Meniscectomy and osteoarthritis: what is the cause and what is the effect?

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Osteoarthritis (OA) is a major health burden among the middle aged and elderly. Partial meniscectomy, the most common orthopedic surgical intervention, is recognized as a strong risk factor for knee OA. Loss of the main meniscal functions, load distribution and shock absorption, are often critical steps in knee OA development. This review outlines the concept of a dual relationship between meniscectomy and OA. A meniscal tear may not only lead to meniscectomy and OA, but early stage knee OA may also lead to meniscal tear and meniscectomy, with the meniscal tear representing a signature feature of developing OA of the joint.

Arthroscopic partial meniscectomy is the most common surgical intervention performed by orthopedic surgeons, with more than 450,000 procedures in the USA annually [1]. Meniscectomy, whether total or partial, is recognized as a strong risk factor for the development of knee osteoarthritis (OA) (Figure 1) [2,3]. OA is the most common cause of musculoskeletal disability in developed countries, and is listed among the top ten of global disease burdens according to the WHO [4]. The disorder is more than ten-times as common as rheumatoid arthritis and, in the USA, approximately 6% of the population aged 30 years or older and 11–15% of those aged 65 years or older suffer from symptomatic knee OA [5]. The prevalence of the disorder increases drastically with age and the proportion of elderly people in society continues to increase. Therefore, OA will cause increasing socio–economic costs, costs that are tremendous already [6]. Treatment for OA is symptomatic, but efforts are being made to develop drugs that may slow or halt the progression of OA. The disease is the main cause of joint replacement surgery, even though studies of the natural progression of the disease show that a relatively small proportion of OA patients require arthroplasty [7].

Function of the menisci: shock absorption & load transmission

The menisci are two semicircular fibrocartilage structures located between the articular surfaces of the femur and tibia in the medial and lateral joint compartments. Each covers approximately two-thirds of the corresponding articular surface of the tibia (Figure 2). In cross section, both menisci are wedge shaped with a thick peripheral base. The attachments of the menisci are intricate. In short, the medial meniscus is firmly attached to the joint capsule, whereas the lateral meniscus is more mobile. Both of the menisci are attached to the tibia through the anterior and posterior horns, where circumferential matrix fibers continue as ligaments attached to the intercondylar bone.

The peripheral border is infiltrated by capillaries that penetrate 10–30% of the meniscus width [8]. A branch from the tibial nerve innervates the peripheral part of the meniscal tissue, where the nerve fibers mostly follow the capillaries [9].

The sparse meniscal population of fibrochondrocytes produces and maintains the meniscal matrix. In contrast to articular cartilage, which contains principally Type II collagen and an abundance of proteoglycan, meniscal matrix collagen is 98% Type I and the meniscus contains much less proteoglycan (<1%). The tightly woven collagen fibers are arranged predominantly in a circumferential pattern. The most important properties of the meniscal matrix are the ability to resist tension, compression and shear stresses [10].

The main functions of the menisci are shock absorption and load transmission during joint movement and loading [11–13]. The menisci distribute stress over a large area of the articular cartilage. When the knee is loaded, the tensile strength of the meniscal matrix (hoop tension) counteracts extrusion of the meniscus. Therefore, the healthy meniscus responds mainly to load with compression. The meniscus may also be important in joint stability, proprioception and lubrication [14–16].

Meniscal tears: often not traumatic

Classically, two major categories of meniscal injuries are described: traumatic lesions and gradual degeneration with aging [17–20]. Traumatic lesions usually occur in younger, active individuals with or without associated cruciate or collateral ligament injury. The meniscal tear is commonly due to internal rotation of the femur as the flexed knee

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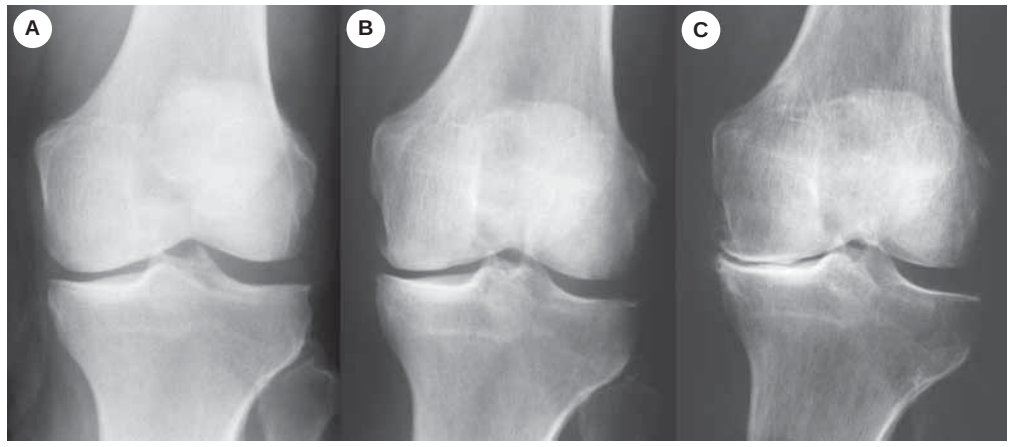
future medicine

Figure 1. Radiographic progression of knee osteoarthritis.



The radiographs were obtained **(A)** 7 years, **(B)** 13 years and **(C)** 21 years after total meniscectomy. Typical features of radiographic osteoarthritis, such as joint space narrowing, marginal osteophytes and sclerosis are visible.

moves toward an extended position. The meniscus usually splits vertically and parallel to the circumferential oriented collagen fibers (Figure 3). Traumatic injury is considered more frequent in the medial meniscus, mainly due to its lower mobility, larger diameter and thinner periphery.

Degenerative tears, described as horizontal cleavages, flap (oblique) or complex tears, are associated with older age [17–20]. These tears are common. In asymptomatic subjects with a mean age of 65 years, a tear was found in 67% of the subjects using magnetic resonance imaging (MRI), whereas in patients with symptomatic knee OA, a meniscal tear was found in 91% [21]. Similar findings have been made in random necropsy cases where 60% of the subjects had a horizontal cleavage lesion [18]. These numbers would suggest that some 30 million individuals in the USA over the age of 65 have a meniscal tear. Obviously, having a meniscal tear does not by itself justify surgical intervention.

Total meniscectomy: 'when in doubt, take it out'

To appreciate the present and future concepts of treatment of meniscal lesions, it is helpful to briefly review the history of meniscal surgery. Interestingly, the first known report was a procedure of meniscal repair. In 1883, a British surgeon, Thomas Annandale, successfully sutured a torn medial meniscus [22]. However, 4 years later he published another report in which he justified total excision of the meniscus rather than suture, and this view prevailed for over 80 years [23].

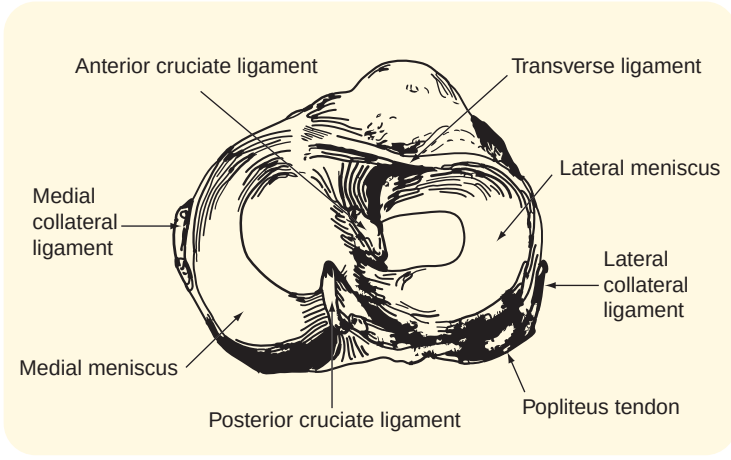
In the mid 1930s, King reported on degenerative joint changes after meniscectomy in dogs [24] and that a detachment of the meniscus from the periphery might heal due to its vascular supply [25]. In the late 1940s, Fairbank speculated that frequent radiographic changes found after meniscectomy were due to the loss of the load-protective function of the menisci, resulting in remodeling of the joint [26]. However, removal of the menisci was considered a mostly benign procedure for at least another 20 years.

From the late 1960s to the 1980s, an increasing number of follow-up reports of meniscectomy were published, all indicating a high frequency of radiographic OA and reduced knee function [27–35]. However, a lack of standardized radiographic assessment and outcome measures precluded consistent quantification of the OA risk. In 1998, a sixfold increase in the risk of radiographic OA 21 years after total meniscectomy, compared with controls matched for age and sex, was shown in a Swedish study using standardized assessment and low loss to follow-up [3].

Partial meniscectomy & new optimism

In 1947, based on short-term outcome, even partial meniscectomy was suggested to be an alternative to total excision [36]. However, there was a strong conviction among knee surgeons that total excision was necessary to produce good results of the regeneration of meniscal tissue [37]. Not until approximately 20 years later, when the arthroscopic technique was introduced, was interest increased in excising only the damaged portion of

Figure 2. The anatomy of the menisci (the tibial plateau seen from above).



Modified from Warren RF, Arnocky S, Wickiewicz TL: Anatomy of the knee. In: *The Lower Extremity and Spine in Sports Medicine.* Nicholas JA, Hershman EB (Eds). CV Mosby Co., St. Louis, USA, 657–694 (1986).

the meniscus. During the same period of time, several biomechanical studies reported on the load-bearing and shock-absorbing functions of the menisci [11–13,38,39]. It was then time to shift the paradigm towards a more restrained attitude to total meniscectomy, some 80 years after the introduction of the procedure.

Where are we today?

There are several short-term benefits of the arthroscopic technique of surgery and partial meniscal resection in terms of factors such as the length of hospital stay and rehabilitation [40–42]. Furthermore, with a substantial portion of the circumferentially oriented matrix fibers intact in the partially resected meniscus, hoop tension may still develop to counteract meniscal extrusion when the knee is loaded. Substantial function may thus remain in the residual meniscus during shock absorption and load transmission. However, despite numerous follow-up reports, evidence for an improved long-term outcome compared with total extirpation is still limited [28,43–48]. A study from Lund University, Sweden, using substantial subject numbers, showed for the first time that partial meniscal resection induced fewer radiographic changes related to OA than total meniscectomy [2]. However, the frequency of symptomatic knee OA was not substantially lowered, which suggested that partial meniscectomy was not the final answer.

As a consequence, for younger individuals with traumatic injury to the meniscus, meniscal repair is strongly advocated when the lesion is located within the vicinity of the vascularized zone (with the potential to heal). However, rehabilitation after repair is much more demanding than after meniscal resection and the long-term outcome of meniscal repair, compared with partial meniscectomy, with respect to OA is still unknown [49,50].

Meniscal replacement using allogenic, xenogenic or artificial materials has been tested in symptomatic younger individuals who have undergone total meniscectomy. However, transplant survival is variable and long-term results using standardized outcomes are lacking [51].

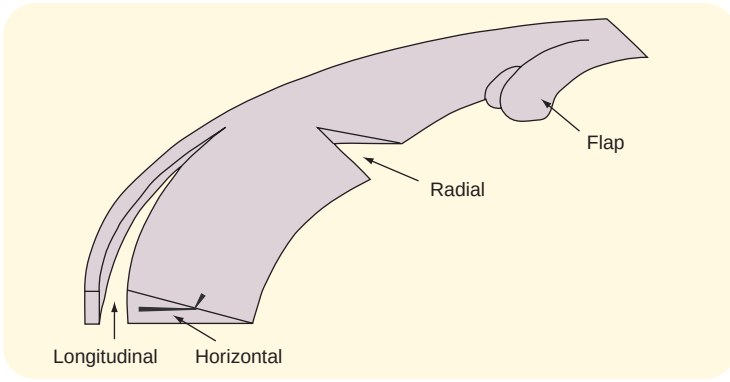
Meniscal tear: a feature of OA

Although preserving meniscal tissue during meniscal surgery may provide some benefits, the reduction in the frequency of knee OA compared with total resection appears to be modest [2]. The reason could be that many of the middle aged and older patients operated on already have early stage knee OA at the time of having meniscal symptoms. The surgical intervention may merely remove evidence of the disorder, while the joint degradation of OA proceeds.

The menisci and articular cartilage share many similar components and properties, and are exposed to similar stresses. The pathological processes active in the early stage OA joint that eventually lead to cartilage destruction characteristic of OA are not limited to the joint cartilage only, but would also be expected to affect meniscus and ligament integrity. A tear in a meniscus with degenerative changes is often associated with preexisting structural changes in the articular cartilage, which may represent early stage OA [18]. Shear stress and early proteolytic degradation of the collagenous meniscal matrix may result in decreased tensile strength. A meniscal tear could be the result of a decreased ability of the compromised meniscus to withstand loads and force transmissions during normal knee-joint loads. A lesion may develop spontaneously (e.g., when squatting) or in conjunction with minor knee trauma. Patients with meniscal symptoms due to a degenerative tear may thus constitute a subpopulation enriched in individuals with incipient OA. Depending on how much functionality of the meniscus was lost due to the tear and the surgical procedure, OA development may then be further driven through increased biomechanical loading of the joint cartilage (Figure 4).

Meniscal displacement is common, particularly in knee OA [52,53]. It is often another sign of a degraded or torn meniscus and a possible OA disease process. Meniscal displacement may also

Figure 3. Classification of meniscal tears.

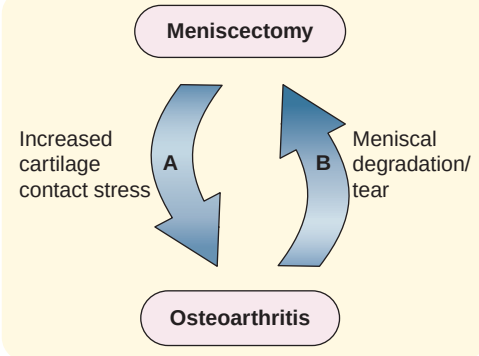


contribute to the increased joint space narrowing seen on radiographs, and meniscal tear and displacement are strong determinants of the rate of cartilage loss in knee OA [54,55].

To operate or not to operate?

The introduction of arthroscopy may have led to a liberalization of the indications for meniscal surgery. The low risk of complications and quick patient recovery has made the arthroscopic technique attractive as a means to investigate and treat 'meniscal' pain, even in older patients. The authors have noticed an increase in the average surgery patient age with time and, consequently, a gradual increase in the proportion of degenerative meniscal tears operated upon. The increased use of diagnostic MRI, which probably visualizes a meniscal tear irrespective of whether the patient is symptomatic or not, contributes to an active decision by the arthroscopist [21]. It may be difficult not to operate on even stable tears if knee symptoms are present. Considering the vast number of subjects with meniscal tears and the high prevalence of knee OA in the middle aged and older population, it is difficult to discriminate between symptoms caused by a meniscal tear and symptoms of early stage OA. The osteoarthritic disease process (and symptoms) may start at a much younger age than previously considered. The etiology of pain in OA is still unclear, but recent findings suggest that bone marrow lesions identified by MRI or soft-tissue involvement are important [56,57]. The prevention of OA cannot be used as a reason for meniscal resection, particularly when the symptoms do not convincingly suggest an unstable lesion [58]. By contrast, extensive removal of meniscal tissue, particularly coupled with degenerative changes, will lead to a disappointing result [30,59].

Figure 4. The conceptual linkage between meniscectomy and osteoarthritis.



(A) The classic route where a meniscal lesion in a knee leads to meniscectomy and increased risk of osteoarthritis (OA). **(B)** The hypothetical route where OA leads to meniscal tear and meniscectomy.

The principles of management of meniscal tears associated with OA in the middle aged and elderly should be congruent with those for managing knee OA in the same population; many of the findings and symptoms are shared [60]. All patients should receive information and advice and be encouraged to self-help (e.g., education, exercise, weight loss if overweight and lifestyle alteration). Simple over-the-counter analgesics may also be useful. On the next level, required by some patients, simple nonsurgical interventions (e.g., nonsteroidal anti-inflammatory drugs, other drugs, supervised physiotherapy or orthotic devices) are applicable. Only a few patients will need more advanced treatment, such as injections or arthroscopy.

Genes & environment interact to drive OA development

Several community-based population studies have shown an association between OA of the hand and OA of the knee, suggesting that hand OA may be part of a more generalized OA [61]. Hand OA has a significant heredity, indicating the presence of a genetic risk factor [62,63]. In the early 1980s, a study by Doherty and colleagues suggested an interaction between local joint injury and systemic factors in OA [33]. Thus, the classic view of secondary OA may be incorrect and the distinction from primary OA not as clear as previously thought. A more recent study corroborated this association between hand and knee OA after meniscal injury [64]. A degenerative type of meniscal tear was found more frequently at index surgery in patients with radiographic

hand OA at follow-up. Subjects with bilateral knee OA at follow-up had radiographic hand OA more frequently than subjects with unilateral knee OA. These findings provide additional support for an interaction between genetic and environmental risk factors in OA, although metabolic effects cannot be excluded.

A worse outcome after lateral compared with medial meniscectomy has been shown in several studies [2,29,34,35,48,65]. The lateral meniscus carries higher loads in the knee compared with the medial meniscus. Consequently, if removed, the slightly convex lateral tibial plateau will be exposed to relatively more cartilage contact stress. This may further facilitate the OA process, compared with the more concave medial tibial plateau after removal of the medial meniscus [11,12]. This may provide yet another example of the interaction of local environmental factors with the inherent risk of the individual.

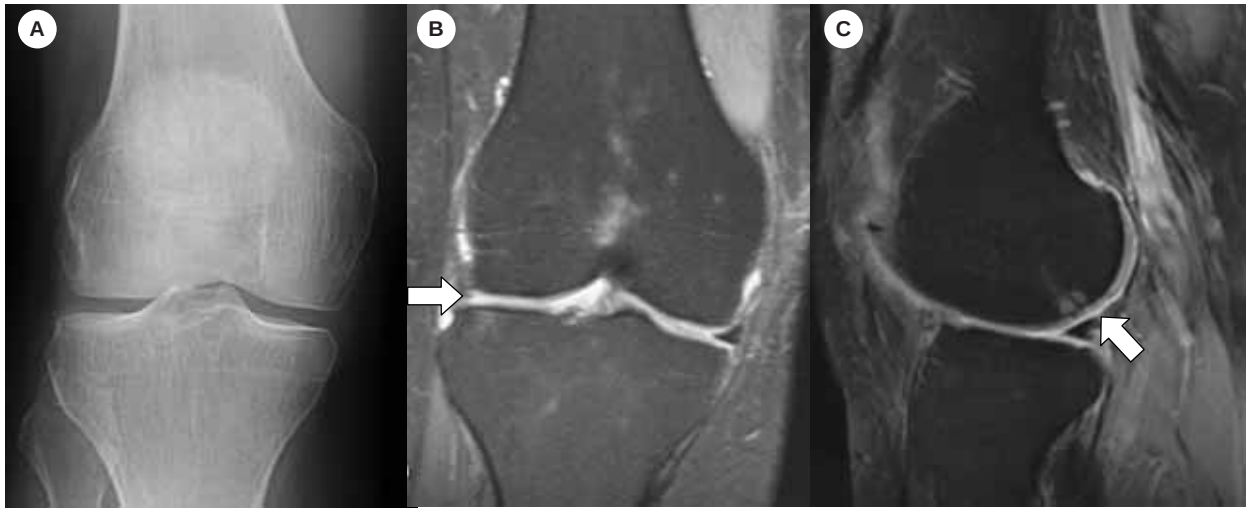
Ongoing challenges & unmet needs

The cause and effect relationship between OA and meniscal tear still remains to be proven longitudinally, but recently initiated large natural history studies, for example, the Osteoarthritis Initiative (OAI), which include repeated MRI examinations of subjects at risk of knee OA, may provide such data [101].

If the degenerative meniscal lesion is regarded as signaling incipient OA, it is not surprising that surgical intervention directed to the meniscus has little or no influence on long-term, patient-relevant outcome [21,66,67]. In addition, the short-term benefit from meniscal surgery of these lesions is questionable, as several studies indicate poor results [30,68,69]. Middle-aged and older patients with meniscal pain and meniscal lesions represent a challenge for the health professional. It is difficult to discriminate between symptoms caused by a meniscal tear and symptoms of early stage knee OA. Therefore, in joints without specific mechanical symptoms, meniscal surgery is often not indicated.

The weak evidence base for many of the current treatments suggests that this therapeutic area is in great need of well-designed, randomized, controlled clinical trials to assess the true effects of arthroscopic meniscal resection, meniscal repair or nonsurgical treatments, compared with placebo or sham treatment. Stratification, with regard to lesion type, age, activity level and other variables, will provide a challenge in trial design, but there is no shortage of patients. Blinding of patient and assessor and ethical issues represent additional challenges, but the lack of surgeon equipoise may provide the greatest hurdle of all for a successful trial [70].

Figure 5. Discrepancy between findings of conventional radiographic examination and magnetic resonance imaging.



Over the last year, this 38-year-old subject has experienced knee aching related to joint use, relieved by rest. **(A)** The frontal knee radiograph shows normal findings, whereas **(B)** coronal T2-weighted magnetic resonance imaging reveals status after subtotal lateral meniscectomy and **(C)** sagittal image shows reduced cartilage thickness and bone marrow edema. Findings are compatible with early stage knee osteoarthritis.

Many of the middle-aged patients with knee symptoms are probably likely to suffer from early stage OA in the absence of definite features on conventional knee radiographs (Figure 5). Therefore, other major challenges of research during the next decade will be to standardize and validate the methods and criteria for diagnosing and monitoring preradiographic osteoarthritic disease using, for example, MRI and biomarkers of OA.

Conclusions

The history of meniscectomy has been characterized by a firm belief in radical surgery, with serious long-term consequences for the individual and society. The menisci play an important protective role for the knee joint through shock absorption and load distribution. Currently, the consensus in surgical treatment of meniscal tears is to preserve as much functional meniscal tissue as possible. Still, meniscal lesions are tremendously common, especially in the osteoarthritic knee. This challenges the health professional in choosing the best treatment, both in the short- and long-term. A degenerative lesion in the symptomatic middle-aged or older individual, could suggest early stage knee OA and should be treated accordingly. Surgical resection of non-obstructive degenerate lesions may only remove

Executive summary

Meniscus structure & composition

- The meniscus structure is C-shaped with circumferentially oriented collagen (Type II) fibers, fibrochondrocytes (sparse) and proteoglycans. The central two-thirds lacks blood supply and nerves.

Meniscus functions

- The functions of the meniscus include shock absorption, load transmission, joint stability, proprioception and joint lubrication.

Epidemiology of meniscal tears

- There are two major catagories of meniscal injuries: traumatic (mainly younger, physically active individuals) and degenerative (extremely common, mainly middle-aged and older patients).

Diagnosis

- Diagnosis involves a careful anamnesis and clinical examination, possibly supported by noninvasive imaging, such as magnetic resonance imaging (MRI).

Treatment – meniscal tears

Historically

- Total meniscectomy (1880s to 1970s).

Present & future

- Partial meniscectomy (1970s onwards).
- Meniscal repair (1970s onwards).
- Meniscal transplant (1980s onwards).
- Drugs to prevent meniscal degradation? (2015 onwards).

Treatment – special considerations

- Meniscal repair when possible (traumatic lesions, potential to heal).
- For stable degenerative tears, a restrictive attitude towards resection is advocated as knee symptoms may be caused by early stage knee osteoarthritis (OA).

Future challenges

- Randomized clinical trials (surgery vs no surgery).
- Criteria to diagnose and monitor preradiographic OA and meniscal lesions using, for example, MRI and biochemical markers.
- To identify risk factors for the fast progression of OA.

Conclusions

- The menisci fulfill important roles in shock absorption and load distribution to protect knee joint cartilage.
- Meniscal tears are extremely prevalent in the middle aged and elderly, regardless of knee symptoms.
- Meniscectomy could lead to OA, however, OA may also lead to meniscal tear and meniscectomy (remains to be proven longitudinally).
- Meniscal resection of the stable degenerate lesion may only represent cosmetic surgery, while the OA joint degradation proceeds.

evidence of the disorder while the OA degradation proceeds. Well-designed, randomized, controlled clinical trials are needed.

Future perspective

Within the present decade, longitudinal MRI studies will provide important clues for understanding the role of meniscal integrity and position on the loss of cartilage and symptoms in knee OA. We will probably see several potential inhibitors of cartilage breakdown in early stage development, which may also have an effect on meniscal degradation. However, the clinical implications of disease-modifying drugs could be limited, as coupling between cartilage loss and symptoms is vague. Another problem associated with the development of effective drugs is the challenge of monitoring disease progression, both on a structural and patient-relevant level. In most cases, OA is a slowly progressive and complex disorder and its course is difficult to predict. An area of attention will be to identify risk factors for fast progression of the disease, including those associated with meniscal degradation.

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Website

101. Osteoarthritis Initiative: a knee health study
www.oai.ucsf.edu

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