The general low level of understanding of problems in the patellofemoral joint is reflected in the large number of operative procedures which have been developed. Surgery outcomes are also unpredictable and decision-making is difficult when the physician only knows the patient has pain through a subjective report from the patient. Treatment of patella joint problems is still a black hole in orthopaedics. For athletes, a cartilage injury is a major problem as operative procedures in the patellofemoral joint are quite complex in comparison to other joints, which can be treated transarthroscopically.

INCIDENCE
Widuchowski et al. presented findings on 25,124 patients who underwent knee arthroscopy and found an incidence of 60% for chondral injuries, with patellar lesions accounting for 36% of those. Flanagan et al. found a 36% overall prevalence of full-thickness focal chondral defects in athletes. Patellofemoral defects (37%) were more common than femoral condyle (35%) and tibial plateau defects (25%). Patella defects were also more common than trochlea defects (64% vs 36%). It is important to note that 14% of athletes were asymptomatic at the time of diagnosis. Subsequently, we do see a lot of patellofemoral chondral damage when performing arthroscopies and we have to be careful when choosing the suitability of surgical intervention.

TYPE AND ORIGIN OF LESIONS
Patellofemoral lesions can be divided into six categories:
1. Pure chondromalaciae patellae.
2. Lesions due to direct trauma-contusion chondral damage.
3. Lesions due to traumatic dislocation of the patella.
4. Lesions due to direct/indirect trauma due to repeated instability.
5. Lesions due to defective extensor mechanisms after anterior/posterior cruciate ligament (ACL/PCL) injuries and repairs.
6. Primary osteoarthritis (OA) of the patellofemoral joint.

INSTABILITY
The majority of lesions could be caused by some degree of instability with or without dysplasia of the patellofemoral joint. Subsequently, different degrees of instability and dysplasia need to be

— Written by Mats Brittberg, Sweden
identified if a surgical procedure is to be performed and all co-morbidities need to be addressed at the time of surgery.

TREATMENT ALTERNATIVES

In various studies, reliable and satisfying clinical results have been obtained in the treatment of cartilage lesions located on the medial and lateral femoral condyles, however patellar defects still present a challenge, with substantially poorer treatment outcomes. The explanation for these inferior results lies in the specific biomechanical properties of the anterior compartment of the knee joint.

There are many biological repair options available for treatment of patellofemoral cartilage defects, but there are very few studies showing long-term results for different methods. Many of the cartilage repair methods available today could be performed transarthroscopically for different location sites in the knee but most techniques require an arthrotomy when performed in the patellofemoral joint.

Defect size and defect location within the patella have been found to be significantly associated with clinical outcomes. Larger cartilage lesions of the patella are associated with an inferior outcome. Cartilage defects located on the lateral patellar facet are correlated with a better clinical outcome than those located on the medial facet or those involving both facets.

Debridement/chondroplasty

Trimming of cartilage flaps in International Cartilage Repair Society (ICRS) Grade I and/or II lesions might be an option even in large defects, when the patient suffers from locking phenomena but has no major pain component.

Pure bone marrow stimulation

Microfracture and abrasion arthroplasty can be performed transarthroscopically. Drilling of the patella surface can be done retrograde or with the use of flexible drills. A few reports indicate that one may achieve acceptable long-term results at least in young patients. Augmentation with a membrane such as the Autologous Matrix-Induced Chondrogenesis (AMIC) technique is a possible alternative. Shouldering cartilage is then needed. There are now instruments with curved guides combined with flexible drills that can be used to drill the patella surface transanthroscopically. A retrograde drilling into a patellar defect with a vector guide is another option.

Bone marrow stimulation in conjunction with a cell ingrowth guiding matrix

Chopin® carbon pads and the biomimetic scaffold Maioregen® (Figures 1 to 3) can both be implanted into the subchondral bone to induce strong cell ingrowth and repair tissue induction. Both of these techniques can be used as a salvage technique for treating patellar cartilage defects.

Figure 1: A patella defect prepared by a burr to create a subchondral space for a Maioregen® implant.

Figure 2: An exact size of the defect is cut out from a Maioregen® collagen implant to be inserted into the patella defect in a press fit manner.

Figure 3: The Maioregen® collagen implant is put into place and covered with fibrin glue.
treatment for early OA of the patellofemoral joint and bipolar lesions and when shouldering cartilage is lacking.

Bone marrow aspirate concentrate (BMAC)-derived multipotent stem cells\textsuperscript{17} implantation is another one-stage procedure which can be used for patellar lesions, but needs to be done via open surgery. Bone marrow is harvested from the ipsilateral iliac crest using a special aspiration kit and centrifuged using a commercially available system to obtain a concentration of bone marrow cells four to six times the baseline value. With the use of an enzyme, the bone marrow concentrate is activated to produce a sticky clot material. The clot is put into the defect and covered by periosteum, collagen membrane or a hyaluronan membrane and anchored by sutures\textsuperscript{17}. An augmentated bone marrow stimulated lesion with a strong induced artificial blood clot formation is another interesting alternative\textsuperscript{18}.

Osteochondral autografts

It is difficult to find the right matching plugs due to mismatches between cartilage height in the patella and the donor sites. Short-term results are good, but as yet not enough long-term results have been published. Shouldering cartilage is also needed for this procedure\textsuperscript{19,20}.

Osteochondral allografts

Aside from the difficulties in finding the right donor and the risk of disease transmission, the allograft is of interest when treating large defects in the patellofemoral joint\textsuperscript{21,22}.

Chondrocyte implantation

There are several studies showing that it is possible to use autologous chondrocyte implantation (ACI) for patellofemoral joint cartilage repair, with optimal results occurring when co-morbidities have been addressed\textsuperscript{23-27}.

The clinical results of ACI have been found to differ significantly with the site of the cartilage damage in most published studies.

Usually, patellofemoral ACI procedures require open surgery. However, today’s third generation ACI facilitates the use of patellofemoral ACI treatments transarthroscopically in the patellofemoral joint. New scaffolds also ensure the contours of the facets, which should be compared with the difficulties of using mosaicplasty plugs, to avoid incongruity.

Shouldering cartilage is not needed for chondrocyte implantation. Since the introduction of ACI in 1987 it has been confirmed that this technique can produce mechanically and functionally stable cartilage in patients with full-thickness cartilage defects and is cost-effective, even though cell expansion in-vitro is expensive\textsuperscript{28}.

As an example of a fourth generation chondrocyte implantation, one may consider the use of particulated auto- or allografts\textsuperscript{22,29}. Cartilage is harvested as a one-stage procedure and the biopsy is crushed into small fragments, put onto a resorbable membrane covered with fibrin glue and implanted into the cartilage lesions with the fragments facing the defect. The most active cells migrate out of the crushed cartilage into the defect area to start a repair process.

Mini metal implants

Small metal implants that can be implanted into the subchondral bone are now seen more and more frequently and can be used as a salvage treatment for failed biological grafts and as an initial treatment option in osteonecrotic lesions\textsuperscript{30,31}.

Patellofemoral joint arthroplasties

When the patellofemoral joint becomes osteoarthritic, with the remaining compartments more or less healthy, a patellofemoral joint prosthesis might be a good alternative\textsuperscript{32}.

Figure 4: A large trochlear defect.

Figure 5: The large trochlear defect has been covered by a chondrocyte seeded hyaluronic acid membrane. A second layer of the cell seeded membrane is prepared and will be placed over the first layer to cover the defect completely.
SURGICAL OUTCOMES IN THE PATELLOFEMORAL JOINT

In various studies, reliable and satisfying clinical results have been obtained in the treatment of cartilage lesions located on the medial and lateral femoral condyles, however patellar defects still present a challenge with substantially poorer outcomes reported. Although the lower proportion of satisfactory clinical results following treatment of retropatellar defects is not restricted to the ACI technique and has also been observed with other cartilage repair procedures such as microfracture and mosaicplasty, the clinical results of ACI have been found to differ significantly with the site of the cartilage damage in most published studies. The explanation for these inferior results lies in the specific biomechanical properties of the anterior compartment of the knee joint. There are greater shear forces than in the medial and lateral compartments, which hinder the differentiation of transplanted cartilage cells compared to the hydrostatic forces that are dominant in the femoral condyle and during stair climbing. The forces arising in the femoropatellar compartment reach 8 to 10 times body weight.

Bone marrow stimulation

There is very little written about microfracture and the patellofemoral joint. Steinwachs et al write that AMIC seems to be particularly suited to treating damaged retropatellar cartilage, which is advantageous because these defects can be hard to treat with standard microfracture alone, however they have no clinical long-term results to present. Dhollander et al presented a prospective 2-year clinical and magnetic resonance imaging (MRI) outcome of AMIC for the treatment of patellofemoral cartilage defects in the knee. Ten patients were clinically prospectively evaluated over 2-years. A clinical improvement became apparent during the 24-months of follow-up but the magnetic resonance observation of cartilage repair tissue (MOCART) scoring system revealed a slight, but statistically significant tendency to deterioration on MRI, between 1 and 2 years of follow-up. The formation of intralesional osteophytes was observed in 3 of the 10 patients (30%). The authors concluded that AMIC is safe and feasible for the treatment of symptomatic patellofemoral cartilage defects and resulted in a clinical improvement. However, the favourable clinical outcome of the AMIC technique was not confirmed by MRI findings. Their AMIC procedure was performed with a collagen membrane, but there are now different modified AMIC procedures available. Gobbi et al studied a BMAC with ACI variant matrix-induced autologous chondrocyte implantation (MACI). MACI patients with trochlear lesions showed better results than those with patellar lesions, while location was not a prognostic factor in the BMAC group. MRI showed complete filling of the defects in 76% of patients with MACI and 81% of patients with BMAC and histological analysis revealed hyaline-like features. Both techniques were viable and effective for large patellofemoral chondral lesions at minimum 3-year follow-up. AMIC procedures with the use of a hyaluronan membrane might, however, give different results.

Osteochondral autografts

Hangody et al presented good-to-excellent results in 79% of those treated with patellar and/or trochlear mosaicplasties at mean 10 years post-surgery. They recently showed a significantly better result with lesions on the condyles in a group of elite soccer players, compared with lesions on the patella or on the trochlea region.

Osteochondral allograft (OCA)

Gracitelli et al showed that patellar allograft survivorship was 78.1% at 5 and 10 years and 55.8% at 15 years. Pain and function improved from the preoperative visit to latest follow-up and 89% of patients were very satisfied with the results of the OCA transplantation. OCA transplantation was successful as a salvage treatment procedure for cartilage injuries of the patella.

Autologous chondrocyte implantation

Peterson et al reviewed the long-term clinical durability of treatment with ACI in we do see a lot of patellofemoral chondral damage when performing arthroscopies and we have to be careful when choosing the suitability of surgical intervention.
61 consecutive patients. Good-to-excellent results were seen in 85% of patients (29 of 32) who had defects on the femoral condyles, including osteochondritis dissecans lesions. Overall, there were 10 treatment failures among the 61 patients (16%), with failure rates lowest among patients with isolated femoral condylar lesions (5%) and osteochondritis dissecans lesions (14%) and somewhat higher in those who had ACI combined with ACI repair (18%) and highest among the patients treated for patellar lesions (24%)44.

In another study45, clinical results obtained in 70 patients treated with ACI for full-thickness patellar defects, with special reference to defect location and size, age, body mass index and sports activity were presented. Defect size and defect location within the patella were found to be significantly associated with clinical outcome. Larger cartilage lesions of the patella were associated with an inferior outcome (p=0.007) and cartilage defects located on the lateral patellar facet were correlated with a better clinical outcome than those located on the medial facet or those involving both facets (p=0.07). Reported results for patellar ACI include a mixed population of patients with/without a concomitant correction of the extensor mechanism46.

Forty-four patients were included in a study designed to compare the outcome of patellar ACI with extensor realignment to patellar ACI with normal patellofemoral tracking47. Patellar ACI with concomitant extensor realignment had a superior outcome to patellar ACI with normal patellofemoral tracking47.

Gomoll et al48 presented multi-centre data on patella ACI grafts and found that when performed with attention to patellofemoral biomechanics, self-rated subjective good and excellent outcomes were achieved in more than 80% of patients treated with ACI, even in a patient population with large and frequently bipolar defects49. Filardo and colleagues50 found that patient characteristics differ between patellar and trochlear cartilage defects. The results obtained were significantly different, with a markedly good outcome in cases with trochlear lesions and less satisfactory results for patients affected by cartilage lesions of the patella51. Subsequently, the authors suggest that patellar and trochlear defects should be considered separately when evaluating the outcome of cartilage treatments in this anatomic region. The study included a total of 49 consecutive patients with full-thickness patellofemoral chondral lesions of the knee that were treated with MACI and followed prospectively for a minimum follow-up of 5 years. A statistically significant improvement in all scores was observed after treatment. Patellar lesions were more likely to require a realignment procedure and were more common in women. There were better results for trochlear lesions compared with patellar lesions at all follow-ups.

Buckwalter et al52 studied the effect of using particulated allografted cartilage for patellar defects and had satisfactory results at short-term (mean 8.2 months) follow-up52. However, six of the 13 patients had concomitant anteromedialisation of the tibial tubercle performed at the same time as cartilage repair52. Similar results were also presented by Tompkins et al in 201349.

**CARTILAGE REPAIR CONCOMITANT PROCEDURES**

As mentioned in the introduction of this article, most patellofemoral cartilage lesions could be caused by some degree of instability with or without dysplasia of the patellofemoral joint. Those biomechanical issues need to be identified if a surgical procedure is to be undertaken and all comorbidities must be addressed at time of surgery. Tibial tubercle osteotomies and patellofemoral ligament reconstructions should be considered to stabilise and unload the joint and the lesions.

Sometimes an unloading osteotomy is needed even in patients with normal patellofemoral biomechanics to improve the outcome. However, it is important to remember that – as noted by Fulkerson9 – elevation of the tibercle of 1.25 cm decreases patellofemoral contact forces by 60 to 80%, but further elevation provides less benefit and that most often no more than 1 cm of medialisation is needed.

- Medialisation may cause too much medial loading. Be extra careful when treating medial lesions! An overly medialised tibial tubercle with a painful and poorly-repaired patellar cartilage lesion may need to be returned to a lateral position via anterolateral tibial tubercle transfer.
- **Proximal patellar lesions:** the patella will articulate on more proximal cartilage with the knee flexed. This lesion responds poorly to tibial tubercle anteriorisation procedures as such an operation causes load shift onto the proximal patella.
- **Lateral release will relieve abnormal tilt of the patella, but if there is lateral facet degeneration, osteotomy is also needed.** Distal lateral patellar cartilage damage does well with anteromedialisation alone.
- **Total patellar, bipolar and trochlear chondral lesions do poorly with anteromedialisation alone; good results could be achieved when ACI is added.**
- **Bipolar uncontained patellofemoral chondral lesions with bone erosion:** consider patellofemoral arthroplasty.

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with large biological implants such as MaioRegen, endoprosthetic surgery or osteochondral allografts.

**Outcomes of unloading**

Of interest to note is that Pidoriano et al\(^a\) correlated the region of the patellar articular cartilage lesion with patient outcomes in a series of patients who had Fulkerson’s anteromedial tibial tuberosity transfer without cartilage restoration. They reported good and excellent results in 56% of patients with medial facet patellar lesions (Type III) and in 20% of patients with proximal pole or panpatellar lesions (Type IV)\(^a\). In addition, patients with central trochlear lesions had largely poor results with anteromedial tibial tubercle transfer.

Trinh et al\(^39\) conducted a review that showed statistically significant improvements in patients undergoing both isolated ACI and ACI combined with osteotomy for patellofemoral chondral defects in all studies. Furthermore, significantly greater improvements in multiple clinical outcomes were observed in subjects undergoing ACI combined with osteotomy\(^39\). In 2014, Gillogly and Arnold\(^40\) presented a study with a mean follow up of 7-years where patients with failed primary treatment of isolated patellar full-thickness articular cartilage defects and patellofemoral malalignment treated with ACI and anteromedialisation of the tibial tubercle at least 5 years prior were contacted for final postoperative outcome scores. A combined ACI and anteromedialisation resulted in significant improvements in symptoms and function, with a low incidence of adverse events in those patients with isolated symptomatic patellar chondral defects\(^40\).

**DISCUSSION**

Treatment of cartilage lesions in the patellofemoral joint is a true challenge. From studies published in the literature it seems clear that correcting the coexisting background factors with realignment, stabilising or unloading procedures, along with the treatment of cartilage lesions, will improve the clinical outcomes\(^39\). Noyes and Barber-Westlin\(^41\) tried to determine if there is an ideal operation for large advanced articular cartilage lesions on the undersurface of the patella in young patients. A systematic search of PubMed was conducted to determine the outcome of operations performed for large patellar lesions in young patients. The authors concluded that a long-term beneficial effect might not occur in a third of ACI and patellofemoral arthroplasties and in two-thirds of osteochondral allograft procedures. Furthermore, they were unable to determine an ideal surgical procedure to treat large symptomatic patellar lesions in patients under 50 years old\(^41\).

However, in the author’s experience of treating cartilage lesions in the patellofemoral joint for more than 25 years, bone marrow stimulation alone is not enough to achieve a satisfactory result.
In most instances. Small defects can be treated with augmented bone marrow stimulation with a membrane (variants of AMIC), mini-fragment (particulated) auto- or allografts, a gel reinforcement of the blood clot or BMAC. Larger defects are better treated with ACI, a biomimetic dual-layer implant or osteochondral allograft. Defects in the patellofemoral joint could also be treated by mini metal implants for both small and larger defects when primary solutions have failed. Pure isolated patellofemoral joint OA responds very well to arthroplasty.

All these treatment options must be considered in conjunction with realignment procedures when needed. Failure to address such adjunct abnormalities will endanger the success of the repair, whatever the technique used. In athletes, however, a more conservative approach than in the general population may be required. In a recent study Kaplan et al looked at 20 top asymptomatic basketball player’s knees with MRI. The overall prevalence of articular cartilage lesions on MRI was 47.5% in their study group. There were trochlear groove articular lesions in 25%. The patella had articular cartilage lesions in 35%. It is subsequently important to remember that asymptomatic lesions are present in a high percentage of top athletes.

In an active athlete a debridement of flaps and synovectomy as well as harvest of cartilage for the tissue bank might be the first option when conservative treatment has failed. In a trochlear lesion, filling the debrided defect with an augmented gel (BST-CarGel) or with an AMIC technique using a membrane of collagen or hyaluronan may be a less invasive option. Fragment ACIs especially with allograft fragments may also be suitable. For larger defects, ACI and osteochondral grafts are to be used but ideally after finishing the season or after retirement, as those techniques most often need open surgery and have longer rehabilitation times.

However, a recent paper by Campbell et al showed the rate of return to sports was greatest after:
- osteochondral autograft transplantation (89%)
  followed by:
- osteochondral allograft (88%)
- ACI (84%)
- microfracture (75%)

Furthermore, osteochondral autograft transplantation and ACI had statistically significantly greater rates of return to sports than microfracture (P < 0.001). They also found that athletes who had a better prognosis after surgery were the ones that:
- were younger
- had a shorter preoperative duration of symptoms
- had undergone no previous surgical interventions
- took part in a more extensive rehabilitation protocol
- had smaller cartilage defects.

Scillia et al studied American Football players (NFL) and found that the majority (67%) were able to return to play after arthroscopic knee surgery including only debridement of flaps of injured articular cartilage lesions (chondroplasty). Athletes who played more games per season were more likely to return to play after chondroplasty of articular cartilage lesions of the knee, but those undergoing a more invasive treatment with a concomitant microfracture were 4.4 times less likely to return to the NFL than were those who did not undergo this procedure.

To treat cartilage lesions in the athlete, especially in the patellofemoral joint, doctors could use the ideas presented by Mandelbaum et al, where the first step is a chondroprotection procedure that aims to prevent loss of existing cartilage. This may include a simple flap debridement plus a synovectomy, combined with rehabilitation including an analysis of how the athlete can optimally biomechanically load his/her affected joint in order to protect the joint from further cartilage deterioration. Regular follow-ups monitoring the joint is mandatory to ensure we know when to intervene with a more aggressive cartilage restoration.

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