



Lateral meniscus with tears or with histologic calcification does not increase the risk of lateral osteoarthritis after medial unicompartmental arthroplasty

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Received: 9 July 2023 / Accepted: 19 July 2023 / Published online: 28 July 2023
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Abstract

Purpose Meniscal tears or histological meniscal calcifications (in the absence of radiological chondrocalcinosis) are frequent in osteoarthritis. Whether lateral meniscal lesions influence clinical outcomes after medial unicompartmental knee arthroplasty (UKA) is unknown.

Methods We analyzed 130 patients (130 knees) with medial unicompartmental knee arthroplasties between 2005 and 2015. These 130 knees had full articular cartilage thickness in the lateral compartment and no radiological chondrocalcinosis on preoperative radiographs. The lateral meniscus was analyzed with preoperative MRI and a biopsy of the anterior horn at the time of surgery. Synovial fluid was collected and analyzed for calcium pyrophosphate dihydrate crystal deposition (CPPD crystals). Lateral meniscal tears were untreated when detected on MRI or during surgery, with the hypothesis that these tears on the opposite compartment would remain asymptomatic in medial UKA. At average 10-year follow-up, patients were evaluated with clinical and radiographic outcome, with a focus on the risk of joint space narrowing of the lateral femorotibial compartment.

Results CPPD crystals were present in the synovial fluid of 70 knees. Lateral meniscal tears were seen on MRI in 34 (49%) normal meniscuses of the 60 knees without CPPD crystals and in six other knees without histological meniscal calcification despite CPPD crystals. Histological calcification was present on 61 lateral meniscuses with 53 meniscal tears. The results showed no significant differences in the clinical outcomes between knees with lateral meniscal tears or lateral meniscal histological chondrocalcinosis or both lesions and those without these conditions. Additionally, radiographic progression of osteoarthritis in the opposite femorotibial compartment of the knee was not more frequent in patients with these meniscal issues. The ten year cumulative survival rates, measured by the need for total knee arthroplasty, were 91% for knees without meniscal lesions and 92% for knees with these lesions.

Conclusion On this basis, treatment of meniscal tears of the lateral compartment and routine aspiration of the knee to assess for birefringent crystals in the planning of medial UKA do not appear necessary.

Keywords Unicompartmental arthroplasty · Chondrocalcinosis · Meniscal tear · Meniscus calcification

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Introduction

Many parameters [1–4] may influence the results of a unicompartmental knee arthroplasty (UKA), but the indication [5, 6] for a unicompartmental prosthesis is usually based on the clinical or radiological evaluation of the opposite femorotibial compartment and the presence of the anterior cruciate ligament. According to the literature [7–9], radiological chondrocalcinosis does not appear a risk of degeneration of the opposite compartment after UKA. But, even in the absence of radiological calcification, the existence of meniscal tears [10, 11] or histological meniscal calcifications [11–13] is frequent in osteoarthritis. Meniscal tears [14] and histological chondrocalcinosis predispose to the development of arthropathy [15] in knees without arthroplasties, but whether these meniscal lesions, when present in the opposite compartment, influence clinical outcome and degeneration of the opposite compartment after medial unicompartmental (UKA) surgery is unknown.

With minimally invasive approaches, it is not easy to thoroughly explore the opposite femorotibial compartment (cartilage or the meniscus) during UKA. Furthermore, we could not find the exact frequency of these associations in patients operated on with medial UKA in the literature. The increasingly frequent practice of MRI in osteoarthritis [16] makes assessing the lateral meniscus preoperatively possible. Nevertheless, it has been reported that the presence of histological calcinosis of the meniscus (in the absence of radiological calcinosis) and calcium pyrophosphate dihydrate crystals (CPPD crystals) in the synovial fluid makes the diagnosis of meniscal tears more difficult with MRI [17]. Therefore, aspiration of the knee to remove birefringent crystals before doing an MRI in the planning of UKA could be helpful to both improve the sensibility of MRI to detect tears and diagnose histological meniscal calcifications.

We, therefore, asked what was the prevalence of lateral meniscal tears or histological meniscal chondrocalcinosis of the knees at the time of medial UKA surgery and what was the occurrence of joint space narrowing in the lateral femorotibial compartment when these lesions were present and untreated.

Methods

Patients

We examined 130 consecutive patients (130 knees) who underwent fixed-bearing medial unicompartmental knee arthroplasty (UKA) between 2005 and 2015. These

patients were selected based on specific criteria, including having a functioning anterior cruciate ligament, a normal thickness of articular cartilage in the lateral compartment, the absence of radiological chondrocalcinosis, and undergoing preoperative MRI.

In our study, we defined [18] severe radiographic osteoarthritis (OA) as “Kellgren & Lawrence” (KL) grade 4 (12 knees), moderate OA as KL grade 3 (54 knees), and mild OA as KL grade 2 (64 knees). We collected data on the coronal knee alignment by analyzing full-limb radiographs taken according to a standardized protocol, and we measured the hip-knee-ankle (HKA) angle, typically 180° angle. The average HKA angle before surgery in the knees treated with UKA was 174° (or 6° varus), ranging from 178 to 165°.

The indications were medial compartment osteoarthritis with an intact anterior cruciate ligament, a fixed flexion deformity less than 10°, a varus deformity less than 15°, and healthy articular cartilage in the opposite compartment (confirmed by stress radiograph) and in the patellofemoral joint (verified by patellofemoral view).

We recorded the mean preoperative Knee Society scores [18] at the most recent follow-up (average 10 years, range from 5 to 15 years). Additionally, we collected medical treatment [19] received after surgery and assessed the difficulty levels of patients performing activities of daily living: restroom, cooking, standing up from a chair, going shopping, and going upstairs. Furthermore, we conducted yearly radiographic evaluations to investigate the presence of chondrocalcinosis after surgery.

Arthroplasty and medial femorotibial compartment

Arthroplasty

The Ceraver uni Knee (Ceraver Osteal, Roissy, France) was used, and the preoperative, intraoperative, and follow-up data were prospectively recorded. The prosthesis's components (femoral and tibial) were fixed with cement. The femoral component, made of cobalt chrome, was implanted using instrumentation that allowed for precise positioning with minimal cuts (distal, posterior, and chamfer cuts). The tibial metal back, made of a titanium alloy, was cemented and had a snap-fit mechanism for the insertion of the polyethylene tibial implant. The tibia was cut perpendicularly to its long axis in both the coronal and sagittal planes, with a minimal resection of 4 to 7 mm of bone. Care was taken to avoid overcorrection of the deformity.

The hip-knee-ankle (HKA) angle was measured on postoperative radiographs of the entire limb, with the patient bearing weight to assess the alignment. A varus deformity results in an angle less than 180°, while a valgus deformity results in an angle greater than 180°. The average HKA

angle after surgery in the knees treated with UKA was 177° (or 3° varus), ranging from 180 to 170° .

Synovial fluid examination

For synovial fluid examination, synovial fluid was collected without anticoagulant and analyzed within 24 h using compensated polarized light microscopy [20]. One drop of uncentrifuged fluid was examined for calcium pyrophosphate dihydrate (CPPD) crystals, which appear as weak or non-birefringent rod- or rhomboid-shaped crystals under the microscope.

Medial femorotibial compartment

Intra-operative samples from articular cartilage (two samples—one from femur and one from tibia), medial meniscus (entire excised meniscus) and synovium (which was attached to articular cartilage and/or to the meniscus) were sent for histologic study and assessed for the presence of calcification (calcium pyrophosphate crystal deposition). Cartilage and meniscus were analyzed as the biopsy of lateral meniscus (see below).

The medial femorotibial compartments were grouped into two categories:

- No calcification on radiographs, no CPPD crystals in synovial fluid, and no histologic calcinosis on cartilage or medial meniscus
- No calcification on radiographs, but CPPD crystals in synovial fluid with or without histologic calcinosis on cartilage or medial meniscus

Knees were subdivided according to the medial compartment in histological chondrocalcinosis knees (HCKK) or in non-histological chondrocalcinosis knees (NCKK).

Evaluation of the lateral meniscus on preoperative MRI

An MRI was performed preoperatively to assess the anterior cruciate ligament. This MRI was used to study the lateral meniscus at the time of surgery. MR images were obtained with a 2.5-T system (General Electric Medical Systems, Milwaukee, WI) with an extremity coil. The following imaging sequences were acquired: sagittal and axial spin-echo T1-weighted (TR range/TE range, 400–750/15–20; matrix size, 256–192), intermediate-weighted (1800–3500/19–40; matrix size, 256–192), T2-weighted (2500–3500/60–80), and inversion recovery (TR/TE, 4000/26) (approximately).

The evaluation of meniscal tear on the lateral femorotibial compartment was based on T1-weighted, intermediate-weighted, and T2-weighted sequences. A meniscal tear was defined as a linear region of increased signal within a meniscus communicating with one of the articular surfaces on more than one image. T1-weighted coronal, intermediate-weighted, and T2-weighted spin-echo sagittal images were used for meniscal assessment.

No surgical treatment was performed on these tears of the lateral meniscus.

Lateral meniscus biopsies

The diagnosis of lateral meniscal chondrocalcinosis was determined at the time of surgery by a biopsy (Fig. 1) performed on the anterior part of the lateral meniscus followed by radiographic examination.

Digital contact radiography (DCR)

Using a high-resolution device, standardized radiographs (film focus distance 8 cm, 25 kV, 3.8 mAs) were obtained from the piece of meniscus (Fig. 2).

Histological examination

A triangular specimen was cut vertically from the biopsy of the lateral meniscus. Four-micrometer sections were cut and stained. Haematoxylin and eosin (HE) staining was used to evaluate meniscal degeneration (grade) according to the histopathological degeneration score of fibrous cartilage [20]. von Kossa and Alizarin Red staining, counterstained with Light Green, confirmed the deposition of calcium phosphate crystals in the meniscus (Fig. 3).

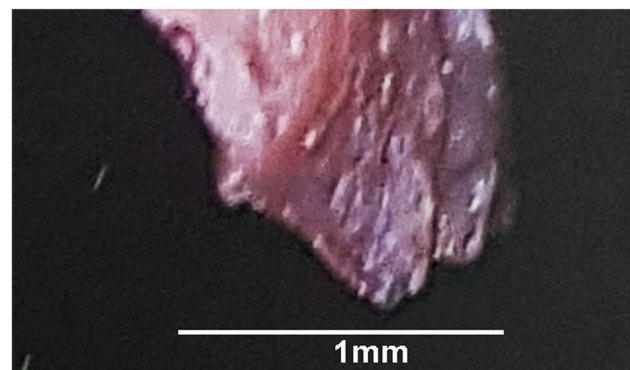


Fig. 1 Biopsy of the lateral meniscus: normal aspect on radiograph and on MRI

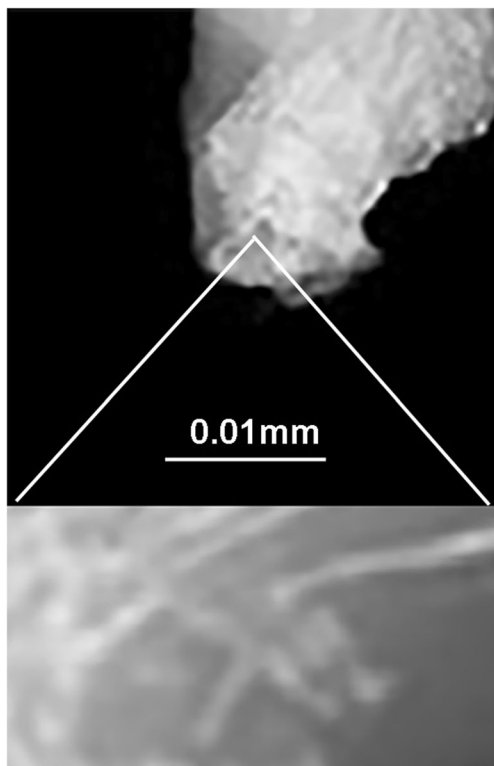


Fig. 2 Same biopsy as Fig. 1. Digital contact radiography (DCR images) of the biopsy of the lateral meniscus with a high-resolution device demonstrating meniscal calcification and also calcification in the cartilage matrix

Lateral femorotibial degeneration or osteoarthritis in the survival analysis

The lateral femorotibial compartments were grouped in four categories:

- Normal lateral meniscus
- Lateral meniscus with a tear on MRI and absence of histological calcification
- Lateral meniscus with histological calcification without a meniscal tear
- Lateral meniscus with histological calcification and with meniscal tear

Joint space was measured in millimeters on standard radiographs. These radiographs were obtained before the operation, early in the postoperative period, and usually at each year interval until the most recent follow-up. Radiographic progression of osteoarthritis was defined as 2-mm joint space loss.

Failure included any joint space narrowing of the lateral femorotibial compartment or any operation involving the removal of lateral meniscal tear (as arthroscopy), or supplementation of an additional lateral UKA for lateral compartment disease progression or any revision for TKA.



Fig. 3 Same meniscus: histological deposition of calcium phosphate crystal (arrow)

Statistics

We expressed qualitative data as percentages within groups and quantitative data by mean, standard deviation, or range. Qualitative data between groups were analyzed by the chi-square test or Fisher's exact test and continuous variables by Student *t*-tests or Wilcoxon rank-sum tests. The cumulative survival rates of the implants were assessed using Kaplan–Meier analysis, with revision surgery as the endpoint. The significance level was set at a threshold of $p < 0.05$. We employed univariate Cox proportional-hazards models to examine the unadjusted associations between baseline variables (such as meniscal tears, meniscal calcification) and the risk of degeneration in the opposite compartment.

Results

Frequency of histological chondrocalcinosis in the absence of radiological calcifications

At the time of surgery, no CPPD crystals were found in synovial fluids of 60 knees: cartilage calcification was absent on knees, the medial meniscus, or the lateral meniscus.

CPPD crystals were found in synovial fluids among 70 knees. Calcification was present in cartilage (condyle or tibia) of 51 knees (73%), in 70 knees (100%) for the medial meniscus, and in 61 knees (87%) for the lateral meniscus; Therefore, meniscal and hyaline calcifications are a systemic process where medial meniscal fibrocartilage is more prone to calcification than lateral meniscus or hyaline cartilage. Both menisci were calcified in 87% (61/70) and a single meniscus in 13% (9/70). There was a correlation between presence of histological meniscal calcification and increased age ($p=0.02$).

According to these results, knees were subdivided according to the presence or absence of CPPD crystals in the joint fluid as histological chondrocalcinosis knees (HCKK) or non-histological chondrocalcinosis knees (NCKK).

The age of the patients at surgery was average 72 (range 61–89) years. At the time of surgery, OA stage, varus was similar ($p=0.46$) for the patients with HCKK or NCKK. Patient demographics were not similar for age, with older patients with more meniscal tears and more meniscal calcifications. Clinical preoperative knee scores of NCKK knees before UKA (67 points \pm 12) were similar ($p=0.12$) to knee's scores of the HCKK group before UKA (knee, 66 points \pm 8). The average overall changes in knee scores after three months of follow-up were comparable ($p=0.24$) between the NCKK group (87.3 points \pm 12) and the HCKK group (89 points \pm 21). During the latest follow-up, the knee score remained similar in both groups, with scores of 86.4 points \pm 11 for the NCKK group and 88.3 \pm 18 for the HCKK group.

Frequency of lateral meniscal tears and meniscal calcifications

Non-histological chondrocalcinosis knees (NCKK)

When no CPPD crystals were found in synovial fluids, lateral meniscal tears were seen on MRI in 34 (57%) of the 60 knees and confirmed on visual exploration at the time of surgery. No surgical treatment was performed on these tears of the lateral meniscus.

Histological chondrocalcinosis knees (HCKK)

On the nine lateral meniscus without histological calcification, 3 meniscal tears were diagnosed on MRI. On visual examination during surgery, three other meniscal tears were diagnosed; therefore, the presence of CPPD crystals makes the diagnosis of meniscal tears complex on MRI.

On the 61 lateral meniscus with histological calcification, 15 meniscal tears were diagnosed on MRI. On visual examination, 38 other meniscal tears were diagnosed;

therefore, histological calcification increases the frequency of tears (87%; 53 among 61 meniscuses) and makes the diagnosis of meniscal tears on MRI very difficult. Only 28% (15 among 53) were detected on MRI.

Outcomes of the lateral femorotibial compartment

At final follow-up, 42 among the 70 knees with histological chondrocalcinosis at surgery exhibited signs of radiological chondrocalcinosis on radiographs during the follow-up period. Twenty-eight knees have still the absence of any radiological calcification despite histological calcification (Fig. 4). The same phenomenon (radiological chondrocalcinosis was observed on 20 knees among the 60 knees without CPPD crystals found in synovial fluids.

Among the 130 knees with average ten years of follow-up, only seven knees (5%) had some radiographic progression of arthritis (2-mm joint space narrowing) in the opposite compartment. In these seven knees, there was no evidence of severe disease progression (pain, subchondral sclerosis, valgus deformation); five were NCKK and two HCKK. Curiously, the risk of 2-mm joint space narrowing degeneration in the opposite femorotibial compartment was unrelated to meniscal tears (none) or histological meniscal



Fig. 4 Same knee at a 10-year follow-up with normal lateral joint space and no meniscus calcinosis visible on standard radiograph

calcification (none). No arthroscopy was performed to treat a meniscal tear. And no other treatment (no supplementation of an additional lateral UKA) was necessary for these seven knees.

There was no overcorrection of the deformity on the HKA. However, the radiographic progression of the disease in the lateral compartment was rather observed in knees with normal correction (average 178° , range 180 to 177° for the seven knees with 2-mm joint space narrowing). Age over 80 years at the time of surgery was an independent factor to the risk of joint space narrowing (2 mm) in the opposite compartment ($p=0.03$). Female participants were less likely to have joint space narrowing, but this factor is not significant ($p=0.32$). Weight was not significant ($p=0.41$).

OA grade increased the risk of risk of joint space narrowing (2 mm) in the opposite compartment ($p=0.03$) of these seven knees, when severe grades (5 among 7 knees had grade 4) were compared with moderate grade (2 knees with grade 3).

Independent risk factors for failure of UKA and future total knee arthroplasty

During the last assessment, five tibial and one femoral components failed, and therefore, six knees (5%) among 130 required revision. The occurrence of aseptic loosening did not show any significant difference between the groups ($p=0.24$).

The cumulative survival rates at ten years were 92% for knees without histological chondrocalcinosis and 91% for knees with histological chondrocalcinosis, using the endpoint of revision to tricompartmental knee arthroplasty. The 95% confidence intervals for both the NCKK and HCKK groups overlapped at the ten year mark (p -value = 0.64 based on log rank analysis), indicating that there was no difference in survivorship between the two groups. The timing of revision in groups did not show a significant difference ($p=0.12$), although patients with histological chondrocalcinosis tended to undergo revision at a later stage compared to the other group.

Being younger than 70 years old at the time of unicompartmental knee arthroplasty (UKA) was an independent factor associated with a higher risk of future total knee arthroplasty ($p=0.01$) within the first ten years of follow-up. Male participants were less likely to undergo total knee arthroplasty, but this factor was not statistically significant ($p=0.24$). Weight also did not show a significant association ($p=0.36$).

The severity of osteoarthritis (OA) grade did increase the risk of total knee arthroplasty, especially when comparing severe grades to moderate grade ($p=0.04$). Among patients,

having KL grade 3 OA increased the risk of total knee arthroplasty (HR = 2.4 [95% CI = 1.78 to 3.36]; $p=0.03$). Malalignment also posed a risk ($p=0.04$ for interaction according to the likelihood ratio chi-square test): among patients, having HKA $< 175^\circ$ increased the risk of total knee arthroplasty ($p=0.03$).

Discussion

Chondrocalcinosis is a condition characterized by calcification in the menisci or articular cartilage, which occurs as consequence of the deposition of calcium pyrophosphate dihydrate crystals, calcium hydroxyapatite crystals, dicalcium phosphate dihydrate, or a combination of these crystals [21]. Calcium pyrophosphate dihydrate crystal deposition is the most frequent [22]. Punctate or linear intraarticular calcifications are seen on the radiographs in classic calcium pyrophosphate dihydrate crystal deposition disease [23].

Previous studies have demonstrated a link between chondral calcium crystal (CaC) deposits and the degeneration of joints. However, it is still unclear whether chondrocalcinosis contributes to or is a consequence of osteoarthritis [24, 25]. Arthroscopic evidence suggests an association between chondrocalcinosis and meniscal tears [11]. Magnetic resonance imaging (MRI) is considered the most precise and minimally invasive method for diagnosing damage to cartilage and menisci [15]. Nevertheless, it has been reported that the presence of histological calcinosis of the meniscus (in the absence of radiological calcinosis) makes diagnosing meniscal tears more difficult.

Imaging methods commonly employed to detect calcifications in the articular cartilage and menisci are typically based on X-ray technology, including conventional radiographs and CT scans. Conventional radiographs provide higher spatial resolution; however, calcifications may not be sufficiently dense to be visible or overlap with bone structures. Identifying chondral calcium crystal (CaC) deposits in severely degenerated joints can be challenging [16, 17]. On the other hand, CT scans facilitate the detection of chondrocalcinosis by offering high contrast between calcifications and cartilaginous structures. The tomographic nature of CT enables the assessment of calcifications in all compartments and even in severely degenerated joints. Although calcium itself is not directly visible on MRI, certain gradient-echo sequences may allow visualization of chondrocalcinosis. This is due to the limited presence of MR-visible protons in the crystals and the local susceptibility effects induced by the crystals, resulting in distinct signal losses. However, the effectiveness of MRI in detecting chondrocalcinosis

depends on the quality of the MRI technology employed [17]. In this regard, ultra-high-field MRI, which offers higher signal and more prominent local susceptibility effects, can provide superior visualization of chondral calcium crystal compared to lower field strengths and may even surpass conventional radiographic methods in terms of calcification detection.

When patients are being assessed for UKA, the main investigation is radiology as histology is not normally available. Two possible questions about investigation are as follows: should patients before UKA need routine aspiration of the knee to assess for birefringent crystals in the planning of UKA and detect histological chondrocalcinosis when not radiological calcification is present; and do meniscal tears in the opposite compartment need to be detected and eventually treated according to the fact that some meniscal tears are asymptomatic and some painful. We hypothesized that these tears when present should remain asymptomatic in the absence of overcorrection of the deformity as recommended for UKA.

The most important finding of the present study was that there was no significant difference in survival of the lateral femorotibial compartment when patients undergoing medial UKA had untreated lateral meniscal tears or histological meniscal calcification as compared with knees with normal lateral meniscus. No patient had a secondary arthroscopy for pain or treatment of meniscal tear [26, 27]. Furthermore, repair of meniscus tears does not prevent always joint space narrowing [28].

Deposition of CPPD crystals in fibrocartilage and hyaline cartilage is a common and predominantly age-related phenomenon. In terms of applying this research to clinical practice, preoperative aspiration of joints to assess for the presence/absence of birefringent crystals under polarized light could be applied much more readily when planning UKA than obtaining histological tissue samples. This study has shown that when crystals are present in the liquid of joint aspiration, histological meniscal chondrocalcinosis is frequent, but the HCCK does not influence the survival rate of the lateral femorotibial compartment. On this basis, routine aspiration of the knee to assess for birefringent crystals in the planning of UKA does not appear necessary.

The presence of birefringent crystals has another consequence: It may make the diagnosis of meniscal tears more difficult on MRI, particularly when histological calcification of the meniscus exists. However, meniscal tears, when not treated, do not influence the risk of joint space narrowing after medial UKA. Therefore, aspiration of the knee to remove birefringent crystals before doing an MRI in the planning of UKA also does not appear necessary.

In another study [7], synovial fluid samples were collected during surgery, and calcium pyrophosphate (CPP)

crystals were detected in 85 out of 234 (36%) knees that did not show radiological signs of chondrocalcinosis (CC) prior to surgery. However, on postoperative radiographs during the follow-up period, these knees exhibited signs of chondrocalcinosis. A similar observation was made in the current study. This suggests that in the early stage of the disease, CPP crystals are primarily present in the synovial fluid, and calcification may not have occurred yet, resulting in chondrocalcinosis not being visible on plain radiographs.

Our study confirms that calcium crystal deposition disease is highly prevalent in knee joints with degenerative arthritis in patients planning UKA, with a frequency depending on the age of the patient. In the Framingham study [24], radiographic knee chondrocalcinosis was 33% in a population aged 63 to 93 years, 27% in a population younger than 70 years, and 44% in a population older than 80 years. But the prevalence of calcium crystal in the joint aspiration or meniscus could be as high as 100% in patients older than 80.

In conclusion, unicompartmental arthroplasty is a safe solution [29–31] when the technique is accurate. The presence of calcium pyrophosphate dihydrate (CPPD) crystals was found to be significant in patients undergoing unicompartmental knee replacement surgery. We conducted a comparison between patients who had histological chondrocalcinosis (CC) and those without histological CC in terms of clinical outcomes, disease progression in the opposite compartment, and implant survival. Patients with CPPD crystals experienced similar challenges in their daily activities following knee replacement surgery and received comparable treatment to patients with severe osteoarthritis (OA) but without CPPD crystals. Both groups achieved excellent pain relief, function restoration, and durable implant survival. The primary reason for revision surgery was aseptic loosening, which was similar in both groups.

Author contribution Data collection: PH, SK, and JH; redaction: PH; lecture and corrections: NZ, WG, JG, QZ, and JH.

Data availability University of Paris on demand.

Code availability None.

Declarations

Ethical approval All data are reported in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate Patients agree.

Consent for publication The authors agree to publish the manuscript.

Competing interests The authors have no conflict of interest.

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