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REVIEW ARTICLE

Spontaneous osteonecrosis of the knee: what do we know so far? A literature review

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Abstract

Purpose Spontaneous osteonecrosis of the knee (SONK) is said to be a relatively common disease which may lead to an end-stage osteoarthritis of the knee. The aim of this paper was to review the literature on this field published until now, discuss the results of both conservative and surgical treatment options, as well as to introduce new methods of treatment, which may be applicable in SONK treatment.

Methods We searched the PubMed and Cochrane databases until November 2019 and presented the most recent findings in this work.

Results The exact aetiology of SONK still remains unclear; however, recent studies suggested that early stage of SONK is rather a result of the subchondral fracture than primary osteonecrosis. So far described conservative treatment includes non-weight bearing or protected weight bearing with a knee brace, nonsteroidal anti-inflammatory drugs, analgesics, and bisphosphonates. Surgical management includes arthroscopic debridement, core decompression, osteochondral autograft, high tibial osteotomy, and unicompartmental knee arthroplasty or total knee arthroplasty.

Conclusions Although the aetiology of SONK remains unknown, there are many treatment options, and the choice of the most suitable one is challenging. We think that subchondroplasty may be one of the effective methods.

Keywords Spontaneous osteonecrosis · Subchondral lesion · Subchondroplasty · Orthobiology

Definition

Spontaneous osteonecrosis of the knee (SONK) has been mentioned for the first time by Ahlback et al. in 1968 when he noticed "a peculiar radiolucent lesion of the subchondral bone" [1]. Nowadays, SONK is said to be a relatively common disease usually described as a focal, subchondral lesion which may lead to an end-stage osteoarthritis of the knee [2]. In the latest radiological publication, it is stated that SONK is a subchondral insufficiency fracture (SIF) that has already progressed into collapse, with secondary necrosis found in the collapsed specimens [3]. Natural course of SONK as a consequence of subchondral collapse and necrosis may alter biomechanics of the knee joint due to structural changes and eventually joint destruction [4, 5]. In up to 94% cases, this disease affects the medial femoral condyle. However, it has been also reported to affect lateral femoral condyle, tibial plateau, and patella [2–7]. Knee osteonecrosis is a general disorder that encompasses three different conditions: SONK, which is the most common category, secondary osteonecrosis, and post-arthroscopic ones according to Zywiel et al. and his classification [8, 9].

Aetiology

The exact aetiology of SONK still remains unclear; however, there have been few possible explanations in the literature. Previously, it was mostly believed that SONK was appearing secondary to ischaemia, and this may have resulted in future necrosis [10].

At present, we have been able to learn more about its etiology thanks to several publications. Yamamoto et al. showed that SONK may be a result of insufficiency fractures in the osteopenic bone and this eventually may lead to fluid storage, to bone oedema, and, in consequence, to necrosis [10]. Two

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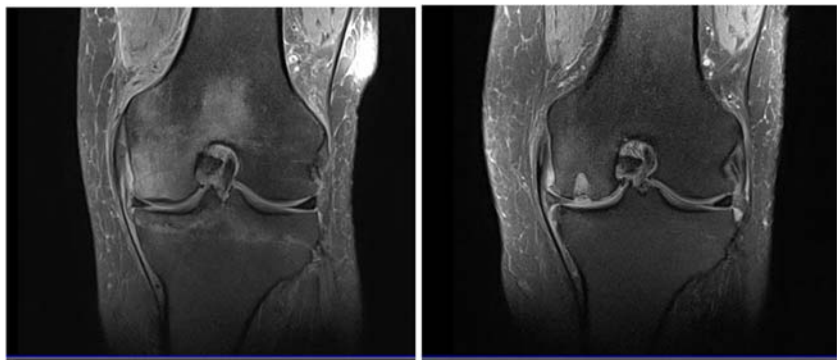

Fig. 1 MRI scans present SONK progression in 1 year follow-up when no treatment was applied

years later, Akamatsu et al. showed positive correlation between low bone mineral density and the incidence of SONK among women over 60 years of age [11]. In the meanwhile, some publications investigating meniscal extrusion and SONK have been published [12, 13]. This correlation has been investigated later by Yasuda et al. They have reported high association of medial meniscus extrusion and femorotibial angle with the radiological stage and volume of the SONK lesion. They summarized their research claiming that increased loading in the medial femoral condyle with greater extrusion of the medial meniscus and varus alignment may contribute to expansion and secondary osteoarthritic changes of a SONK lesion [14]. What is more, recent review published by Hussain et al. claims that meniscectomy and meniscal tears, particularly of the medial meniscus posterior root, increase contact pressures and create an environment from which insufficiency fractures can emanate. They also suggested rethinking a new definition of SONK as a subchondral insufficiency fractures [15].

Moreover, in 2016, Hatanaka et al. histopathologically examined a surgically resected specimen from an early stage of SONK. On a mid-coronal cut section, they found a linear fracture line paralleling the subchondral bone endplate. In addition, fracture-related bone debris was focally observed on the osteochondral side of the fracture. Those findings in total suggested that early stage of SONK is rather a result of the subchondral fracture than primary osteonecrosis [16].

In terms of the risk factors recognized for the onset of SONK, female sex, age, cartilage degeneration, low bone mineral density, and medial meniscus posterior root tears have

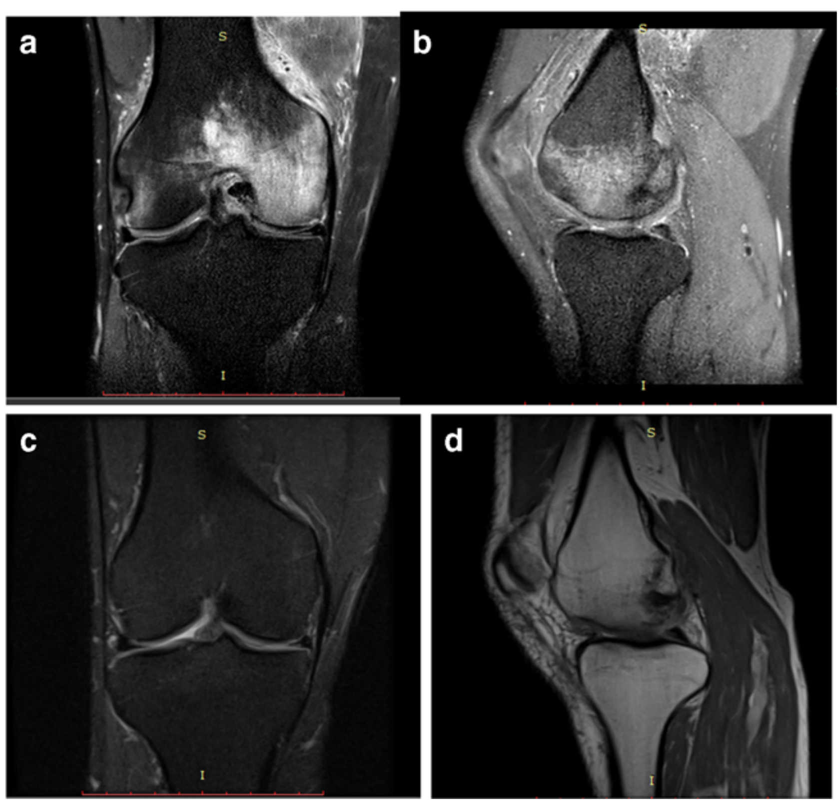

Fig. 2 MRI scans of same patient taken at the first appointment (**a**, **b**) and 9 months later after conservative treatment including 6 weeks of non-weight bearing and 6 weeks of partial weight bearing (**c**, **d**)

Fig. 3 **a** and **b** present MRI scans taken 6 months apart in the same patient without treatment

been proven so far [1, 17–20]. Furthermore, Akamatsu et al. reported that an anatomical angle (femorotibial angle) > 180 degrees and depth of lesion seen in the sagittal view > 20 mm on MRI were predictive factors for a poorer prognosis 1 year after the onset of the symptoms [17].

Clinical presentation and imaging

According to Pape et al., the prevalence of SONK is reported at 3.4% regarding to 176 patients enrolled in their study [21]. This disease more often affects women, and it is mostly unilateral [22, 23]. As already mentioned, up to 94% cases affect medial femoral condyle. This significant divergence in prevalence is considered to be due to the differences in blood supply between medial and lateral condyles. This statement is supported by cadaveric study performed by Reddy et al. They demonstrated that the medial femoral condyle has limited intraosseous blood supply with apparent watershed areas, whereas the lateral femoral condyle has both a rich intra- and extraosseous vascular supply [23, 24].

Patients usually reports with knee pain which typically gets worse at night and on weight bearing, but it can also appear without putting a stress on the knee. According to Mont, this may be mistakenly recognized as medial meniscus tear [25]. Patients may also present deteriorated, asymmetrical gait patterns [2]. Sometimes they have a history of osteoporosis or osteopenia [26]. Focal tenderness during palpation over the medial femoral condyle is said to be the most common finding in patients with SONK [7]. The onset is usually acute without prior trauma, mostly unilateral [26]. In elderly, SONK should be considered in differential diagnosis with meniscal tears, osteoarthritis, or stress fractures of the tibial plateau [4]. In this case, it is important to remember that SONK has a sudden onset, whereas in OA, symptoms usually intensify progressively. The strong indication for diagnosis of SONK is the pain which starts to occur without loading the limb, e.g., during rest or at night. Anterior-posterior, tunnel, sunrise, and lateral views radiographs may be obtained [26], but in the early stage of SONK, X-rays usually show no characteristic findings. Lucent area seen in the epiphyseal region is a typical finding as well as flattening of the respective condyle but mostly in the late stages [26, 27].

The method of choice in case of SONK is magnetic resonance imaging (MRI), and it has been proven to be both sensitive and specific [8, 28, 29]. On MRI scans, findings like bone marrow oedema, subchondral crescent linear focus on T1 and potentially T2 sequences, focal epiphyseal contour depression, or subchondral low signal may suggest occurrence of SONK. It is known that bone marrow edema may have various causes; therefore, crucial in early SONK is the presence of a focal subchondral lesion [30].

Fig. 4 An X-Ray presenting early stage of collapse of SONK (grade II according to Koshino classification)

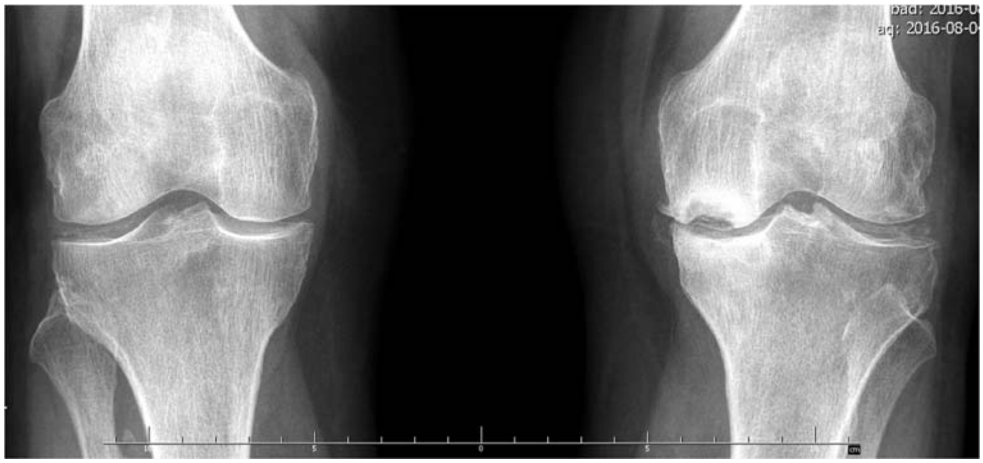

Fig. 5 An X-Ray presenting subchondral collapse on the medial femoral condyle

In the author's experience, since the initial lesions may not be visible on X-rays, any sudden aggravation of pain in the knee joint should be an indication for MRI; however, so-called diagnostic window when scans may be negative might be potentially troublesome. Therefore, some authors suggest performing MRI when the symptoms last at least six weeks [26, 31].

As already mentioned, in the latest radiological publication, it is stated that a SONK is a subchondral insufficiency fracture (SIF) that has progressed into collapse, with secondary necrosis found in the collapsed specimens. According to this paper, that area of low signal intensity immediately subjacent to a subchondral bone plate is of utmost importance in early lesions, and it is considered to be an essential finding observed in almost all cases of clinical SONK [3]. At times bone scintigraphy is performed. It may demonstrate increased uptake in the affected condyle, but this method has been shown to be less sensitive in the case of SONK in comparison to MRI [32]. Moreover, some authors stated that bone scan is unnecessary while using a modern and widely performed MRI [30]. In 1979, Koshino et al. were the very first to propose staging system for SONK based on X-ray. According to them, there are four stages in the Koshino classification, which are based on clinical and radiographic findings. Staging is shown in Table 1 [33]. To the knowledge of the authors, no classification based on MRI findings has yet been established.

Fig. 6 MRI presenting massive subchondral collapse on medial tibial plateau

Decision-making

Treatment of SONK is based on the size of the lesion and staging according to Koshino X-ray classification and may be both non-operative and operative. Few studies shown that large lesions > 5 cm^2 frequently lead to condyle collapse, while small lesions < 3.5 cm^2 have tend to regress without surgical treatment. Medium-sized changes might regress over time, however, not in all cases [23, 34] (Figs. 1, 2, 3, 4, 5, 6).

Another approach to evaluating the size of the lesion and treatment selection has been proposed by Lotke et al. They were calculating the width of the lesion based on AP radiograph and presented as a percentage of the subchondral lucency width of affected femoral condyle. Based on this, they concluded that lesions involving more than 50% of condylar surface required arthroplasty [35].

These measurements were followed by Jureus on 40 patients, and six out of seven who have undergone knee arthroplasty had lesion affected more than 40% of condyle [20]. Some authors also propose measurements using MRI scans. Kerboul's necrotic angle modified for the knee by Mont et al. could also be applied in case of SONK [9]. Lecouvet et al. proposed predictive date for irreversible osteonecrosis: subchondral low signal on TS of > 4-mm-depth or > 14-mm-long, focal epiphyseal contour depressions and lines of low signal in deep affected signal [31]. Those findings were used inter alia to diagnose early SONK with MRI by Yates et al. with a good result [30].

Conservative treatment

Non-surgical management, intended for small lesions, includes non-weight bearing or protected weight bearing

Table 1 Koshino classification of spontaneous osteonecrosis of the knee

Stage I	Knee symptoms, normal radiographic findings
Stage II	Demonstrates the weight-bearing area with flattening and subchondral radiolucencies surrounded by osteosclerosis
Stage III	Extension of the radiolucencies around the affected area and subchondral collapse
Stage IV	Degenerative phase with osteosclerosis and osteophyte formation around condyles

with a knee brace, nonsteroidal anti-inflammatory drugs (NSAIDs), analgesics, and bisphosphonates. Whereas bisphosphonates have different results, the other mentioned methods seem to be effective in literature [30]. Bisphosphonates were suggested to have the potential efficacy in preventing or delaying the need for surgery among patients with SONK. They inhibit bone resorption and are widely used in metabolic bone diseases with increased osteoclastic activity. It was hypothesized that if accelerated resorption of the bone could be reduced during revascularization process until sufficient new bone could be formed, the structural failure could be avoided [36]. Jureus et al. conducted the study using 70 mg of alendronate once a week for six months and reported that only 18% of the patients suffered from subchondral collapse [20]. However, Meier et al. designed a randomized, placebo-controlled study showing no benefit of bisphosphonates over anti-inflammatory drugs [36]. In the other hand, the latest research published in 2018 by Bhatnagar et al. showed excellent results over a period of one year using a combined therapy with NSAIDs and bisphosphonates in a group of ten patients, mainly with stage 1 SONK. Each patient had X-rays taken: weight-bearing anteroposterior view, notch view, and lateral view. These were later evaluated on the basis of the already mentioned Koshino staging system. Patients were advised crutches-assisted non-weight-bearing ambulation for the first six weeks and stick-assisted walking for the next six weeks. During this interval, quadriceps and hamstring exercises were encouraged to preserve muscle mass and prevent muscle wasting. If radiographs repeated at three months did not show any signs of progression/worsening, then full weight-bearing unsupported ambulation was allowed. This is one of the few works that describes in details the protected weight bearing. However, it was carried out on a relatively small group of patients [37].

In 2013, there were also enthusiastic results of study over pulsed electromagnetic fields therapy for SONK treatment. Authors reported significantly reduced pain, size of necrotic lesion, and reduction of mean femoral bone marrow lesion's area [38]. Nonetheless, we have not found any further studies reporting on these therapies.

What more, there are no protocols regarding weight-bearing limits during treatment. Considering the cause of SONK etiology, non-weight-bearing and crutches-assisted treatment from six to 12 weeks seems reasonable. It is worth remembering that SONK occurs most often in elderly people, in whom walking on crutches for such time may be difficult to achieve. This kind of approach, according to the author's experience, contributes to the reduction of resting and night-time pain. In the literature, one study presented the results of such management was found. Bhatnagar has applied crutches-assisted non-weight-bearing ambulation for the first 6 weeks and stick-assisted walking for the next six weeks (together with NSAIDs and bisphosphonates) with a good result [3].

Surgical treatment

Surgical treatment should be indicated in patients with osteonecrotic lesions larger than 5 cm^2 or when lesions involve more than 50% of the medial femoral condylar surface according to Lotke et al. [35], likewise in patients who failed after three month of non-operative treatment.

Surgical management include arthroscopic debridement, core decompression, osteochondral autograft, high tibial osteotomy, and eventually unicompartmental knee arthroplasty or total knee arthroplasty.

If the patients are in the pre-collapse state, we should consider joint preserving techniques. If patients progressed to subchondral collapse, osteochondral autograft may be beneficial; however, joint arthroplasty seems to be a treatment of choice.

The results of the surgical treatments are summarized in Table 2.

New approach to SONK treatment

One of the methods in which one may see a potential treatment option is subchondroplasty (SCP). This procedure has been developed to treat bone marrow lesions by injecting a calcium phosphate bone substitute (CPBS) into compromised subchondral bone, under fluoroscopic guidance. CPBS is often used in conjunction with arthroscopy to serve as bone void fillers and provide mechanical support of the articular surface. The goal of SCP is to improve the structural integrity of damaged subchondral bone and create the potential for subchondral bone remodeling [48]. There have been also some reports suggesting the possibility of decompression of the subchondral layer

Table 2 Summary of the results of the surgical treatment of SONK

Authors	Year	Method	Results	Follow-up (average)
Miller et al. [39]	1986	Arthroscopic debridement	4 of 5 patients rated good post-operatively	31 months
Akgun et al. [40]	2005	Arthroscopic microfracture	25 of 26 satisfied, 1 patient with no improvement	27 months
Deie M et al. [41]	2008	Artificial bone grafting and core decompression	JOA score improved, VAS decreased from 8.4 points to 1.5; 2 cases of 12 need further surgeries	24.6 months
Tanaka et al. [42]	2009	Osteochondral autografting	Increase in mean Lysholm score from 54.7 to 92.3	27.7 months
Saito et al. [43]	2014	Opening-wedge HTO	Increase in mean Knee Society knee score and function; 1 of 77 patient underwent total knee replacements	6.5 years
Heyse et al. [44]	2009	Unicompartmental knee arthroplasty	75.7% very satisfied, 21.6% satisfied, 2.7% dissatisfied	10.9 years
Kumagai et al. [45]	2017	Mosaic osteochondral autograft (OAT)vs bone marrow stimulation (BMS) technique as concomitant procedure with opening-wedge HTO	Cartilage repair in OAT was significantly better; however, clinical outcomes were not significantly different	2 years
Radke et al. [46]	2005	Unicompartmental vs bicompartmental knee arthroplasty	On short-term result unicondylar implants have better results but on long-term bicondylar	3.4 years
Langdown et al. [47]	2005	Unicompartmental knee arthroplasty	All patients were satisfied and improved in Oxford Knee Score	5.2 years

pathology with intraosseous PRP and/or whole blood supplementation [49].

Cohen et al. performed a study on a group of patients with histologically and mechanically altered subchondral bone, osteoarthritis-related bone marrow lesions describing more detailed, using subchondroplasty combined with arthroscopy. They treated tibial and femoral lesion using navigation guide, and then they were confirming proper location using fluoroscopy. Calcium phosphate was the material of choice. They observed significant improvements in both pain and function measured by the visual analog scale (VAS) and the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, through two years postoperative follow-up [50].

To the best of our knowledge, there are currently no studies on treatment outcomes for patients with SONK diagnosis treated with subchondroplasty with CPBS or intraosseous PRP/whole blood injection. However, as the main pathology is located in the subchondral bone, it seems to us that such studies would be reasonable.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with human participants or animals performed by any of the authors.

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