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# CHONDROMALACIA PATELLAE: ETIOLOGY, DIAGNOSIS, AND TREATMENT – A NARRATIVE REVIEW

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## ABSTRACT

Chondromalacia patellae (CMP) is a degenerative disorder of the hyaline cartilage of the patella, forming part of the patellofemoral joint. Due to its key role in joint biomechanics, CMP commonly manifests as anterior knee pain and functional limitation, which can significantly impair patients' quality of life. Early and accurate diagnosis, along with appropriate treatment, is crucial due to the very limited regenerative capacity of articular cartilage. This narrative review analyses current evidence regarding the etiology, diagnostic approaches, and treatment options for CMP, including conservative management, regenerative therapies (autologous chondrocyte implantation and mesenchymal stem cell therapy), and surgical interventions. A comprehensive literature search of the PubMed database (2010–2025) was performed, prioritising meta-analyses, systematic reviews, and randomised controlled trials relevant to the topic. CMP represents a complex degenerative condition requiring an integrated clinical and imaging-based approach. Magnetic resonance imaging is highlighted as the primary non-invasive diagnostic modality, while evidence supporting regenerative therapies remains promising but limited. Early recognition and tailored management strategies are essential to prevent disease progression and improve long-term functional outcomes.

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## KEYWORDS

Chondromalacia Patellae, Patellofemoral Joint, Anterior Knee Pain, Magnetic Resonance Imaging, Conservative Treatment, Surgical Treatment

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## Methods

A comprehensive literature review was conducted using the PubMed database. The search strategy focused on current evidence relating to the etiology, diagnostic modalities, and therapeutic options for CMP. The search included articles published primarily between 2010 and 2025, with additional earlier landmark studies incorporated when they contributed essential foundational knowledge. The review followed a narrative approach. To ensure methodological quality, publications were screened based on relevance to the research question, and applicability to clinical and diagnostic practice. Priority was given to randomised controlled trials, systematic reviews and meta-analyses.

## Introduction

Chondromalacia patella (CMP) is a degenerative process of the hyaline cartilage of the patella, resulting in structural changes of varying degrees of severity. In clinical practice, it very often affects the cartilage of the entire patellofemoral joint (PFJ), including the femoral block, as well as the femoral condyles, which are not anatomically part of the PFJ. The function of the joint is to stabilise the limb extensor apparatus, control knee movement, and transfer loads, especially during activities such as descending stairs, running, or squatting. Clinically apparent chondromalacia can therefore cause anterior knee pain in patients during everyday activities, which is one of the reasons why it is necessary to diagnose the condition correctly at the earliest possible stage. Cartilage, as an avascular tissue nourished by the diffusion of nutrients from the synovial fluid, has a very poor ability to regenerate spontaneously, so changes in its structure are usually irreversible <sup>[1]</sup>.

CMP is not a homogeneous entity in terms of etiology, and differential diagnosis is very broad, requiring a precise clinical and imaging approach, as well as treatment, because we do not have a single, standardised therapeutic approach.

The aim of this paper is to present the current state of knowledge on the etiology, diagnostic methods and therapeutic options for chondromalacia of the patellofemoral joint, with particular emphasis on the role of imaging tests and the possibilities of the treatment.

### **Anatomy of patellofemoral joint**

The patella, which is the largest sesamoid bone in the entire body, has two poles: the upper pole attaches to the quadriceps tendon and the lower pole connects to the patellar ligament, which attaches at its other end to the tibial tuberosity and stabilises the patella during movement. Its articular surface is divided into two main facets: lateral and medial, which in turn are covered with hyaline cartilage with the greatest thickness in the entire body (up to 5-7 mm), which results from and indicates the need to carry heavy loads. The second surface of the joint is the femoral block, consisting of the medial and lateral slopes.

The entire joint is stabilised by the ligament-muscle apparatus, which, in addition to the aforementioned quadriceps muscle and patellar ligament, includes: the medial patellofemoral ligament (MPFL), which is the most important medial stabiliser, and the lateral retinaculum, which stabilises the patella laterally.

### **Etiology and risk factors**

The etiology of CMP is a very complex phenomenon. It results from the interaction of many traumatic, congenital, environmental and biomechanical factors. Most of them result in abnormal distribution of forces in the patellofemoral joint and the associated excessive load on individual fragments of cartilage. Traumatic factors include, among others: direct injuries to the patella, dislocations, as well as subluxations, which are the most common cause, but are also often undiagnosed [2]. In addition to these, we also deal with repetitive microtraumas, most often associated with excessive training loads, improper technique, as well as work performed regularly in low positions, requiring frequent kneeling and squatting [3]. These factors overlap, which is the basis for further, more severe degeneration. Congenital factors include increased susceptibility of cartilage to microtrauma and overload resulting from a genetically weaker collagen structure in diseases such as Ehlers–Danlos syndrome, generalised joint hypermobility, osteogenesis imperfecta or selected chondrodysplasias [4], as well as certain anatomical variants of the bone, such as: flattened lateral femoral condyle, osteochondrial ridge or excessive laterally placed tibial tubercle. Post-operative rehabilitation periods leading, among other things, to quadriceps atrophy may also contribute to the weakening of tissue resistance.

However, the largest group consists of biomechanical factors related to the transfer of forces during movement. Shortening of the iliotibial band or insufficiency of the vastus medialis muscle increases the risk of patellar maltracking, i.e. abnormal movement of the patella in the femoral trochlea, leading to uneven distribution of forces and potential development of structural changes, and as a result of knee valgus, as well as flat feet, the load on the cartilage shifts from the even to the lateral compartment of the knee [5].

### **Diagnostic approaches and imaging modalities**

Articular cartilage has no pain receptors. This means that degenerative changes may remain asymptomatic or with discrete symptoms for a long time, until the stimulation of the subchondral layer receptors begins. On the other hand, these symptoms, even those more characteristic of CMP, such as anterior knee pain, especially during activities that increase PFJ compression, including movie-goer's sign, which is pain after sitting for a long time with bent knees, e.g. while driving a car., effusion, retropatellar crepitus and quadriceps wasting, are not specific to it [6]. Therefore, a properly conducted differential diagnosis is necessary, covering other disease entities, including patellar malalignment, excessive lateral patella pressure, osteochondral injury, meniscal tear, Hoffa's syndrome, and synovial plica [7], and based on a combination of clinical approach and appropriate cartilage imaging methods.

Clinical diagnosis is based on a subjective and objective examination, which is founded on the assessment of symptoms and the performance of clinical tests. Individual clinical tests used in the diagnosis of anterior knee pain (including patellofemoral pain) have limited diagnostic value. In a study of 113 knees with PFPS [8], most tests showed good repeatability, but the correlation with imaging results was low, confirming their limitations as a standalone diagnostic tool. It is necessary to supplement the diagnosis with imaging methods that allow for accurate assessment of structural cartilage changes. Imaging methods used in clinical practice include: arthroscopy, RTG, arthrography, CT arthrography, USG and MRI.

Arthroscopy, which allows for direct visual assessment, remains the gold standard. However, apart from therapeutic indications, it is not routinely performed due to its invasiveness. Radiographs should not be the method of choice, as they can only show advanced stages of the disease with images such as significant cartilage loss or joint space narrowing. The situation is similar with arthrography and CT arthrography.

Ultrasound is a widely available examination, useful in the assessment of soft tissues around the patella, such as tendons or ligaments, as well as the presence of effusion in the knee joint, but its accuracy in the direct assessment of articular cartilage is limited [9]. On the other hand, modern ultrasound techniques — such as

quantitative ultrasound parameters (e.g. ultrasound roughness index, reflection coefficient, backscatter, elastography) — have the potential to detect cartilage changes at a very early stage, even before the manifestation of structural defects [10].

In clinical practice, magnetic resonance imaging (MRI) is currently the primary tool for diagnosing structural changes in the patellofemoral joint cartilage. Unlike ultrasound, MRI allows direct visualisation of the layered structure of the cartilage and assessment of its thickness, continuity and signal, enabling the diagnosis of both superficial and deeper damage, as well as the detection of early changes. Additionally, unlike arthroscopy, it is a non-invasive and increasingly accessible diagnostic method [11].

In the context of diagnostic imaging, the classification of CMP changes is also important, as it allows for the standardisation of description and assessment of the progression of changes. The best-known, classic model is the Outerbridge classification, which is used primarily during arthroscopy. During MRI, the Modified Noyes Classification is most commonly used. The classification divides cartilage into four grades on the basis of its MRI aspects: grade 0, normal; grade 1, increased signal intensity on T2-weighted images; grade 2a, a superficial partial-thickness chondral defect extending down to < 50% of the cartilage depth; grade 2b, a deep partial-thickness chondral defect extending down to > 50% of the cartilage depth; and grade 3, a chondral defect extending down to the calcified layer [13].

**Table 1.** Outerbridge classification of chondromalacia patellae [12]

Grade	Description
0	Normal articular cartilage
I	Intact articular surface with softening, swelling and oedema
II	Fissures and fragmentation of the articular surface involving an area $\leq 1.25$ cm (half an inch) in diameter
III	Focal partial-thickness cartilage defect involving an area > 1.25 cm (half an inch) in diameter
IV	Full-thickness cartilage defect extending to the subchondral bone

### Therapeutic strategies

The aim of CMP treatment is to alleviate pain, restore joint function, improve muscle balance and biomechanics, and slow down the progression of cartilage damage. Before considering other treatment options, a conservative treatment trial lasting at least one year should be undertaken. This treatment is considered difficult, and there is no single established standard of care.

The basis of therapy is to limit activities that overload the PFJ below the pain threshold and to rest, especially in cases of injury. The next step should be rehabilitation with a particular focus on physiotherapy, which should include closed chain exercises targeting the quadriceps muscle (and especially its often weakened medial head - the vastus medialis muscle), as well as exercises to strengthen the hip external rotators and core muscles [14,15]. Detailed decisions regarding physiotherapy and the entire treatment process should be made on the basis of a physical examination and imaging results, which may indicate a more precise etiology and a related individualised therapeutic approach, e.g. recommending orthopaedic insoles in the case of flat feet.

If conservative treatment fails, we still have cell therapies and surgical treatment at disposal in our therapeutic arsenal. Cell therapy can be divided into autologous chondrocyte transplantation and mesenchymal stem cell (MSC) injection. Unlike conservative and surgical treatments, which aim to reduce symptoms and slow down the progression of changes, these therapies are more causal in nature, focusing on the regeneration of diseased and lost cartilage. They are the subject of much research and represent the future of CMP treatment [16].

#### Autologous chondrocyte transplantation

In this method, we are probably dealing with the mechanism of hyaline-like cartilage formation as the final tissue, which is confirmed by histological studies [17], as a result of transplanting the patient's own cartilage, previously harvested from a healthy fragment during arthroscopy, followed by biopsy. Chondrocytes are isolated from the harvested material and then cultured for 4-6 weeks [18]. The disadvantage of this method is the need for surgery, which in itself can damage the cartilage.

### Mesenchymal stem cell injection

The first advantage of this method, which distinguishes it from ACI, is its low invasiveness. The injected cells usually come from bone marrow. Currently, the prevailing hypothesis is that the main mechanism of action of stem cells is paracrine, including through modulation of inflammation and stimulation of chondrocytes to regenerate and produce matrix [19]. The results are promising, with regenerative changes observed on MRI, but more randomised clinical trials are needed to determine the effectiveness of the method in the treatment of CMP.

### Surgical treatment

The third line of treatment is surgical treatment, including patellar cartilage excision, shaving, drilling, proximal soft tissue, and distal bony patellar realignment surgery, as well as partial patellectomy [20]. The indications for this are persistent symptoms despite conservative treatment, severe changes that do not qualify for regenerative therapies, as well as pathological ligament tension, patellar track disorders or abnormal biomechanics requiring soft tissue or bone axis correction. Once again, the decision must be made as part of an individualised approach that takes into account the patient's age and the exact condition of their cartilage.

Cartilage debridement is particularly indicated in cases of unstable cartilage edges, which can cause irritation to healthy cartilage through friction. It can be performed using two basic techniques: mechanical smoothing or thermal smoothing using a radiofrequency probe. Both methods are performed arthroscopically. Arthroscopic lateral retinacular release is indicated for lateral patellar tilt and the presence of a tight lateral retinacular capsule and loose medial capsule. It involves cutting the excessively tight lateral retinaculum, which improves the path of the patella, which previously placed excessive strain on the lateral compartment of the cartilage. Patellar realignment surgery involves attempting to restore or improve the patella's movement in the femoral groove, while partial patellectomy involves removing a fragment of the patella with particularly diseased cartilage. The indications for this radical procedure are deep (reaching down to the bone), extensive and unstable damage that is not suitable for regenerative treatment.

### Conclusions

Chondromalacia of the patellofemoral joint is a multifactorial condition in which biomechanical abnormalities and traumatic events play central roles. Correct diagnosis requires a combination of an individualised clinical approach, as there is no single 'golden' clinical test with sufficient sensitivity and specificity, and imaging methods, among which magnetic resonance imaging is the most accurate. Similarly, treatment must be individualised, with conservative treatment as the first line of treatment, which should be focused in particular on improving biomechanics. Regenerative methods, which represent the future of CMP treatment, are being intensively developed, but they still require high-quality research to determine their exact effectiveness, especially in the long term, and to standardise them in terms of patient age and the severity of the changes.

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