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Review

Histopathological examination of post-arthroscopy osteonecrosis of the knee: a scoping review

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ABSTRACT

Background: Post-arthroscopy osteonecrosis of the knee (PONK) was originally described based on magnetic resonance imaging (MRI) findings in the absence of any histopathological evidence. However, several authors have demonstrated the absence of necrosis in histological samples of patients undergoing reoperation after diagnosis of PONK. The aim of this study was to evaluate and synthesize the available literature related to the histopathological characteristics of PONK cases and to determine the appropriateness of related terminology.
Methods: A PRISMA-compliant scoping review of PubMed, Scopus, and Cochrane was performed. Studies reporting histological analyses performed on bone samples harvested from patients with a presumptive diagnosis of PONK were included. General study characteristics, radiographic and MRI features, time elapsed between arthroscopy and histological sampling, and results of histological analysis of the bone samples were extracted.
Results: Five articles were included, for a total of 22 patients (23 knees, mean age 63.5 years), resulting in 17 bone samples available for histological examination. The most common finding was the presence of subchondral insufficiency fractures (SIF) (94.1%), with necrosis being reported only in one case.
Conclusions: Due to the absence of necrosis in most histopathological examinations, the term "PONK" seems inadequate to describe the corresponding clinical condition. Considering the pathological features of the analysed bone samples, SIF should be considered along with PONK when diagnosing and managing these cases until more definitive evidence becomes available.

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1. Introduction

Post-arthroscopic osteonecrosis of the knee (PONK) was first described by Brahme et al. [1] in 1991, in a retrospective analysis of seven patients who underwent arthroscopic partial meniscectomy and subsequently experienced persistent knee pain. The diagnosis of knee osteonecrosis in these cases was based on magnetic resonance images (MRI) and radiological criteria derived from osteonecrosis of the femoral head and other sites, without histological evidence of the necrotic process [1]. Since then, several authors [1–6] described post-arthroscopy subchondral bone changes as osteonecrosis based solely on MRI, lacking histopathological confirmation. This led to the widespread recognition of post-arthroscopy or post-meniscectomy osteonecrosis as a distinct form of osteonecrosis, separate from existing classifications [7,8]. However, the number of PONK cases described in the literature is very limited compared to the number of procedures performed [2,4,9–11]. Kobayashi et al. [12] demonstrated that postoperative bone marrow signal changes are common following meniscectomy, with prevalence rates exceeding 30%, whereas the incidence of knee osteonecrosis after arthroscopy is less than 1% [2]. The discrepancy between the number of expected cases and those described suggests that the bone marrow alterations observed after arthroscopic surgery may represent a different clinical entity from necrosis, as assumed by Higuchi et al. [13]. Several authors demonstrated the absence of necrosis in histological knee samples of patients undergoing surgery with a previous suspected diagnosis of osteonecrosis [13–22]. This challenges the validity of PONK not only from a histological standpoint but also from a clinical perspective. Firstly, several patients underwent MRI without respecting the window period as described by Nakamura et al. [23], indicating that subchondral lesions may have developed before surgery [24]. Secondly, subchondral lesions seem to be more associated with meniscal pathologies [14,25–28] than with the arthroscopic procedure itself [24,25,29–34]. Finally, post-operative bone marrow signal alterations are common, asymptomatic, and often self-limiting [12]. Recently, the term "osteonecrosis" has been questioned in favour of subchondral insufficiency fracture (SIF) [19,23–27].

We conducted a scoping review of the literature to analyze the results of histological examinations of bone samples from patients who underwent surgery following a diagnosis of PONK. Our aim was to evaluate and synthesize the available literature related to the histopathological characteristics of PONK cases and to determine the appropriateness of related terminology.

2. Materials and Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR) [35]. The corresponding checklist was followed to ensure completeness (Supplementary Table) The protocol for this review was registered in the Open Science Framework (OSF) database (https://osf.io/****).

2.1. Electronic literature search

A systematic search of PubMed/MEDLINE, Scopus, and Cochrane databases was performed on January 5, 2025, using the following search string: (("Histology" OR "Histological Analysis") AND "Knee Osteonecrosis"). According to a PEO framework, we sought studies including patients with a presumptive diagnosis of PONK (P) who underwent a knee reoperation with bone sample harvesting (E), and whose samples subsequently underwent histopathological analysis (O). Articles not written in English, literature reviews, meta-analyses, letters to the editor, cadaveric studies, preclinical studies, articles addressing forms of necrosis other than PONK, and those lacking histological analysis were excluded.

2.2. Study selection

The initial screening of the articles was performed independently by two reviewers (P.Z. and G.F.P.). In case of disagreements, a third reviewer (L.A.) was consulted to solve conflicts. After removing duplicates, titles and abstracts were screened, followed by a full-text evaluation of the remaining manuscripts. Additionally, references cited in the included studies were examined to ensure no relevant articles were missed. The screening workflow is depicted in a PRISMA flow diagram.

2.3. Risk of bias

Given the observational design of included studies, the Methodological Index for Non-Randomized Studies (MINORS) tool was utilized to assess the quality of studies. To avoid imprecisions, selected papers were rated independently by two reviewers (P.Z. and G.F.P.).

2.4. Data extraction

The following data were extrapolated and tabulated: author and year of publication, study design, level of evidence, demographic data of included patients, radiographic and MRI features of PONK, the time between arthroscopy and histological sampling, and the result of the histological analysis of the bone sample. Data extraction was performed independently by two reviewers (P.Z. and G.F.P.) To assess inter-rater reliability, Cohen's kappa was calculated using a contingency table summarizing the agreement between reviewers. The table included categories for "double yes," "double no," and "disagreement" (one "yes," one "no"). The observed agreement and the expected agreement under random conditions were calculated, resulting in a kappa value of 0.913, indicative of excellent inter-reviewer agreement.

3. Results

3.1. Study selection

A total of 518 studies were identified through the search strategy. After removing duplicates and screening titles and abstracts, 39 full-text articles were evaluated. Of these, 34 studies were excluded for the following reasons: not reporting histopathological outcomes (n = 26), literature reviews (n = 3), and including cases of osteonecrosis other than PONK (n = 5). Ultimately, five articles were included in this review (Figure 1).

3.2. Study characteristics

The included studies consisted of two case reports [14,18] and three case series [13,15,17], published between 2000 [15] and 2019 [14] in Japan [13,14,18] and USA [15,17]. Collectively, 22 patients (12 males, 10 females; mean age: 63.5 years) were included, for a total of 23 knees. Only three studies [13,14,17] reported the patients' body mass index (BMI), with an average of 29.2 kg/m^2. Follow-up was mentioned in four studies, ranging from 5 to 13 months (Table 1). All patients underwent arthroscopic meniscectomy, after which presumed PONK was diagnosed based on X-rays and MRI. All patients underwent re-intervention during which a bone sample from the subchondral lesion was harvested for histological examination. The average MINORS score of included studies was 10.4/16, indicating a low-to-moderate risk of bias (Supplementary Table).

3.3. Post-arthroscopy radiographic and MRI features

All studies reported the radiographic features of the lesions, with four studies [13,14,17,18] using Koshino's classification [36] to stage them. According to this classification system, there was one stage I lesion, five stage II lesions, and three stage III lesions. In the remaining 14 cases, staging was either not reported or unclear. MRI characteristics were consistently documented, with all authors diagnosing knee osteonecrosis based on bone marrow signal changes. These changes typically presented as a low-signal intensity area with a focal area of lower signal intensity in the periphery on T1-weighted images, and high-signal intensity in the corresponding area with an associated focal area of low-signal intensity in the central lesion on T2-weighted images. The medial femoral condyle was involved in 13 cases, the lateral femoral condyle in one case, the medial tibial plateau in two cases, and the lateral tibial plateau in one case. The size of the injuries was not described.

3.4. Histological findings

The average time interval between knee arthroscopy and reoperation was 30.4 weeks. Of the 23 knees, 17 bone samples were available for histological examination. In 12 cases, SIFs were reported in the absence of osteonecrosis; in four cases, SIFs coexisted with small areas of necrosis; necrosis was reported in only one case [15], without defining the presence or absence of SIFs. Overall, the most frequent histological finding was SIF, observed in 94.1% of the cases. Radiologic and histopathological outcomes are reported in Table 2.

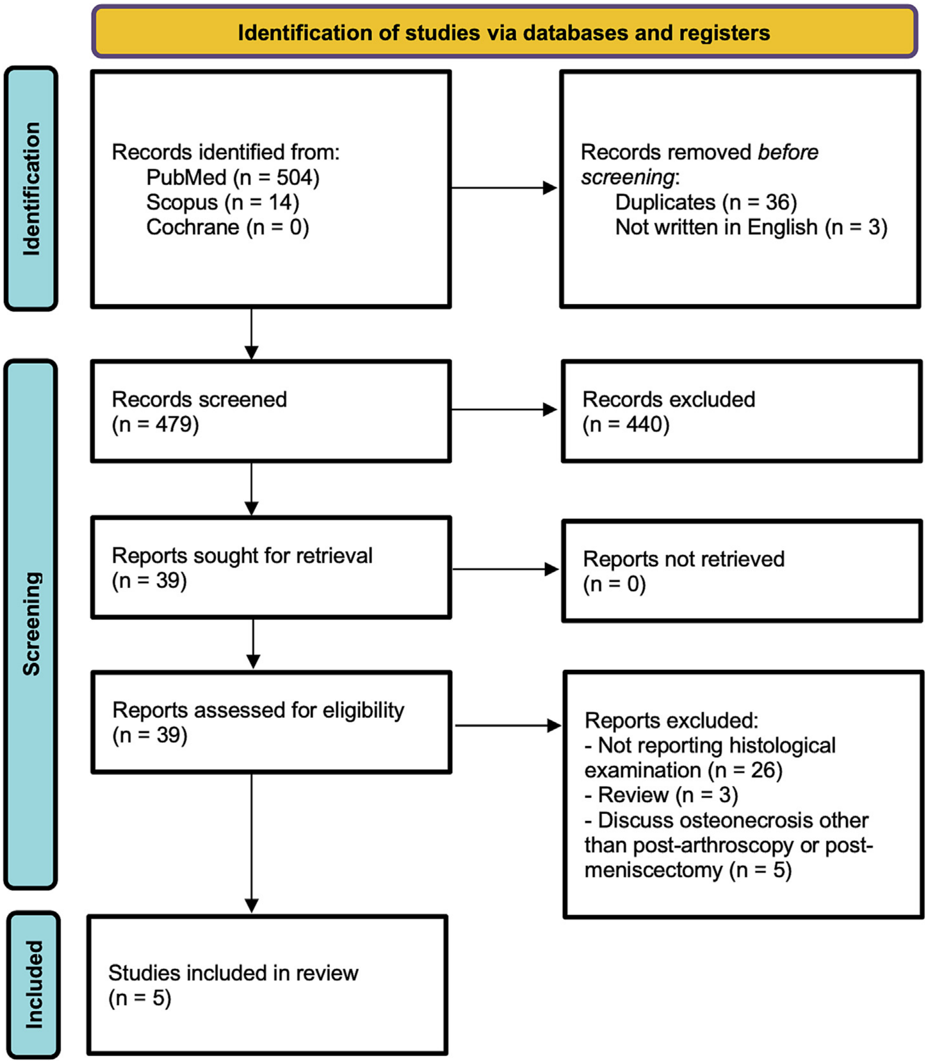

Figure 1. PRISMA flow chart showing the article screening workflow.

Table 1
General characteristics of included studies.

Study	Country	Study design (LoE)	Sample size (n of knees)	Age (mean, range or ± SD)	Sex (M\F)	BMI (kg/m^2; mean, range or ± SD)	Follow-up duration (months)	Risk factors for ON
Fukui 2019 [14]	Japan	Case report (IV)	1 (1)	69	1\0	26	13	Arthroscopic meniscectomy
Johnson 2000 [15]	USA	Case series (IV)	7 (7)	60 (41–79)	3\4	NS	7.8 (average); range: 5–10	Arthroscopic meniscectomy and chondral shaving
Nakamura 2002 [18]	Japan	Case report (IV)	1 (1)	64	1\0	NS	6	Arthroscopic meniscectomy
MacDessi 2008 [17]	USA	Case series (IV)	7 (8)	64 ± 8.4 (53–78)	5\2	30.6 ± 6.0 (18–35)	6.6 (average); range, 3–12	Arthroscopic meniscectomy
Higuchi 2013 [13]	Japan	Case series (IV)	6 (6)	66 (59–72)	2\4	28 (21–35)	NS	Arthroscopic meniscectomy

BMI = body mass index; LoE = level of evidence; NS = not specified; ON = osteonecrosis; SD = standard deviation.

Table 2
Radiologic and histopathological outcomes of included studies.

Study	Radiographic findings	MRI findings	Location	Koshino's classification (stage)	Type of reoperation	Time between arthroscopy and histological sampling (weeks)	Histological specimen
Fukui 2019 [14]	Radiolucent area	T1: diffuse low signal intensity with a band of lower signal intensity. T2: inhomogeneous area of high signal intensity with a focal area of low signal intensity	MFC	II	UKA	43	No evidence of ON, signs of previous fracture with callus formation, fracture-related bone debris and granulation tissue
Johnson 2000 [15]	Flattening of the condyle, subchondral lucency and/or sclerosis with signs of OA in 6/7 patients	High-intensity signal of fat in the bone marrow replaced by low-intensity signal in the center of the lesion. The location of post-arthroscopy ON correlatedgeographically with pre-existing pathology	MFC (n = 4), LFC (n = 1), MTP (n = 1), LTP (n = 1)	NS	3 TKA, 2 HTO (1 resolved, 1 lost to F/U)	33	1 ON
Nakamura 2002 [18]	Subchondral flattening and collapse with both radiolucent and sclerotic areas	Diffuse low signal intensity area on T1, localized low signal intensity area surrounded by a high signal intensityarea on T2	MFC	III	TKA	24	No evidence of ON, SIF with fracture callus, reactive cartilage, and granulation tissue
MacDessi 2008 [17]	No findings of ON	Increased signal within the subchondral bone seen on T2	MFC (n = 7), MTP (n = 1)	I	TKA	29 (12–48)	6 SIFs, 2 SIFs + small areas of ON
Higuchi 2013 [13]	Different findings according to Koshino's classification	Bone marrow signal changes	NS	II (n = 4), III (n = 2)	3 HTO, 3 UKA	28 (21–35)	4 SIFs (Koshino II), 2 SIFs + ON (Koshino III)

LFC = lateral femoral condyle; LTP = lateral tibial plateau; MFC = medial femoral condyle; MTP = medial tibial plateau; NS = not specified; SIF = subchondral insufficiency fracture; ON = osteonecrosis; UKA: unicompartmental knee arthroplasty; TKA: total knee arthroplasty; HTO: high tibial osteotomy.

4. Discussion

Our aim was to better understand PONK aetiopathogenesis and to evaluate the appropriateness of the term "osteonecrosis" based on histological evidence. Our main finding was that necrosis, as an isolated histological finding, was identified in only one of the 17 available bone samples. The most frequently observed histological finding was SIF, present in 94.1% of the cases. In four cases, small areas of necrosis were described within typical SIF lesions, although it would be inaccurate to classify these small lesions as osteonecrosis [22,37–40]. Our results showed that diagnosing PONK solely based on imaging might be incorrect. Similarly, Nakamura et al. [18] concluded that osteonecrosis diagnosed through radiography and MRI could be misleading, as typical MRI changes of osteonecrosis can occur without actual necrosis. An improved understanding and interpretation of the spectrum of subchondral bone lesions on MRI is essential. Based on the histopathological findings currently described in the literature, the correct term to describe these radiological subchondral bone signal alterations should be "SIF" rather than "PONK". Subchondral insufficiency fracture of the knee is a type of stress fracture related to repetitive stress on the knee joint [41]. The histological characteristics of SIF have been previously described [37,42,43] and include fracture callus, reactive cartilage formation, and granulation tissue, which significantly differ from the typical characteristics of avascular necrosis. These include empty osteocytic lacunae in bone trabeculae with bone infarction [40,44] as well as different MRI findings [41,45]. Small areas of necrosis may be present in SIF, but it remains unclear how SIF can progress to necrosis. The primary underlying theory is that the absence of the stabilizing and protective effect of the meniscus, following injury or meniscectomy, can cause subchondral microfractures due to increased instability and elevated joint pressure peaks [14,17,46,47]. Meniscal lesions, particularly radial or root tears, disrupt the hoop stresses, simulating the absence of the meniscus [48–52]. Similarly, arthroscopic meniscal debridement could increase peak stresses, leading to subchondral plate failure and microfractures [46,53,54]. The correspondence between the meniscal lesion and/or meniscectomy area and the site of SIF supports this theory. Additionally, the medial femoral condyle is particularly vulnerable to subchondral damage due to its anatomical and biomechanical features as well as lesser vascularization [40], which subject the medial compartment of the knee to greater load stresses [55–59]. In line with the current literature, we found that the medial femoral condyle was the most affected by SIF. Yamamoto and Bullough [37] suggested that the increased contact pressure after meniscectomy [47] may lead to subchondral microfractures, which are detectable by MRI. They recommended not confusing these lesions with necrosis, while not excluding the possibility that SIF may lead to early osteonecrosis in patients with systemic comorbidities (e.g., hyperlipidemia, hypertension, older age, diabetes mellitus) [60–63]. Similarly, MacDessi et al. [17] suggested that total or partial meniscus removal following meniscectomy can increase the risk of microfractures, particularly in the setting of osteoporosis. They also noted that if the bone does not heal, progression to a subchondral fracture can occur, which may be mistaken for necrosis. Takeda et al. [22] proposed that necrosis may be the consequence of delayed healing or non-union of subchondral fractures. In our review, the only case of isolated necrosis was described by Johnson et al. [15]. In their study, they included seven cases of presumed PONK, with histological confirmation of necrosis reported in only one case. However, these authors did not specify the presence or absence of other histological findings, leaving uncertainty regarding the presence of typical SIF lesions. Additionally, they included patients with mild knee osteoarthritis and visible subchondral lesions not only on MRI but also on X-ray, suggesting an advanced stage of the disease according to the Koshino's classification [64]. Therefore, it is not possible to exclude that necrosis could be a potential complication of failed healing and progression of SIF, although not as the primary cause of the pathology. This theory has been supported by other authors [18,37,39,41,65–67]. Our findings align with several authors [19,20,22,37,68,69], who reported the absence of necrosis in histological examinations of bone samples from patients undergoing surgery for presumed spontaneous osteonecrosis of the knee (SONK). In these studies, the most frequent histopathological finding was SIF with necrosis absent or limited to small areas and only in advanced stages [19–22,37]. From this point of view, PONK and SONK show no histopathological differences, and both conditions share similar demographic and clinical characteristics [7,8,24,70–72]. SONK predominantly affects females, whereas PONK is more commonly associated with meniscal injuries regardless of sex. However, this lack of female prevalence might be obscured by the low number of PONK cases reported in literature, while several SONK cases being actually associated with meniscal lesions [25]. Both conditions present with the sudden onset of unilateral knee pain, primarily involving the medial femoral condyle with a single lesion [7]. No associated diseases or involvement of other joints have been reported [7]. MRI findings do not appear to significantly differ between the two conditions, with both showing bone marrow edema-like signal intensity and a subchondral hypointense line in the affected condyle [7,41,45,73]. It is thus reasonable to question whether we are referring to the same clinical entity under two different names. In our view, there is no distinction. Just like the term "SONK", which is now widely discussed and replaced by the term "SIF" [17,25,41,73–75], we strongly recommend using the latter to describe the aforementioned subchondral bone lesions, which have to date been described under the terms "PONK" or "post-meniscectomy osteonecrosis". Regardless of semantics, the terminology is clinically important for understanding aetiology, prevention, prognosis, effective communication with patients, and collaboration with colleagues.

This study has some limitations. The main limitation is the extreme scarcity of literature and evidence for accurately characterizing PONK, despite its clinical significance, which may affect the generalizability of the findings. The second limitation is the overall low level of evidence, closely related to the study designs. These mainly included small and localized histological samples typically from a single site, non-standardized or incomplete imaging, and variability in lesion locations, reported injuries, and outcomes. However, the qualitative histological analysis enhances the value of the reported findings. Evidence of subchondral fractures challenges the current nomenclature without minimizing the clinical relevance of the pathology. However, it raises concerns about the associated histological findings, stressing the need for precise definition and correct terminology, Larger, multicentre studies with more robust methodologies are needed to validate the results and provide stronger evidence for the proposed hypotheses. In the future, cases of presumed osteonecrosis or SIF should be accompanied by histopathological assessment of the affected bone with careful correlation between histological and MRI findings. This would facilitate a more straightforward differential diagnosis between SIF and necrosis without the need for histological examination.

5. Conclusions

Due to the absence of necrosis in most histopathological examinations, the term "PONK" seems inadequate to describe the corresponding clinical condition. Considering the pathological features of the analysed bone samples, SIF should be considered along with PONK when diagnosing and managing these cases until more definitive evidence, including clinical and MRI correlations, becomes available.

CRediT authorship contribution statement

Pierangelo Za: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Giuseppe Francesco Papalia:** Writing – review & editing, Investigation. **Luca Ambrosio:** Writing – review & editing, Validation, Investigation. **Sebastiano Vasta:** Writing – review & editing, Investigation. **Fabrizio Russo:** Writing – review & editing, Investigation. **Gianluca Vadalà:** Writing – review & editing, Supervision. **Rocco Papalia:** Writing – review & editing, Supervision.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.knee.2025.05.025.

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