Osteochondritis dissecans of the knee: Pathophysiology and contributing factors

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The term osteochondritis dissecans of the knee was first coined by König in 1887 who suggested an inflammatory or even infectious cause to this disease. However, subsequent studies could not confirm the presence of local or systemic inflammatory processes.

The lesion was described by Hughston as being a fragment of avascular bone covered by articular cartilage that is separated from the normal underlying bone by a layer of fibrous tissue forming a barrier preventing revascularization. The fragment may either detach completely and lead to a loose body, allow for revascularization and spontaneously heal, or lead to non-union and remain in its crater within the femoral condyle [1,2].

The primary cause of this localized devascularization remains unknown and is thought to be multifactorial. A meta-analysis conducted by Andriolo et al. [3] provides an insight into the diversity of recent studies in this domain (table 1).

An analysis of the hypotheses presented today in relation to the etiology of osteochondritis provides a framework for the assessment of possible risk factors.

I - Epidemiology

The incidence of osteochondritis of the knee is estimated to range between 9 and 12 per 100,000 in those aged younger than 19 years. It is generally not encountered before 6 years of age, with 25% appearing between the ages of 6 and 11 years old and 75% between 11 and 19 years old. Even though it is 2 to 4 times more prevalent in boys compared to girls, the incidence of osteochondral lesions in girls appears to be on the rise [4]. It appears equally as prevalent on either knee and 15% of cases are bilateral.

The medial condyle is most commonly affected with up to 80% of cases appearing in this region, especially on the lateral border, with the remaining 20% of cases involving the lateral condyle.

Some cases have been described with lesions at the level of the trochlea, patella, and even the tibial plateau [5]. The natural history after conservative treatment of benign forms is generally favorable. In more severe forms with osteochondral defects, secondary osteoarthritis may appear in up to 50% of patients at 20 years follow-up in the absence of surgical repair [6].

II- Pathophysiology

A – Mechanical origin

1 - Traumatic

In all published studies, it has been suggested that micro-traumatic events secondary to physical exercise may be the primary cause of osteochondritis dissecans. This is further confirmed by an increase in the incidence of lesions found in girls who are increasingly partaking in sports requiring large amounts of pivoting or high impact on the knees. However, in multicentric studies conducted by the European Pediatric Orthopedic Society (EPOS), only 55% of subjects affected with osteochondritis dissecans engaged regularly in sports [7].

Even though some cases have been reported in the literature and documented by MRI, an acute traumatic cause is generally not found [8].

Moreover, lesions that resemble osteochondritis have been reproduced experimentally through repeated contusions of the knees, with the development of subchondral fracture that later progressed toward non-union [6].

2 - Biomechanical

Certain types of sports induce high pressures on the knees due to certain positions, such as kneeling in baseball players. These young athletes present more frequently with osteochondritis of the posterior aspects of the condyles [9].

Furthermore, a higher prevalence of bilateral posterior and bicondylar osteochondritis was reported in patients with cerebral palsy ambulating in a crouched gait pattern [10]. However, in a series of 34 subjects presenting with trochlear osteochondritis, Price et al. found that 90% participated in sports that placed extreme pressure on the femoro-patellar joint, such as Basketball and football (soccer) [11].

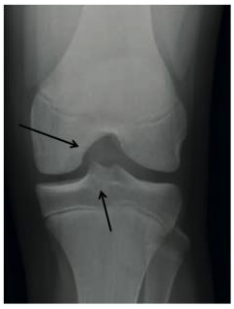
Jacobi noted that most subjects presenting with osteochondritis of the lateral condyle were in slight genu valgum, with genu varum leading to medial osteochondritis [5].

3 – Anatomical

Many Japanese publications have studied the incidence of lateral osteochondritis in subjects with a discoid meniscus, a variant that is especially prevalent in Japan. Osteochondritis was found in 5% of patients who had not been previously operated on the meniscus, whereas 20% of patients who had been previously operated by meniscoplasty later developed osteochondritis, with larger meniscal resections and younger age being the primary risk factors [12].

Finally, following Fairbanks in 1933 and Smilie in 1957, a number of studies have been conducted in search of impingement between the medial intercondylar eminence (tibial spine) and the lateral aspect of the medial condyle. Moreover, this mechanism is reproduced

during the diagnostic maneuvers of Wilson: pain is elicited when the leg is placed in internal rotation with the knee in flexion. A team of researchers from Toulouse, France, showed a significantly raised tibial spine [13], and Chow et al. found a narrow intercondylar notch in patients with signs of impingement [14]. Other biomechanical factors, such as tibial slope, lateral tibial torsion, and hyperlaxity may also be associated leading to repeated impingement between the tibial spine and the most frequent location of the osteochondral lesion. Furthermore, the proximal attachment of the posterior cruciate ligament could also cause increased traction on this area [15] (figure 1).



Obesity also increases the risk of osteochondritis of all locations. The elbows and ankles are especially affected in heavier patients, with the knees being the more frequent location in children who are moderately overweight. Incidentally, it is difficult to determine whether the risk factors are mainly mechanical or biological [16]. As a result, certain activities and anatomical characteristics either increase the frequency or affect the location of osteochondral lesions due to repetitive localized trauma. Nevertheless, these factors may not fully explain this pathology, which is often found in the absence of these factors.

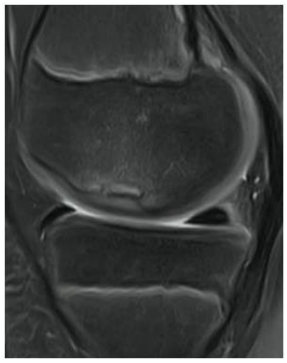
B – Genetic origin

A genetic predisposition is suspected but difficult to demonstrate. Gornitzky et al. [17] showed that 14% of subjects diagnosed with osteochondritis had a relative with the same pathology, and Yellin et al. attempted to identify genetic loci associated with the pathogenesis of osteochondritis [18].

C- Biological origin

1- Osteonecrosis

Intraoperative histologic studies (thereby denoting more severe forms) in search of local and general markers of regeneration confirmed that the deterioration of bony and cartilaginous matrices was situated at the level of the subchondral bone and was associated with the potential for regeneration. Osteonecrosis was a frequent but inconstant finding. A more consistent element was the separation between the undersurface of the osteochondral fragment and the subchondral bone, regardless of its macroscopic stability [20]. Cellular and serologic markers of bony and cartilaginous regeneration can be found in the area of separation. In some cases, the lesions do not involve the subchondral bone and the separation takes place directly beneath the articular cartilage. The cartilage itself is rarely the site of necrosis and can sometimes even be hypertrophied, a finding which may explain the asymptomatic nature of certain lesions [20] (figure 2).



These findings are not compatible with Enneking's hypothesis, which was based on the fact that condylar subchondral bone is vascularized by terminal arterioles. According this hypothesis, osteochondritis dissecans could be secondary to intra-osseous vascular pathology.

2 – Animal studies: Epiphyseal growth plate

Animal studies may provide further insight into the pathophysiology of this disease. In fact, horses are known to frequently suffer from osteochondritis of the knees, such that racehorses may even benefit from systematic screening. Veterinarians have thus searched for animal models that are easy to study, an endeavor that led them on the miniature pig. These pigs are known to present preclinical forms of osteochondritis dissecans, lesions that were first described in 1978 and termed osteochondrosis [21].

Studies based on histologic and MRI data have revealed frequent ossification irregularities at the level of the epiphyseal growth plate. This is usually found between the secondary ossification center of the condyle and the articular cartilage. Contrary to hyalin cartilage, these sites of irregularity contain a temporarily fragilized terminal vascular bed which flows back and forth within the cartilaginous canals. During growth, as the canal is progressively pervaded through the process of chondrogenesis or ossification, this vascularization is interrupted.

Animal models have also shown that osteochondrosis is due to the early obstruction of these canals leading to ischemia and necrosis of the chondrocytes that are situated at the ends of these canals. During the progression of the ossification site, this area of chondral necrosis resists to ossification and thus leads to late focal enchondral ossification. This may evolve toward:

1- Healing, which is the most frequent case
2- Formation of cysts within the subchondral bone
3- osteochondritis dissecans [22]

Since animal models allow easy reproduction of osteochondral lesions by surgically interrupting the vascular supply to the growth plate without affecting that of subchondral bone, histological studies in these models have been thorough [23]. This has led to a better understanding of these injuries, especially why a fragment of osteochondritis dissecans

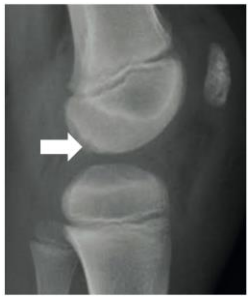
contains rather necrotic subchondral bone or is completely formed by rather necrotic hyaline cartilage. Necrotic subchondral bone and cartilage therefore merely represent the natural history of this disease process.

Increased signal intensity, which may be of liquid or cystic origin, may be found even in the absence of articular cartilage fissures and signify instability. These are generally secondary to the presence of chondroblast-rich granulation tissue.

3 – In children

The femoral epiphyseal cartilage of the miniature pig appears to be very similar to that of children. Lesions that are equivalent to chondrosis in animals have been sought on human femur samples aged 1 month to 11 years. Significant lesions have been found on over 50% of these samples, which are sometimes multiple and bilateral, and are located at the usual sites of osteochondritis dissecans in children.

As these lesions, specifically those affection the posterior condyles, leave no sequelae and are frequently found in children, they are generally considered as normal variants (figure 3).



Comparing these lesions to osteochondrosis in animals suggests that ischemic chondral necrosis in children is a reality and may even progress toward osteochondritis dissecans [22]. Therefore, this entity is probably due to pathological processes that start early on in life, well before the age of 6 years, and well before any clinical or even radiographic manifestations. Progression toward osteochondritis dissecans seems to be influenced by certain factors that promote the persistent separation between the epiphysial ossification center and the subchondral bone, and thus its instability (a primordial sign of poor prognosis) and secondary necrosis.

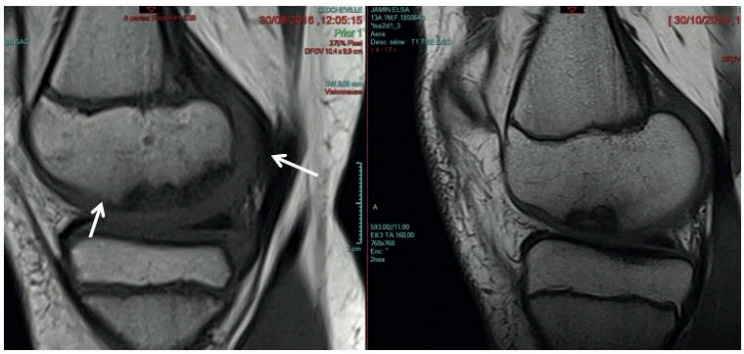


Figure 4 illustrates partial spontaneous healing of an extensive lesion.

III- Risk factors

Osteochondritis dissecans is the result of a frequent, old lesion in which the process of spontaneous healing is impeded by multiple factors.

Genetic factors probably caused the initial osteochondrosis, whereas anatomical and biomechanical factors seem to influence progression toward actual osteochondritis.

Overweight also seems to be an authentic risk factor.

In addition, certain types of sports may play a role in the emergence of symptomatic osteochondritis. Nevertheless, there is no single type of sport or activity level that would be particularly responsible for the occurrence of osteochondritis of the knee, contrarily to, for example, the relationship that is frequently found between high-level gymnastics and osteochondritis of the elbow. The only exception would be baseball players, especially receivers, who may develop osteochondritis of the knee due to prolonged periods in the kneeling position.

It would appear that athletes are more frequently affected by this pathology. However, these patients are also usually more concerned by any limitation in their physical ability. In fact, the same lesions may be asymptomatic in some subjects, such as musicians, but invalidating to a football player.

Mechanical axis deviations of the lower limbs cannot be held responsible either, even though they may influence the location of said lesion.

The roles of certain anatomical factors must also be mentioned:

- A discoid meniscus seems to lead to lesions of the lateral condyle, a finding that has been essentially reported in the Japanese population.
- The prominence of the medial tibial spine probably explains the frequency of osteochondritis dissecans of the lateral border of the medial condyle, which is undoubtedly associated with other dynamic elements.

Conclusion

This seemingly well-known lesion appears to originate from a histologic structure that is still unknown: The epiphyseal growth plate of the chondroepiphysis with its vascular networks and its multidirectional canals. A discrete vascular event that is considered to be normal, is frequently found and often resolves spontaneously. However, in certain difficult to control circumstances, this vascular event may later progress into a necrotic osteochondral fragment that would place the child’s activity and future of the knee in peril.

Further studies in animal models and humans may give insight into this vascular event, one of the objectives of the ROCK (Research on OsteoChondritis of the Knee) group that was founded in 2010 [24].

Images

Table 1: Recent studies on the etiology of osteochondritis dissecans

Type of study	**Number of studies**
Genetic	27
Ossification of chondro-epiphysis	12
Endocrinology	9
Overuse	18
Tibial spine	5
Discoid meniscus	16
Biomechanical	20

Figure 1: Association of two anatomical characteristics: both a hypertrophic medial intercondylar eminence (tibial spine) and a narrow, asymmetric intercondylar notch are risk factors for impingement with the lateral border of the medial femoral condyle.

Figure 2: High signal intensity within the bone; the subchondral bone is thin, and the articular cartilage is hypertrophic.

Figure 3: Irregular ossification of the femoral condyle.

Figure 4: Natural history at 3 years follow-up: The posterior aspect of the osteochondral lesion has healed without the need for specific treatment while the anterior aspect, constrained by higher mechanical loads, has persisted.

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