Osteochondral fragment repositioning associated with bone marrow aspiration in a patient with knee osteonecrosis following Leukemia treatment: a case report

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European Journal of Medical Case Reports
Volume XX(XX):01–06
DOI: XXXX

ABSTRACT

Background: Avascular osteonecrosis (AVN) is an idiopathic condition characterised by subchondral ischemia leading to subsequent articular collapse. It can manifest as primary, secondary, or post-surgical. Bone marrow aspirate and concentrate (BMAC) represents a composite of mesenchymal stem cells with robust self-renewal and differentiation capabilities, employed as a surgical adjunct to enhance the healing process.

Case Presentation: Presented herein is a case of a 16-year-old male with a history of acute lymphocytic leukemia and extended corticosteroid therapy, developing AVN in the lateral femoral condyle and concurrent articular cartilage delamination. Arthroscopic repositioning of the chondral fragment was undertaken, complemented by the application of BMAC. Rehabilitation efforts focused on reinstating joint mobility and fostering knee proprioception.

At the 1-year postoperative follow-up, the patient reported a pain level of 2/10 on the visual analog scale, an International Knee Documentation Committee score of 88 points, and radiographic evidence indicating consolidation.

Conclusion: The integration of BMAC in knee AVN, coupled with subchondral decompression and chondral fragment repositioning, emerges as a viable treatment option, yielding promising short-term clinical outcomes.

Keywords: BMAC, case report, avascular necrosis, leukemia, osteochondral fragment reposition, bone marrow aspiration.

Type of Article: CASE REPORT **Specialty:** Orthopedic Surgery / Knee Surgery

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Received: 08 August 2025
Revised (1): 07 September 2025
Accepted: 09 September 2025

Background

Avascular osteonecrosis (AVN) or osteonecrosis is a condition caused by prolonged bone ischemia followed by subchondral necrosis, primarily affecting weight-bearing joints such as the knee and hip [1]. First described in 1968 by Ahlback, it can be classified as primary (idiopathic or spontaneous), secondary to a predisposing condition, or post-surgical, resulting from cartilage damage during arthroscopic surgery [1].

Knee AVN secondary to chronic corticosteroid use is more prevalent in women under 55 years old and can be bilateral in up to 80% of cases [2]. The use of biological factors such as bone marrow aspirate concentrate (BMAC) has been studied in the past decade as a surgical adjunct for both symptomatic management and its ability to stimulate musculoskeletal tissue healing [3].

BMAC is a heterogeneous combination of various cellular phenotypes, including mesenchymal stem cells. These cells are pluripotent, meaning they have a significant capacity for self-renewal and differentiation into various cell types [4]. While the goal of this treatment is joint preservation, there is no clear consensus in the literature regarding its specific indication [2]. Long-term data demonstrate no increased cancer risk in patients following autologous cell-based therapy using bone marrow-derived stromal progenitor cells, either at the treatment site or systemically, with an average follow-up period of 12.5 years [5]

The aim of this paper is to present a case report of a patient with AVN of the right lateral femoral condyle (LFC) treated with arthroscopic repositioning of the osteochondral fragment combined with BMAC application.

Case Presentation: A 16-year-old male presented to the medical consultation with a 3-month history of progressively worsening right knee pain, rated 7 out of 10 on the visual analog scale (VAS), exacerbated by ambulation.

The onset was insidious, with no identifiable precipitating trauma or event.

His clinical-functional score was 60 points according to the International Knee Documentation Committee (IKDC) questionnaire. No trauma was reported, but he had a history of prolonged corticosteroid treatment for acute lymphocytic leukemia. Physical examination revealed no edema, erythema, or reduced joint range of motion (ROM), but significant pain upon palpation of the LFC. The patient had undergone rehabilitation with kinesiology and crutch support for 3 months at another center without noticeable improvement, but as there was no clinical improvement, he decided to seek medical advice at our hospital.

Radiographs of the knee [Anteroposterior and lateral views] showed changes in the LFC density, consistent with a Ficat stage 2 lesion. Prompting further investigation was performed with magnetic resonance imaging (MRI) and a total bone scintigraphy. The MRI revealed the characteristic low-signal rim in the T1-weighted images. This rim represents the border between dead bone and reactive bone, and it is accompanied by an inner high-signal rim on fluid-sensitive images, forming the "double-line sign" hallmarking the presence of AVN of the LFC. A delaminated cartilage lesion and a subtle flattening of the articular surface were also noticed in the posterolateral region of the LFC. The bone scintigraphy confirmed the AVN (Figures 1 and 2). After confirming the diagnosis and failure of conservative management, surgical intervention was recommended.

Surgical technique

In the first surgical step, BMAC was obtained by placing the patient in the dorsal decubitus position under general and spinal anesthesia. A fine needle was inserted into the proximal tibia to aspirate bone marrow (Figure 3a,b). Forty milliliters of heparinized marrow were collected and separated using Ficoll. The samples were sent for centrifugation and preparation. The centrifugation process consisted of two stages: the first stage at 2,000 revolutions per minute (rpm) for 20 minutes, followed by a second stage at 4,000 rpm for another 20 minutes [6]. After centrifugation, the leukocyte layer was extracted in a laminar flow hood to determine the total cell count, differentiation group, and cell viability via flow cytometry [6]. The specific properties of the BMAC are summarized in Table 1.

Following BMAC collection, arthroscopy was performed, revealing cartilage damage consistent with the Outerbridge classification from imaging studies (Table 2, Figure 4a).

An anterolateral approach to the lateral femoral condyle was performed (Figure 4b–d), creating a window over the softened cartilage area, leaving its distal insertion intact. Microfractures were made, and BMAC was applied to the subchondral bone. The fragment was fixed using three biodegradable screws (SmartNail®; CONMED, Linvatec Arthroscopy), and 10 ml of intra-articular BMAC was injected. Hemostasis was achieved, and the wound was closed in layers with a flat dressing and elastic bandage. A knee extension splint was applied, and the patient was advised to use crutches [7,8].

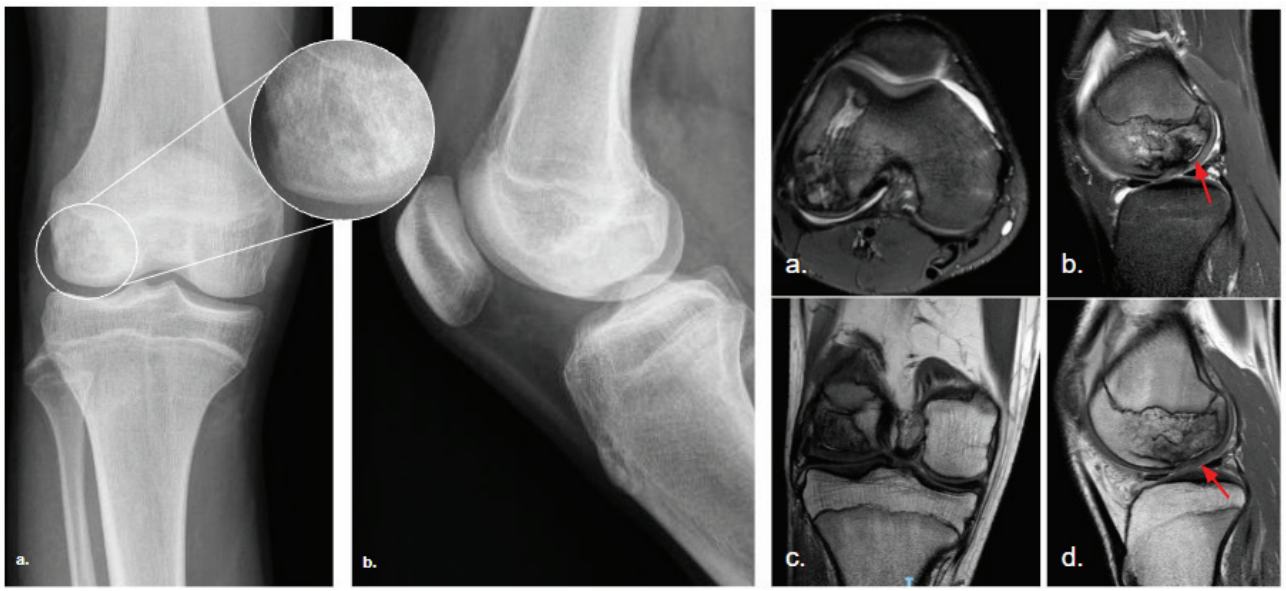

Figure 1. *Anteroposterior (a) and lateral (b) knee radiographs. A radiolucent area associated with a sclerotic rim is observed at the level of the lateral femoral condyle. MRI. A: Axial T2, B: Sagittal T2, C: Coronal T1, and D: Sagittal T2. A well-defined, heterogeneous area involving the LFC can be seen, compatible with AVN. A delaminated cartilage lesion is also evident in the posterolateral region (red arrow). LFC: Lateral Femoral Condyle. MRI: Magnetic resonance imaging.*

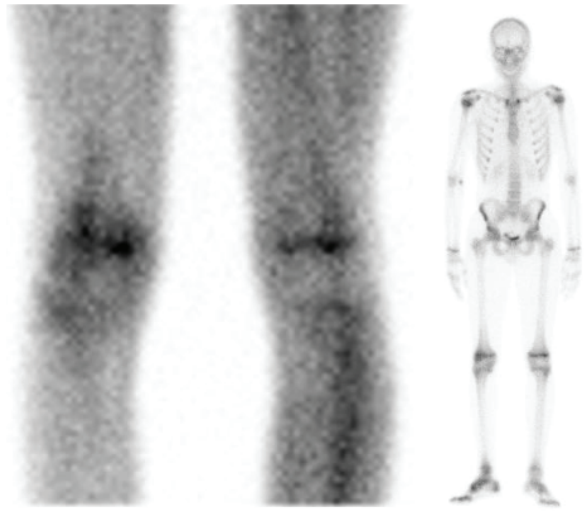

Figure 2. *Bone scintigraphy.*

Note the increased radiotracer uptake at the level of the right lateral femoral condyle.

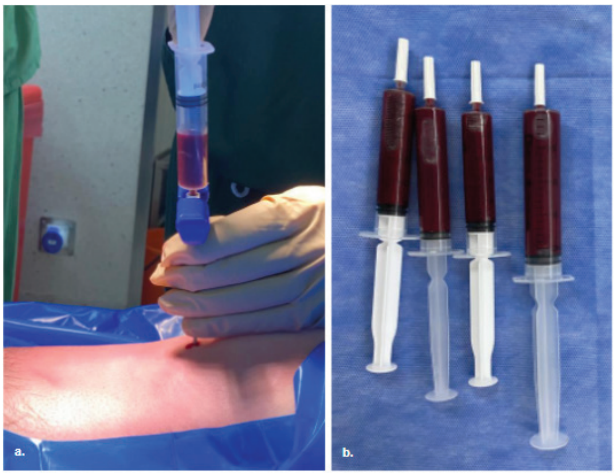

Figure 3. *a) Needle aspiration performed at the anterior tibial tuberosity. b) Sample obtained following bone marrow aspiration.*

Table 1. *BMAC composition.*

Final product volume	10ml
Mononuclear cell count	3.9×10^6
$CD34^+$ cell count	1.98×10^2
Cell viability (flow cytometry)	98.12%

Table 2. *Outerbridge classification.*

GRADE	DESCRIPTION
I	Softening and swelling of the cartilage
II	Fragmentation and fissuring < 0.5 inch in diameter
III	Fragmentation and fissuring > 0.5 inch in diameter
IV	Erosion down to subchondral bone

Postoperative rehabilitation

The main objective of postoperative rehabilitation was to restore full ROM within the first six weeks while maintaining fixation stability. During the first postoperative month, strict rest of the right lower limb was indicated, with non-weight-bearing ambulation using crutches in order to protect the surgical fixation and reduce mechanical stress on the joint. After completing this 4-week period, partial weight-bearing with crutches was allowed for an additional 2 weeks. Following this interval, the patient progressed to full weight-bearing. Throughout this rehabilitation course, the focus was on progressive knee mobilization: flexion-extension exercises were limited to 90° during the first three weeks, with controlled increases thereafter to reach full ROM by week six. At the same time, isometric quadriceps activation was initiated on the first postoperative day to prevent muscle atrophy and promote early neuromuscular engagement. In addition, proprioceptive stimulation of the knee was incorporated early in the process to facilitate joint control and stability during the later phases of weight-bearing progression.

Postoperative follow-up

The patient showed favorable progress, reporting pain of 2/10 on the VAS and a subjective IKDC score of 88 points at the 1-year follow-up. Isokinetic strength testing revealed a 25% deficit compared to the contralateral knee. For a reduced risk of muscle and ligament injury, a bilateral imbalance of less than 10-15% is recommended. Follow-up radiographs showed consolidation of the fragment without articular step-off, and the MRI revealed no delamination at the affected site with good graft integration (Figure 5).

Discussion

We presented a patient with AVN of the LFC treated with necrosis focus decompression and repositioning of the cartilage, combined with intra-lesional and intra-articular BMAC application. AVN is a condition that, in its early stages, can be managed conservatively with weight-bearing restrictions, physical therapy, magnetotherapy to stimulate neovascularization, and the use of NSAIDs [1,2]. Our patient underwent conservative treatment with weight restriction and rehabilitation for 3 months without significant symptom improvement, leading to the decision for arthroscopic surgery.

Kouroupis et al. [9] reported the use of BMAC in an adolescent patient with corticosteroid-induced osteonecrosis of the knee secondary to systemic lupus erythematosus. Their protocol involved multiple ultrasound-guided injections, contrasting with our single-stage surgical approach that combined subchondral microfracture, direct BMAC application, and fragment fixation. Although comparable pediatric cases are scarce, both reports support the use of BMAC as a viable regenerative strategy, particularly in patients with underlying systemic conditions [9].

BMAC has proven to be an effective and safe alternative, particularly in cases where cartilage lesions are in

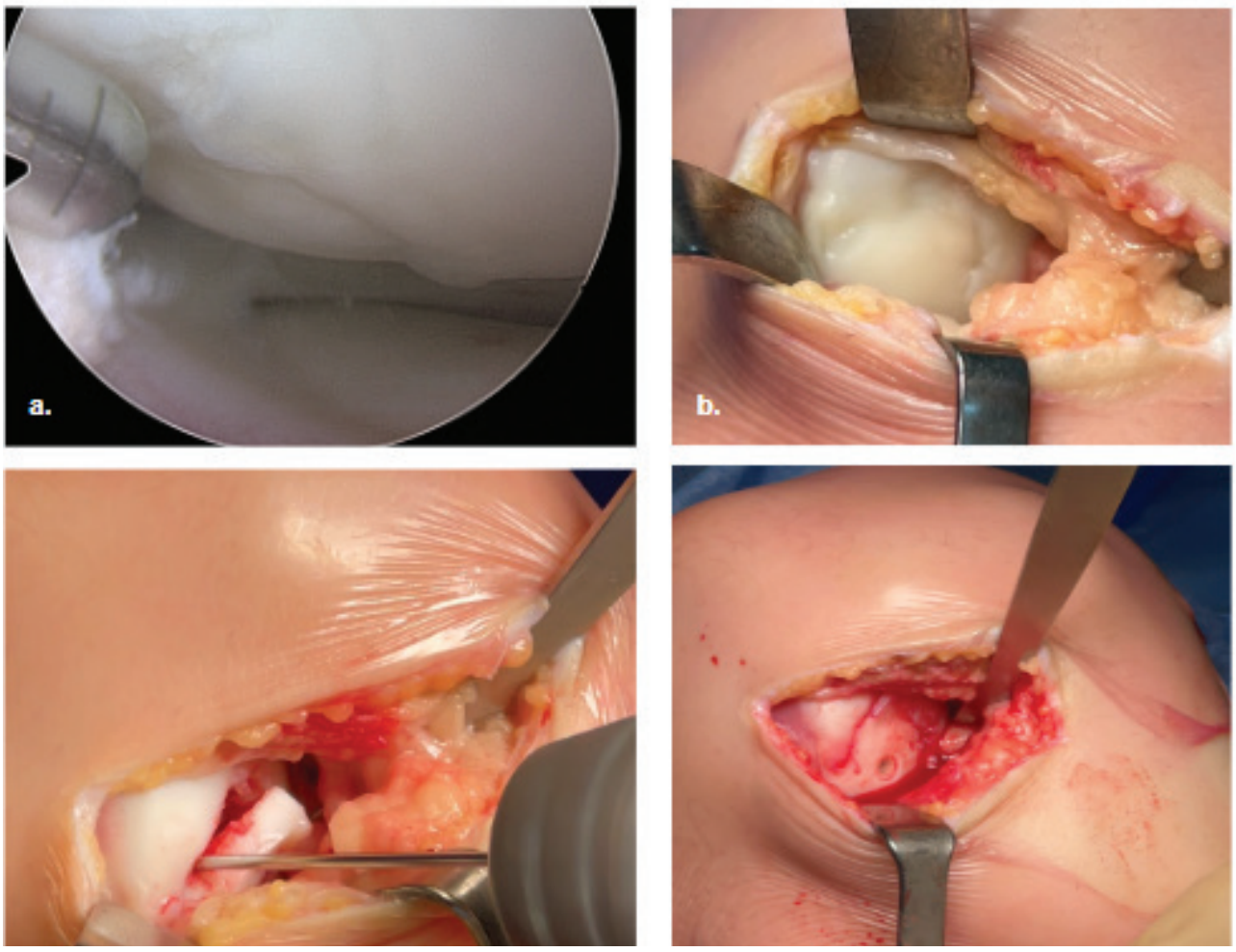

Figure 4. *a) Arthroscopic images showing the osteochondral lesion in the lateral femoral condyle. b) Intraoperative clinical image of the lesion in the LFC. c) Anterolateral approach to the LFC. The softened cartilage area is elevated while preserving its distal insertion. Microfracture drilling is performed, and BMAC is applied to the subchondral bone. d) Cartilage fragment fixed with three SmartNail® screws.*

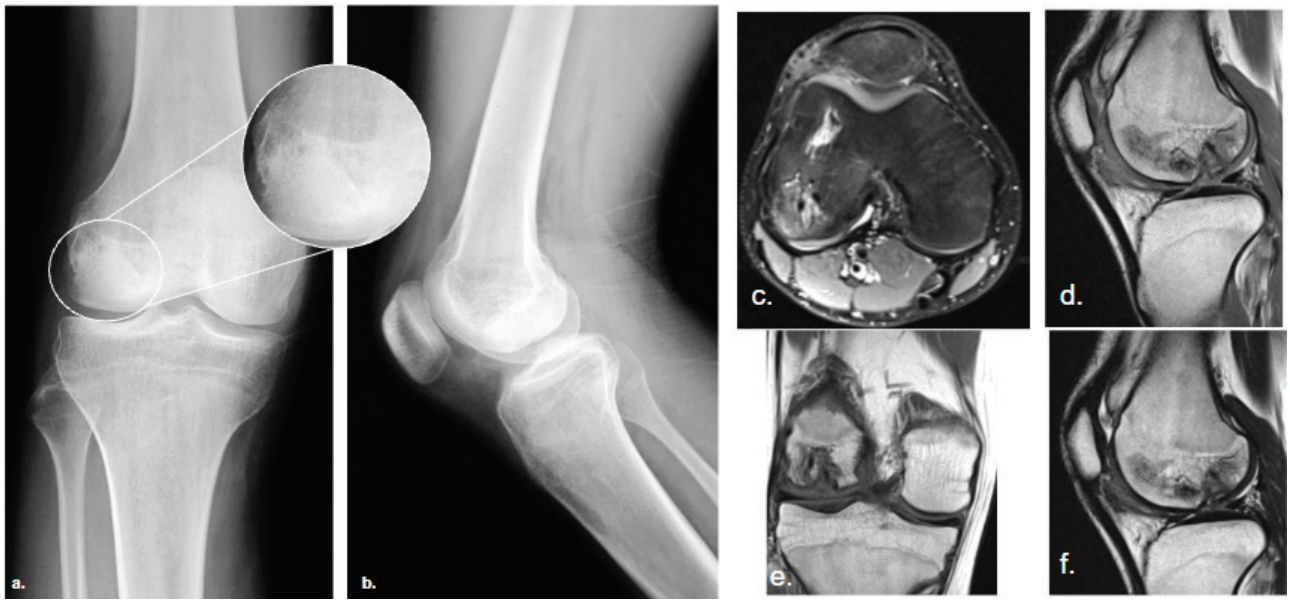

Figure 5. *1-year postoperative imaging. Anteroposterior (a) and lateral (b) knee radiographs. MRI: Axial T2 image (c), sagittal T2 (d), coronal T1 (e), and sagittal T2 (f). Adequate integration of the repositioned fragment, with marked reduction of bone marrow edema and restoration of cartilage continuity.*

early stages (Ficat stages 1 and 2). The goal for young patients is to restore the necrotic area's integrity and the viability of articular cartilage [4,9-11]. Various publications have demonstrated the positive outcomes arising from the use of biological therapies [12,13]. These therapies have shown significant improvements in joint mobility range, pain scores, and knee functional status, even in patients with advanced osteoarthritis [12,13]. Furthermore, there has been an observed increase in bone regeneration, cartilage thickness, and reduction in subchondral edema size [13,14].

These findings suggest that these therapies have a beneficial impact on patients and may be considered promising therapeutic options.

In our patient's case, the postoperative course proceeded without complications, with significant clinical-functional improvement and symptomatic relief, aligning with the current literature [15].

Limitations of this study include the short follow-up period, the lack of a precise indication for this biological therapy, and the inability to determine whether the patient's favorable outcome is due to the addition of BMAC, the cartilage fragment repositioning procedure, or a combination of both. Despite these limitations, the patient demonstrated a clear improvement in quality of life. However, further clinical trials with higher levels of evidence are needed to systematically support the use of BMAC in the treatment of this pathology.

Conclusion

The combination of BMAC with osteochondral fragment repositioning in patients with knee osteonecrosis offers an innovative and effective treatment approach. In this case, the patient demonstrated significant clinical improvement, with pain reduction and functional restoration. While further studies with larger sample sizes and longer follow-up periods are necessary to solidify the long-term efficacy of this approach, the promising short-term results suggest that BMAC, when coupled with appropriate surgical interventions, has the potential to be a viable and safe option for the management of osteonecrosis, particularly in young patients where joint preservation is critical.

What is new?

This case report presents an approach combining arthroscopic osteochondral fragment repositioning with bone marrow aspirate concentrate (BMAC) in a young patient with knee osteonecrosis secondary to leukemia treatment. The technique demonstrated promising short-term outcomes, including pain reduction, functional improvement, and radiographic consolidation. It highlights BMAC as a viable adjunct for joint preservation in early-stage AVN

List of Abbreviations

AVN	Avascular necrosis
BMAC	Bone Marrow Aspirate Concentrate
IKDC	International Knee Documentation Committee
LFC	Lateral femoral condyle
MRI	Magnetic resonance imaging
NSAIDs	Non-steroidal anti-inflammatory drugs
ROM	Range of Motion
VAS	Visual analog scale

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

None.

Consent for publication

Written informed consent was obtained from the patient and from the parents.

Ethical approval

Ethical approval is not required at our institution to publish an anonymous case report.

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Summary of the case

1	Patient (gender, age)	16 years, male
2	Final diagnosis	Avascular osteonecrosis of the lateral femoral condyle secondary to leukemia treatment.
3	Symptoms	Right knee pain (VAS 7/10), worsened with walking
4	Biological therapy	Bone marrow aspirate concentrate (BMAC)
5	Surgical procedure	Arthroscopic repositioning of osteochondral fragment with BMAC application
6	Specialty	Orthopedic surgery / knee surgery