair process and to develop techniques to regenerate or replace the damaged cartilage. While no one technique has been considered universally ideal, each has its merits and limitations. All repair techniques are influenced by the speed of the process and the delicate balance between gradual loading of the repair tissue and the risk of overloading, which leads to reduced tissue quality and outcomes. Return to play after knee cartilage repair procedures remains a time-intensive process for the athlete which continues to challenge the treatment team. The ultimate goal of a definitive cartilage repair process has yet to be met, as evidenced by the multiple treatment techniques available and new approaches being pursued in research institutions around the world.

CLINICAL PRESENTATION AND TREATMENT DECISION-MAKING

Articular cartilage injuries in athletes are common among sports associated with cutting, jumping, pivoting, rapid deceleration and rapid acceleration. This is particularly true of football/soccer, basketball and handball, but may also occur in any sport requiring these repeated athletic movements. Although cartilage lesions may occur in isolation, they are also frequently associated with other problems such as ligament (ACL tears) and meniscus injuries. While not all cartilage defects are symptomatic, when symptoms do occur, the athlete will complain of pain with increased joint loading such as running or changing direction. There may be swelling (effusion) of the knee after activity, a feeling of the knee giving way and locking of the knee. In many cases, associated pain is in a very specific location that corresponds to the site of the cartilage injury. Patients with defects on the condyles will present with pain with weightbearing and localised pain around the defect. An articular cartilage...
defect around the patella or trochlea will be associated with pain at the anterior aspect of the knee while ascending or descending stairs or during a stand-to-sit or sit-to-stand manoeuvre such as getting in and out of a car.

In the more significant cases which may require surgery, (i.e. Outerbridge or International Cartilage Repair Society grade III or IV) lesions most commonly occur at the medial femoral condyle and the patella. Evaluation of the athlete should include a combination of clinical history (including any prior imaging or previous surgery reports), detailed physical examination and imaging.

Plain film radiography should be performed first to determine whether there are issues relating to malalignment (patella maltracking or tibio-femoral malalignment) and degenerative changes of the knee joint. However, plain films do not provide direct information on the status of the articular cartilage between the femur and the tibia (the tibiofemoral compartment) or the patella and trochlea (the patellofemoral compartment). Magnetic resonance imaging (MRI) provides a non-invasive visualisation of the articular cartilage of the knee. As MRI technology has improved, so has the ability to provide information on the size and depth of chondral lesions. In the MRI series, the status of the ligaments and menisci can also be assessed as articular lesions of the knee are also frequently evident with knee ligament or meniscal pathology.

Initial treatment of a suspected or known knee cartilage defect should be undertaken prior to considering surgery. This is particularly the case for patellofemoral defects as their repair is generally more challenging when compared to tibiofemoral defects. The patellofemoral joint bears the added impact of shear forces throughout the range of motion, which influences subsequent repair and rehabilitation. Injection of hyaluronate or in some cases platelet-rich plasma, may also be considered even though the evidence-base behind these approaches has yet to be developed. For surgery to be seriously considered, the athlete’s symptoms should be consistent with a full-thickness cartilage defect. When non-operative techniques of load regulation, rehabilitation, supportive or regenerative injections fail to achieve acceptable results and the level of play remains adversely affected, surgical intervention becomes indicated.

SURGICAL TECHNIQUES AND THEIR INDICATIONS

The goals of surgical treatment include restoration of the normal surface and congruity of the cartilage, controlling the patient’s symptoms, maintaining the durability of the surface to withstand intra-articular forces and preventing progression of the presenting defect(s) to osteoarthritis.

There are generally five types of surgical repair techniques that can be considered for knee articular defects. These include: palliative (chondroplasty), reparative (microfracture), substitutive (osteochondral autograft transfer (OATS-autograft), osteochondral allograft transplantation (OATS-allograft) and regenerative (autologous chondrocyte implantation–ACI). Each technique is briefly discussed below to provide a preliminary understanding prior to their discussion relative to return to play. Thorough descriptions of each of these surgical techniques are described elsewhere.

- **Chondroplasty** is performed during arthroscopy and involves mechanically stabilising the damaged edges of the cartilage by using a rotating blade (hence nicknamed ‘shaving’). Additionally, damaged cartilage within the defect can also be smoothed off in an attempt to prevent further propagation or fretting of loose particles within the knee. In this method which is sometimes called debridement, the subchondral bone is not violated (Figure 1a).

- **Microfracture** is a technique which initially involves trimming and stabilising the damaged edges of the defect, as their repair is generally more challenging when compared to tibiofemoral defects. The patellofemoral joint bears the added impact of shear forces throughout the range of motion, which influences subsequent repair and rehabilitation. Injection of hyaluronate or in some cases platelet-rich plasma, may also be considered even though the evidence-base behind these approaches has yet to be developed. For surgery to be seriously considered, the athlete’s symptoms should be consistent with a full-thickness cartilage defect. When non-operative techniques of load regulation, rehabilitation, supportive or regenerative injections fail to achieve acceptable results and the level of play remains adversely affected, surgical intervention becomes indicated.
the bone so that the blood clot formed from penetration of the subchondral bone can be contained. Microfracture is the most common form of marrow stimulation. The marrow and presumably the mesenchymal stem cells (MSC) that are within the marrow are accessed by puncturing holes in the bone with a tool shaped like an ice-pick, called a microfracture awl. This process produces stellate fracture lines that increase the bony surface area so that a relatively greater amount of bone marrow products such as stem cells, growth factors and platelets can clot to eventually form fibrocartilage repair tissue. More recently, specially shaped drill points designed not to burn the bone edges have been used to access the marrow (Figure 1b).

- **OATS-autograft** is a technique that fills the defect with the patient’s own osteochondral plugs, which are taken from another area of the knee not critical to weightbearing or patella tracking. Typically this technique is used for lesions of 2 cm² or less, where one or two osteochondral plugs of 6 to 10 mm in diameter can be harvested. This technique relies on using healthy cartilage with its native sub-chondral bone attachment undisturbed, allowing reliable bone healing to occur and leave a smooth, healthy articular surface. While it is possible to use this method on larger lesions, as more plugs are used, there is a greater risk of an irregular surface, much like a cobblestone street. Additionally, the more tissue harvested from the non-weightbearing, non-articulating areas of the knee, the greater likelihood there is for unwanted side-effects at the harvest area (Figure 1c).

- **OATS-allograft** is a procedure identical to OATS autograft except that fresh cadaveric knee tissue is used, enabling the surgeon to use as much tissue as required for the osteochondral plug. In this procedure, a cylinder-shaped plug is harvested from a cadaver to match the location and orientation of the prepared defect. This plug is then transplanted into the defect making the edges flush with the surrounding normal native cartilage. While the articular surface of the graft will be smooth and healthy, the underlying bone of this graft needs to be integrated into the patient’s own existing bone. Ultimately the cadaveric bone is gradually replaced by host bone (Figure 1d).

- **Autologous chondrocyte implantation (ACI)** is a two-stage procedure where a chondral biopsy is obtained from a non-weightbearing, non-articulating area of the knee. The total volume of tissue required is about the same as a standard pencil eraser which then allows the chondrocyte cells to be cultured and multiplied about eight to 12 fold. The ex-vivo culture takes about 3 weeks to expand, although the cells can safely be stored until surgery at a convenient time for the athlete. At the time of the implantation, an open arthrotomy is necessary, as with the OATS-allograft and often OATS-autograft procedures. The defect is prepared so that a rim of healthy cartilage is achieved with the edges of the defect being perpendicular to the bone. Next, a porcine-derived bilayer of absorbable Type I/III collagen that is cut to perfectly match the defect’s size is sutured in place with fine absorbable sutures. The suture line is sealed with fibrin glue and the cells injected under the membrane which contains:
  1. a porous layer that assists in cell attachment
  2. a smooth compact layer that is cell occlusive

(Figure 1e).

Figure 1: Figures relating to the five types of surgical procedures.

a) Chondroplasty  b) Microfracture  c) OATS autograft  d) OATS allograft  e) ACI
The selection of the appropriate cartilage repair surgical technique for the athlete requires careful consideration. While generalised clinical algorithms exist to guide the decision-making processes[1,3] the actual selection is not an exact science and there is no single surgical approach for all symptomatic cartilage lesions. Many factors enter into the decision-making process. Table 1 outlines some of the advantages and disadvantages of surgical techniques relating to the tibio-femoral compartment.

The surgeon’s choice of the appropriate repair technique will be primarily guided by two factors:

1. Size of defect(s); <2 cm<sup>2</sup>, 2 to 4 cm<sup>2</sup> or >4 cm<sup>2</sup> and the number of these defects
2. Location of the defect(s); articular surface of the patella, medial femoral or tibial condyle and lateral femoral condyle. Whether ‘kissing lesions’ (lesions on opposing articular surfaces) are evident will also be considered.

Small-to-medium sized defects are best repaired using chondroplasty, microfracture or OATS-autograft. For repair of multiple and/or large defects OATS-allograft and ACI produce superior results. Recently, great strides have been made in improving clinical outcomes for the most challenging defects, such as defects larger than 4 cm<sup>2</sup> and those involving the patellofemoral joint, using ACI[5].

The following factors will be considered with the type of cartilage repair selected and are known to affect outcomes:

- Age of the athlete
- Level of the sports participation
- Duration of symptoms
- Expectations and goals of the athlete
- Previous surgical treatment to the knee
- Concomitant pathology (meniscal and ligamentous)
- Lower limb malalignment/patella maltracking
- Potential compliance to rehabilitation

The last three of these factors are briefly discussed below.

**Concomitant pathology, limb alignment and patella maltracking**

In addition to an evaluation for effusion, joint line tenderness to palpation and provocative meniscal tests, ligamentous testing provides a good indication of ligamentous stability. Should there be any question regarding any aspects of the exam, an MRI can provide additional information on meniscal or ligamentous status.

Persistent ligamentous insufficiency results in excessive shear forces across the articular surfaces of the knee. Tears to the anterior patellar ligament may result in anterior knee pain and give rise to patellar tendinopathy.

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Table 1: Treatment considerations for repair of cartilage in the tibio-femoral compartment (modified from Gomoll et al[3]).

<table>
<thead>
<tr>
<th>Small defects (&lt;2-4 cm&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Large defects (&gt;2-4 cm&lt;sup&gt;2&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very small (&lt;2 cm&lt;sup&gt;2&lt;/sup&gt;)</strong></td>
<td><strong>Small</strong></td>
</tr>
<tr>
<td>OATS autograft</td>
<td>Microfracture</td>
</tr>
<tr>
<td>Mature hyaline cartilage</td>
<td>No donor site morbidity</td>
</tr>
<tr>
<td>Primary bone healing</td>
<td>Arthroscopic procedure</td>
</tr>
<tr>
<td>Quicker recovery and return to play than microfracture</td>
<td>Complex rehab (continuous passive motion and touchdown weight bearing for 6-8 weeks)</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
</tr>
<tr>
<td>Technically difficult (mini-open)</td>
<td></td>
</tr>
<tr>
<td>Donor site morbidity with multiple plugs</td>
<td>Prolonged delay before return to play (6-9 months)</td>
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and/or posterior cruciate ligament may accompany full-thickness chondral defects. Ligament reconstruction will need to occur at the time of cartilage repair in order to reduce the ill-effects of ongoing knee instability. In athletes undergoing articular cartilage repair, the presence of meniscal tears may disrupt the normal biomechanics of the involved compartment. When this is the case, a concomitant partial meniscectomy or meniscal repair will be necessary. In athletes with previous surgery and prior meniscectomy, the function of the meniscus may be totally lost. In such cases, meniscal allograft transplantation should be considered to restore some of the cartilage unloading function of the meniscus.

Detecting limb malalignment or patella maltracking is a crucial part of any cartilage repair procedure. Residual malalignment or patella maltracking will continue to overload the cartilage repair and typically leads to inferior results or failure. If one thinks of an automobile with a steering malfunction causing the tyres to wear out on one side, it is easily understood that putting new tyres on will only lead to the same wear unless the underlying steering problem is first corrected. The most common types of limb malalignment (and it’s typical correction) include:

- **Varus malalignment (medial opening wedge high tibial osteotomy)**
- **Valgus malalignment (lateral opening wedge distal femoral osteotomy)**

Lateral patella maltracking is another issue that needs to be considered before any patellofemoral cartilage repair procedure is undertaken as poor outcomes typically result without such consideration. Conservative treatment of patellofemoral pain should be attempted prior to surgery and is generally successful. However, should surgery be considered necessary, patellofemoral biomechanics should be normalised to maximise the possibility of successful cartilage repair post-surgery. When attempting to correct maltracking of the patella, three considerations should be addressed; tibial tuberosity location, (the Q-Angle and the tibial tuberosity to trochlea groove, TTG distance) as well as the status of the medial and lateral soft tissues.

There is typically a lateral positioning of the tibial tuberosity relative to the trochlear groove. However, if the lateral positioning is considered excessive (>20 mm) an anteromedialisation repositioning of the tibial tuberosity may be necessary. This procedure (called the Fulkerson procedure) not only corrects the lateral maltracking, it also provides the added value of actually decreasing the contact forces across the patellofemoral joint at the site of cartilage repair. With respect to medial soft tissues, the medial patellofemoral ligament is the focus for any correction of maltracking issues. Depending on the patellofemoral pathomechanics, either a (conservative) release of the lateral tissues or conversely, a lateral lengthening, may be necessary.

### Post-surgical rehabilitation

Rehabilitation is integral to maturation of repair tissue and final clinical outcome post-surgery. The overall philosophy of rehabilitation should be to provide a conducive

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### Table 2

<table>
<thead>
<tr>
<th>Activity</th>
<th>Microfracture</th>
<th>OATS autograft</th>
<th>ACI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous passive motion</td>
<td>Immediately post-operative</td>
<td>Immediately post-operative</td>
<td>6-8 hours post-operative</td>
</tr>
<tr>
<td></td>
<td>6-8 hours/day</td>
<td>8-12 hours/day</td>
<td>8-12 hours/day</td>
</tr>
<tr>
<td></td>
<td>0-8 weeks</td>
<td>Up to 6 weeks (at least 2 weeks)</td>
<td>Up to 6 weeks (at least 2 weeks)</td>
</tr>
<tr>
<td>Non-weight bearing</td>
<td>Not specified</td>
<td>Weeks 0-2</td>
<td>Weeks 0-2</td>
</tr>
<tr>
<td>Protected weight bearing</td>
<td>Weeks 0-8</td>
<td>Weeks 2-8</td>
<td>Weeks 2-7</td>
</tr>
<tr>
<td>Full weight bearing</td>
<td>Weeks 6-8</td>
<td>At Week 8</td>
<td>By Weeks 8-9</td>
</tr>
<tr>
<td>Normal daily activities</td>
<td>Weeks 6-8</td>
<td>At 3 months</td>
<td>Gradually increased through weeks 6-12</td>
</tr>
<tr>
<td>Low impact activities</td>
<td>At 3 months</td>
<td>At 3-4 months</td>
<td>At 6 months</td>
</tr>
<tr>
<td>High impact activities</td>
<td>Not specified</td>
<td>At 4-5 months (OATS)</td>
<td>At 9-12 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At 6-7 months (Mosaicplasty)</td>
<td></td>
</tr>
<tr>
<td>Return to sports</td>
<td>At 4-6 months</td>
<td>At 5-6 months (OATS)</td>
<td>At 12-18 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At 9 months (mosaicplasty)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: A comparison of rehabilitation processes for surgery types for knee cartilage repair.
### Table 3

<table>
<thead>
<tr>
<th>Study (comments)</th>
<th>Patients (follow-up period)</th>
<th>Time to RTP</th>
<th>% RTP</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chondroplasty</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scillia et al</td>
<td>NFL football (n=52)</td>
<td>8.2 months</td>
<td>67%</td>
<td>Starting players more likely to RTP (11.6 games/season)</td>
</tr>
<tr>
<td></td>
<td>70 months</td>
<td></td>
<td></td>
<td>4.4% less likely to RTP with microfracture</td>
</tr>
<tr>
<td>Microfracture</td>
<td></td>
<td></td>
<td></td>
<td>No correlation with age, location of defect, position</td>
</tr>
<tr>
<td>Gudas et al</td>
<td>n=60 37 months</td>
<td>4-6 months</td>
<td>52% MF</td>
<td>15 (52%) MF patients returned to sports activities at the preinjury level at an average of 6.5 months (4-8 months)</td>
</tr>
<tr>
<td></td>
<td>mean = 6.5 months</td>
<td></td>
<td>93% OATS</td>
<td></td>
</tr>
<tr>
<td>Gudas et al</td>
<td>n=60 125 months</td>
<td>4-6 months</td>
<td>37% MF</td>
<td>OATS technique allowed higher rate of return, longer maintenance at the preinjury level at 10-year follow-up</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>75% OATS</td>
<td></td>
</tr>
<tr>
<td>Mithoefer et al</td>
<td>High-impact sports (n=32)</td>
<td>4-6 months</td>
<td>44% RTP (25% at same level)</td>
<td>After initial improvement, score decreases were observed in 47% of athletes</td>
</tr>
<tr>
<td></td>
<td>24 months</td>
<td></td>
<td></td>
<td>Best for &lt; 40 years, &lt; 2 cm², &lt; 1 year symptoms, no prior surgery</td>
</tr>
<tr>
<td>OATS Allograft</td>
<td>n=43 30 months</td>
<td>9-12 months</td>
<td>79%</td>
<td>Age &gt; 25, pre-operative symptoms &gt; 1 yr negatively affected RTP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75% Recreational, 25% Collegiate athletes</td>
</tr>
<tr>
<td>Krych et al</td>
<td>n=38 47 months</td>
<td>9-12 months</td>
<td>29%</td>
<td>42% unable to return to duty, only 5.3% at preinjury level</td>
</tr>
<tr>
<td>ACI</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mithoefer et al</td>
<td>Soccer players (n=45)</td>
<td>12-24 months</td>
<td>80%</td>
<td>Most successful in younger competitive athletes with less than 1 year symptoms, of those RTP 87% maintained level &gt; 4 years</td>
</tr>
<tr>
<td></td>
<td>50 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14 months high-level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACI</td>
<td>Young athletes (n=20)</td>
<td>12-18 months</td>
<td>96%</td>
<td>All with &lt; 1 year symptoms returned to pre-injury level but only 33% with &gt; 1 year of symptoms</td>
</tr>
<tr>
<td></td>
<td>48 months</td>
<td></td>
<td></td>
<td>Ave size 6.4 cm², 60% with open growth plates</td>
</tr>
</tbody>
</table>

Table 3: Summary of studies in the area of knee articular cartilage repair.
mechanical environment for cartilage maturation and remodelling, as mechanical forces affect proteoglycan turnover and synthesis. For successful return to training and subsequent return to play, adherence to a well-structured rehabilitation programme that neither overloads nor underloads the repaired cartilage is crucial. The time spent in the various stages of rehabilitation depends on the cartilage repair technique, a summary is provided in Table 2. The reader is referred to a comprehensive review of rehabilitation and return to sport after knee cartilage repair elsewhere.

With respect to the criteria for return to sport, these include the following (≥90%):
- Quadricep/hamstring strength index: this test is done using an isokinetic dynamometer such as a Biodex or Cybex.
- Single-leg hop test (operated/non-operated leg).
- Triple hop test: timed and for distance. For progression to return to play from return to sport:
  - There should be no pain or significant swelling around the knee in any of these phases.
  - The athlete should progress through each of the following steps:
    1. Show agility at full speed with change of direction and sudden deceleration.
    2. Participate in unopposed practice.
    3. Participate in opposed practice drills.
    4. Participate in full scrimmag with simulated game conditions.

Return to play after cartilage repair surgery: the evidence
Systematic reviews and other key studies in the literature are outlined in Table 3. These tell us much about the state of evidence about return to sport and return to play after surgery for knee cartilage repair.

With regard to return to play, there are three variables of interest:
- average time to return to play (see Figure 2a), as well as
- the proportion of athletes who returned to sport and
- the proportion of athletes who returned to sport at the pre-injury level – i.e. return to play (Figure 2b).

Collectively, this information states:
- Patients undergoing microfracture are least likely to return to sport when compared to those patients who underwent ACI or OATS-autograft. Two further points relating to microfracture are notable:
  1. While the rate of return to sport for microfracture seems reasonable (75%), a decline in pain and activity scores 2 to 6 years post-surgery is found. The relatively short period of time that it takes to get athletes back to sport may provide an insufficient period of time for the fibrocartilage to mature or the repair tissue is less durable to load.
  2. Intra-lesional osteophytes may be present in approximately 30% of cases and this may lead to further symptoms from the ill effects of hypertrophic bone in the defect.
- ACI while associated with the longest rehabilitation time, has the most durable positive results for pain and activity scores. Furthermore, performance of the athlete at pre-injury level was best for ACI when compared to microfracture or OATS-autograft.
- For all surgical procedures, athletes with
Clinical points for cartilage repair in athletes

The following points are important to consider with respect to return to play in athletes with knee cartilage defects:

- Articular cartilage defects of the knee can be associated with debilitating symptoms that affect level of play in athletes.
- Conservative treatment should be attempted initially.
- All methods of cartilage repair allow return to play however, there is high variability in time to return and durability of repair tissues.
- Cartilage lesions requiring surgical repair shorten high-level athletic careers.
- The expectations of the athlete need to be managed if surgery is required – extensive rehabilitation is required especially if large lesions are evident.
- A neutral biomechanical environment should be achieved as a prerequisite for articular cartilage surgery.
- Best outcomes for surgery achieved in: young athletes of higher skill level, with smaller chondral lesions (<2 cm²) and symptoms less than 1 year.
- While faster RTP can be gained with microfracture and OATS-autograft, these procedures are more suitable for smaller lesions.
- While ACI has the longest rehabilitation time, it best for larger lesions, has the best durability and the ultimately provides the best chance for an athlete to have an extended career.
- In summary, the ideal method of articular cartilage repair does not yet exist for this all-too-common problem in high-level athletes and continued research is needed to improve the quality and durability of repair tissue to better match the properties of the native knee joint cartilage.

References


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CARTILAGE – SURGICAL OPTIONS TARGETED TOPIC | 305