9 Arthroscopic Core Decompression and Cell Therapy

Ioannis K. Triantafyllopoulos
and Athanasios V. Papavasiliou

9.1 Introduction

Nontraumatic osteonecrosis of the femoral head (ONFH) typically affects relatively young, active patients and frequently results in considerable loss of function [1]. Osteonecrosis (ON) is derived by the Greek words osteo, meaning bone, and necrosis, death. The exact pathophysiology of nontraumatic ON is not thoroughly understood and various "incriminating" factors such as vascular insult, fat emboli, and increased intraosseous pressure have been proposed. If left untreated, the necrotic area of the femoral head could collapse resulting in arthritic changes in approximately 60–70% of the patients [2, 3].

Treatment is based on a number of parameters, such as lesion characteristics (size, the presence of collapse at the time of diagnosis, acetabular involvement), patient's age, and comorbidities [2, 4]. The optimal treatment modality has not yet been identified. Several algorithms of medical and surgical treatments have been developed to delay its progression, with variable success [5]. Surgically, total hip replacement (THR) is the most frequent intervention for post-collapse treatment, and core decompression (CD) is the most commonly performed procedure for symptomatic, pre-collapse cases [6]. Historically, THR for osteonecrosis (ON) had poor results, attributed to the young and active character of the patients and possibly due to chronic abductor inefficiency secondary to the index disease. During the 1980s and early 1990s, studies reported high failure rates [7, 8]. More recent reports and systematic reviews show that the introduction of newer implants and better surgical technique consistently deliver better clinical and implant survival results in comparison to the initial papers [9, 10]. The fact though remains that we are dealing with mostly young patients, so the possibility of failure and revision of the THR constitutes a reality. As a result, there has been an increased focus on early interventions for ONFH aimed at preservation of the native articulation. During early-stage disease, the most common joint preserving procedure performed is CD aiming to increase blood flow to the necrotic area by reducing the intraosseous pressure, alleviating pain, and improving function and inflammatory cell infiltration into the affected areas [5, 6].

I. K. Triantafyllopoulos
Laboratory for the Research of Musculoskeletal System, Medical School, National and Kapodistrian University of Athens, Athens, Greece

5th Orthopaedics Department, Hygeia Hospital, Athens, Greece
e-mail: sportdoc@otenet.gr

A. V. Papavasiliou (✉)
Interbalkan European Medical Centre, Thessaloniki, Greece

N. Bonin et al. (eds.), *Hip Preservation Surgery*, https://doi.org/10.1007/978-3-662-61186-9_9

This chapter will focus on arthroscopically assisted CD techniques and discuss cell-based therapies that attempt to improve surgical outcomes. This recent focus on biology is based on the hypothesis that the harvested cells injected or embedded into the necrotic zone of the femoral head (FH) will repopulate the lesion, restore the local cell population, and enhance regeneration and remodeling [11, 12].

9.2 Core Decompression (CD)

Core decompression (CD) is the most common procedure performed for small- or medium-sized lesions, especially at the pre-collapse stage [13, 14]. It is a generic term that is often accompanied with supplemental procedures (vascularized or non-vascularized grafts, injection of cells, grafting, electrical stimulation, etc.) [15]. CD can be technically demanding, requiring intraoperative biplanar imaging for proper placement of the core drill to the necrotic lesion [13].

During the last decade, the management of hip pathologies has progressed to less invasive techniques. Hence, hip arthroscopy has found its place in the management of ON. It can be of value assessing the joint, and also addressing mechanical pathology (chondral flap lesions, labral tears, loose bodies, cam deformity, etc.) commonly found in these hips. It can also help in a more technical manner by assisting the proper placement of the drill during CD [16].

Theoretically, traction and irrigation pressure during arthroscopy could compress the terminal circulation of the femoral head, resulting in worsening of the underlying pathology of ON. However, only a handful of ON cases have been documented following hip arthroscopy suggesting that this is more a theoretical concern than a true clinical problem [17]. But, since the actual effect of irrigation pressure and traction in the circulation of the femoral head is not known in the already compromised environment of ON, it is our practice to utilize intermittent traction only when working in the central compartment and to use minimal irrigation pressure (pressure controlled at 40 mmHg).

9.3 Retrograde CD Technique

During hip arthroscopy for ON, an area of the femoral head is clearly identified where chondral softening or chondral irregularity is seen. This corresponds to the underlying necrotic lesion [16, 18]. Gentle pressure with a probe can cause the articular cartilage to buckle over the infarcted segment and to spring back to its original state upon release of the pressure. This is considered to be a positive "ballottement" test and suggests softening and lack of subchondral support [18]. Identification of this lesion can supplement CD retrograde drilling by giving two points of reference for aiming the drill in the center of the necrotic lesion—one arthroscopic and one fluoroscopic—thus enhancing our accuracy.

CD is performed percutaneously. A small stab incision is made on lateral proximal thigh through which a guiding pin is introduced and directed toward the area identified by arthroscopy under fluoroscopic guidance. Placement and trajectory of the guide pin is verified on both the anteroposterior (AP) and lateral views. Since the drilling is done under direct vision, it secures the femoral head from over-penetration by the drill and cartilage damage. An 8–10 mm cannulated reamer is over-drilled by the guide pin (Fig. 9.1a, b). The reamer should be kept at least at a 3 mm distance to the subchondral bone. Following the drilling, the necrotic lesion is cleared using a long sharp curette. Fluoroscopic guidance is useful at this stage, helping to estimate the amount of necrotic lesion cleared (Fig. 9.1c).

Placing the arthroscopy camera in the bone canal drilled (bone endoscopy) can also verify the correct placement of the bone channel during core decompression since the appearance of "white" necrotic bone confirms the correct placement [16, 19].

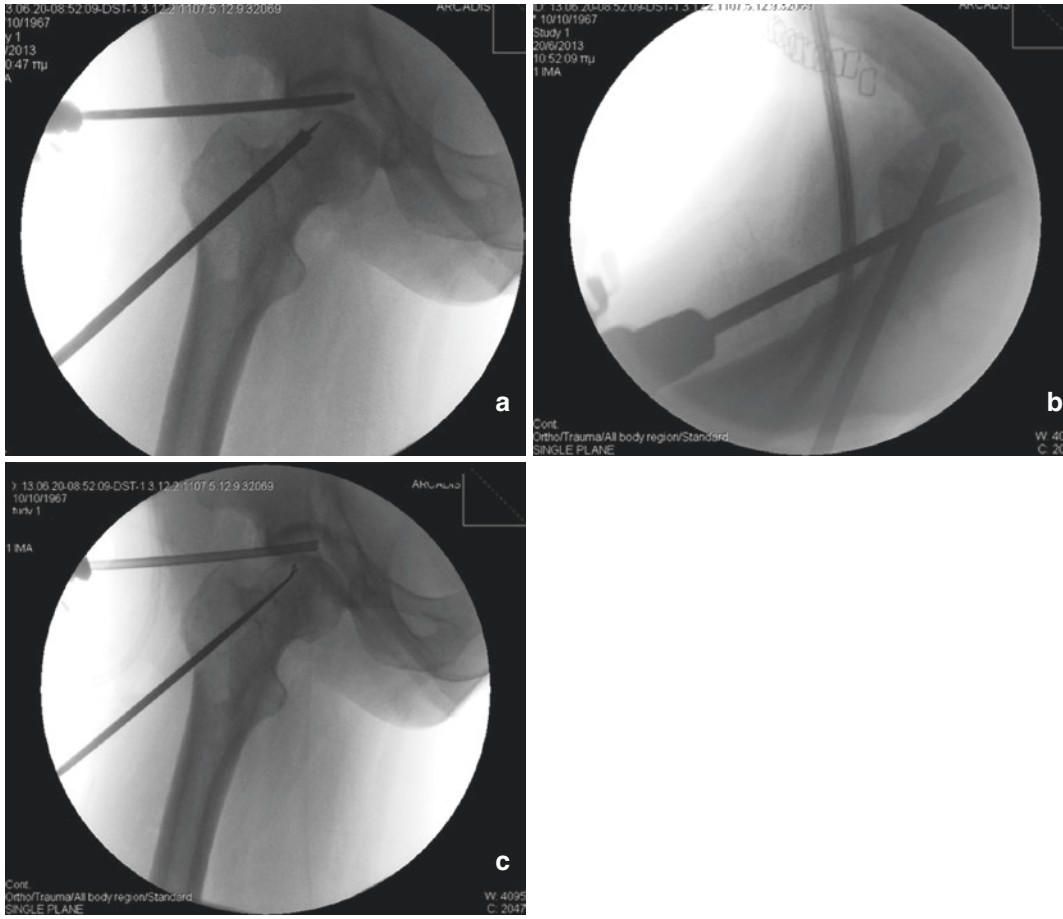

Fig. 9.1 (**a**, **b**) Arthroscopic-assisted core decompression retrograde drilling for osteonecrosis (ON). Intraoperative views on (**a**) antero-posterior (AP) and (**b**) lateral. (**c**) Arthroscopic-assisted curettage of the necrotic lesion

9.4 Head–Neck Junction CD Technique

A modification to the retrograde CD was proposed by Mont where FH decompression is performed through a window at the head–neck junction (trapdoor technique) [20]. However, the procedure as initially described requires extensive dissection and it is technically demanding [15].

In a less invasive fashion, CD drilling can be guided arthroscopically under direct visualization by inserting the drill via the peripheral compartment through the anterior or an auxiliary portal in the direction of the necrotic lesion. It is an area familiar in hip arthroscopy since it is the area where the cam lesion is resected [21] (Fig. 9.2a, b).

With the head–neck junction CD, we lose the benefit of the two-point drill guidance of arthroscopic-assisted retrograde CD since we lose site of the chondral softening lesion, but we have the benefit of being less invasive. The area of the necrotic lesion can be easily reached by moving the hip. In general, the antero-inferior area of the FH is best addressed with the hip in flexion and external rotation, and the superior-

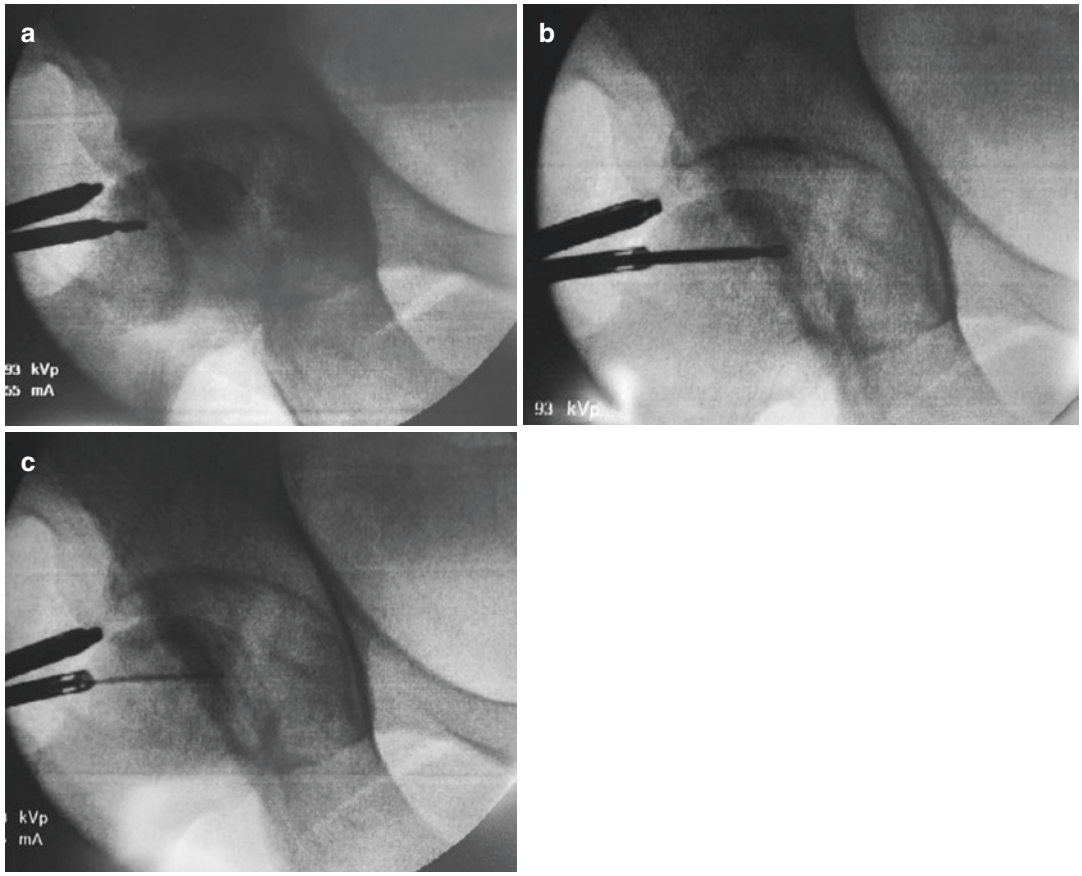

Fig. 9.2 (**a**, **b**) Arthroscopic-assisted head–neck junction core decompression from the peripheral compartment to the necrotic lesion. Intraoperative antero-posterior (AP) image intensifier view. (**c**) Nitinol guidewire inserted in the femoral head (FH) via the drilling track. The firm bony end point confirms that we have not penetrated the FH cartilage

posterior with the hip in extension and internal rotation. With this technique, we advocate multiple drilling with a small diameter drill (2–3 mm) to create more than one core track. This way CD is achieved and we minimize the risk of subchondral collapse that could be caused by a larger drill, since the entry and direction of the drilling is close and parallel to the FH surface (Fig. 9.2b). The thin hip arthroscopy nitinol guidewire can be inserted in the FH via the drilling track verifying by the sense of a firm bony end point that we have not penetrated the cartilage during the decompression (Fig. 9.2c).

Multiple drilling CD has achieved favorable outcomes while having lower complication rates, including a subtrochanteric fracture [22, 23]. A recent study compared standard core decompression and multiple drilling in a cohort of patients with sickle cell disease, finding no statistical significance in outcomes or complications [24].

Conversely, joint effusion, secondary to ON-related synovitis, is seen in up to 72% of cases regardless of articular collapse [25]. It is the author's opinion that an arthroscopic joint washout and synovectomy can be of clinical benefit, since it reduces pain and joint effusion, improves range of motion, and by reducing the capsular stress from the effusion possibly improves the blood flow to the femoral head [16].

Following CD and through the path of the drill, the preferred supplemental biological material can be placed in the lesion.

9.5 Cell-Based Treatments of ONFH

Most of the theories regarding the mechanism of spontaneous ONFH point toward alterations in intravascular blood flow, leading to decreased oxygenation, toxicity, and cellular death. There are several recognized conditions and environmental insults that predispose patients to ONFH, such as high-dose corticosteroid administration, alcohol abuse, hemoglobinopathy, Gaucher disease, and coagulopathies [1, 13, 21, 26].

In ONFH, the decreased population and altered function of the mononuclear stem cells (MSCs) may influence the two different events in the pathogenesis of ONFH: the actual occurrence of ONFH itself and the bone repair process that follows. Accepting the premise that an important part of the underlying pathology in ONFH is cell deficiency, the next rational step is to consider the use of cell-based treatments to enhance the regeneration of lost or damaged bone.

Although clinical experience has shown that dead bone may be replaced by living bone, the osteogenic potential for repair in ONFH is low. A decrease in osteogenic stem cells in the femoral head has been observed beneath the necrotic lesion up to the intertrochanteric region, which might account for the insufficient creeping substitution in bone remodeling of the femoral head after ON. This can explain the fact that although reconstruction and repair have been observed after CD, it is usually slow and inadequate [27, 28].

Even though MSCs act via not-completely understood multifaceted pathways, it seems that they perform two separate functions that can influence the natural history of ON: (1) secretion of a wide spectrum of factors with anti-inflammatory, antiapoptotic, proangiogenic, proliferative or chemo-attractive, capacities, and (2) initiating the differentiation process for functional tissue restoration [29]. In clinical practice, a common source for MSCs is bone marrow mononuclear cells (BMMCs) due to their ease of harvest (iliac crest or femoral condyles), their abundance, and their marked osteogenic properties [29–32]. Tracking studies of BMMCs implanted directly into the necrotic area in ONFH showed 56% of installed cells remained in the implantation site 24 h after implantation. Similar studies in animal models also demonstrated the survival and multiplications of these cells up to 12 weeks postimplantation [33–35].

9.6 The Harvesting Technique of the Cellular Population

The most common site to collect bone marrow is either the anterior or posterior part of the iliac crest depending on the patient positioning and surgeon preference (Fig. 9.3a). Collection of bone marrow from the iliac crest can be accomplished by the use of a single beveled aspirating needle. A number of such systems are available commercially. The highest quality of bone marrow aspiration (number of stem/progenitor cells)

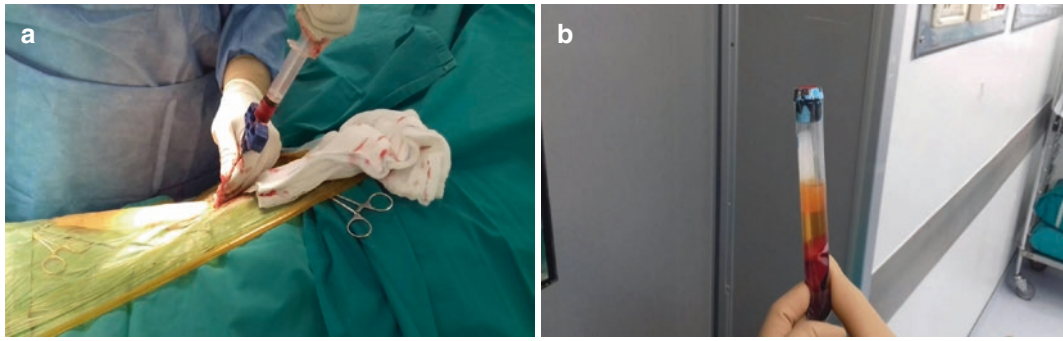

Fig. 9.3 (**a**) Bone marrow aspiration from antero-superior iliac spine (ASIS). (**b**) The aspirate following centrifuge; note the distinct cell separation

is when the aspirate is in small volumes (1–2 mL) and from different locations since, when a greater volume is drawn from any single area the peripheral blood infiltrates and dilutes the aspirate [36]. Technically, in order to achieve this, the needle is turned during successive aspirations thereby affording access to the largest possible space. After one full turn, the needle is slowly moved toward the surface and the process is repeated. The pooled aspirates (the volume can range between 30 and 120 mL) is filtered to separate cellular aggregates and fat (Fig. 9.3b). The aspirated material should be reduced in volume in order to increase the stem cell concentration. This is done with centrifugation, which separates the red blood cells (nonnucleated cells) and plasma in such a way as to retain only the nucleated cells: mononuclear stem cells, monocytes, and lymphocytes. After removing the nonnucleated cells, the aspirate is reduced to a concentrated myeloid suspension of stem cells that can be used for reinjection.

9.7 Arthroscopic Intraosseous Application of the Cellular Population

The procedure is performed at the time of CD. Following the drilling, the thin hip arthroscopy nitinol guidewire can be inserted in the femoral head following the CD track and then, over it, the cannulated arthroscopic needle. This ensures that the drill track is followed and the injected MSCs in the necrotic lesion is accurately placed. Backflow of the injected medium is not observed since the fluid diffuses to surrounding cancellous bone of the femoral head. During the injection time, the pressure in the femoral head can rise, but a normal pressure pattern is restored once the injection is finished [29]. Anecdotally, if excision of the cam deformity is done in conjunction with the CD drilling, overflow of the injected fluid can be observed from the exposed cancellous bone of the osteoplasty site after the injection of the first 10–15 mL, allowing the osteoplasty to act as a release "valve" to the increased pressure [21].

9.8 Conclusions

In summary, there is enough published clinical evidence to support hip arthroscopy as a safe and reliable adjunct in the management of osteonecrosis of the femoral head. It can be of value assessing the joint, and also addressing mechanical pathology commonly found in these hips. It can also help in a more technical manner by assisting the proper placement of the drill during retrograde or head–neck junction CD. But, since an important part of the underlying pathology in ON is cell deficiency, it is rational to consider the use of cell-based treatments to potentially regenerate lost or damaged bone. Cell therapies, particularly when employed at early stages of ONFH, improve clinical results and the survivorship of the native hip, reducing the need for hip replacement. The debate still remains on the ideal source, the lack of standardization and optimization of the harvested cells, their processing, method of transplantation, and even method of surgical delivery. The abundance of different cell-based treatments and our ability to control the behavior of the cells after implantation naturally raises some concerns on their long-term safety. None of the studies reported any major adverse events, but the quality of the evidence remains inadequate with long-term safety data still required [35].

It is the authors' belief that in the era of minimally invasive techniques, the use of cell-based therapies constitutes good clinical practice since it is safe, involves minimal surgical time and difficulty, causes very little morbidity of the donor site, and potentially can influence only positively the outcome of CD. We agree with other published literature that there is enough evidence that cell therapy should not be considered experimental but rather a developing technique [37, 38].

References

1. Lieberman JR, Berry DJ, Mont MA, et al. Osteonecrosis of the hip: management in the 21st century. Instr Course Lect. 2003;52:337–55.
2. Mont MA, Zywiel MG, Marker DR, et al. The natural history of untreated asymptomatic osteonecrosis

of the femoral head: a systematic literature review. J Bone Joint Surg Am. 2010;92:2165–70.
3. Piuzzi NS, Chahla J, Schrock JB, et al. Evidence for the use of cell based therapy for the treatment of osteonecrosis of the femoral head: a systematic review of the literature. J Arthroplast. 2017;32:1698–708.
4. Chughtai M, Piuzzi NS, Khlopas A, et al. An evidence-based guide to the treatment of osteonecrosis of the femoral head. Bone Joint J. 2017;99-B:1267–79.
5. Mont MA, Cherian JJ, Sierra RJ, et al. Nontraumatic osteonecrosis of the femoral head: where do we stand today? A ten-year update. J Bone Joint Surg. 2015;97:1604–27.
6. McGrory BJ, York SC, Iorio R, et al. Current practices 283 of AAHKS members in the treatment of adult osteonecrosis of the femoral head. J Bone Joint Surg Am. 2007;89:1194–204.
7. Cornell CN, Salvati EA, Pellicci PM. Long-term follow-up of total hip replacement in patients with osteonecrosis. Orthop Clin North Am. 1985;16:757–69.
8. Chandler HP, Reineck FT, Wixson RL, et al. Total hip replacement in patients younger than thirty years old: a five-year follow up study. J Bone Joint Surg Am. 1981;63:1426–34.
9. Issa K, Pivec R, Kapadia BH, et al. Osteonecrosis of the femoral head. The total hip replacement solution. Bone Joint J. 2013;95-B:46–50.
10. De Kam DC, Busch VJ, Veth RP, Schreurs BW. Total hip arthroplasties in young patients under 50 years: limited evidence for current trends. A descriptive literature review. Hip Int. 2011;21:518–25.
11. Hernigou P, Manicom O, Poignard A, et al. Core decompression with marrow stem cells. Oper Tech Orthop. 2004;14:68–74.
12. Papakostidis C, Tosounidis TH, Jones E, et al. The role of "cell therapy" in osteonecrosis of the femoral head. A systematic review of the literature and meta-analysis of 7 studies. Acta Orthop. 2016;87:72–8.
13. Mont MA, Jones LC, Hungerford DS. Nontraumatic osteonecrosis of the femoral head: ten years later. J Bone Joint Surg Am. 2006;88:1117–32.
14. Marker DR, Seyler TM, Ulrich SD, et al. Do modern techniques improve core decompression outcomes for hip osteonecrosis? Clin Orthop Relat Res. 2008;466:1093–103.
15. Petrigliano FA, Lieberman JR. Osteonecrosis of the hip: novel approaches to evaluation and treatment. Clin Orthop Relat Res. 2007;465:53–62.
16. Papavasiliou A, Yercan HS, Koukoulias N. The role of hip arthroscopy in the management of osteonecrosis. J Hip Preserv Surg. 2014;1:56–61.
17. Papavasiliou AV, Bardakos NV. Complications of arthroscopic surgery of the hip. Bone Joint Res. 2012;1(7):131–44.
18. Sekiya JK, Ruch DS, Hunter DM, et al. Hip arthroscopy in staging avascular necrosis of the femoral head. J South Orthop Assoc. 2000;9:254–61.
19. Papavasiliou A, Gliatis J. Specific tissues and conditions: osteonecrosis, avascular necrosis. In: McCarthy JC, Noble PC, Villar RN, editors. Hip joint restoration. Worldwide advances in arthroscopy, arthroplasty, osteotomy and joint preservation surgery. New York: Springer; 2017. p. 555–9.
20. Mont MA, Etienne G, Ragland PS. Outcome of non-vascularized bone grafting for osteonecrosis of the femoral head. Clin Orthop Relat Res. 2003;417:84–92.
21. Papavasiliou AV, Triantafyllopoulos I, Paxinos O, Tsoukas D, Kostantoulakis C. The role of cell therapies and hip arthroscopy in the management of osteonecrosis: an update. J Hip Preserv Surg. 2018;5(3):202–8.
22. Mohanty SP, Singh KA, Kundangar R, Shankar V. Management of nontraumatic avascular necrosis of the femoral head—a comparative analysis of the outcome of multiple small diameter drilling and core decompression with fibular grafting. Musculoskelet Surg. 2017;101:59–66.
23. Mont MA, Ragland PS, Etienne G. Core decompression of the femoral head for osteonecrosis using percutaneous multiple small-diameter drilling. Clin Orthop Relat Res. 2004;429:131–8.
24. Al Omran A. Multiple drilling compared with standard core decompression for avascular necrosis of the femoral head in sickle cell disease patients. Arch Orthop Trauma Surg. 2013;133(5):609–13.
25. Karantanas AH. Accuracy and limitations of diagnostic methods for avascular necrosis of the hip. Expert Opin Med Diagn. 2013;7(2):179–87.
26. Jones LC, Hungerford DS. Osteonecrosis: etiology, diagnosis, and treatment. Curr Opin Rheumatol. 2004;16:443–9.
27. Hernigou P, Beaujean F. Abnormalities in the bone marrow of the iliac crest in patients who have osteonecrosis secondary to corticosteroid therapy or alcohol abuse. J Bone Joint Surg Am. 1997;79:1047–53.
28. Hernigou P, Beaujean F, Lambotte JC. Decrease in the mesenchymal stem-cell pool in the proximal femur in corticosteroid induced osteonecrosis. J Bone Joint Surg Br. 1999;81:349–55.
29. Hernigou P, Trousselier M, Roubineau F, et al. Stem cell therapy for the treatment of hip osteonecrosis: a 30-year review of progress. Clin Orthop Surg. 2016;8:1–8.
30. Bianco P, Riminucci M, Gronthos S, et al. Bone marrow stromal stem cells: nature, biology, and potential applications. Stem Cells. 2001;19:180–92.
31. Conway EM, Collen D, Carmeliet P. Molecular mechanisms of blood vessel growth. Cardiovasc Res. 2001;49:507–21.
32. Murphy MB, Moncivais K, Caplan AI. Mesenchymal stem cells: environmentally responsive therapeutics for regenerative medicine. Exp Mol Med. 2013;45:e54.
33. Gangji V, De Maertelaer V, Hauzeur JP. Autologous bone marrow cell implantation in the treatment of non-traumatic osteonecrosis of the femoral head: five year follow-up of a prospective controlled study. Bone. 2011;49:1005–9.

34. Yan Z, Hang D, Guo C, Chen Z. Fate of mesenchymal stem cells transplanted to osteonecrosis of femoral head. J Orthop Res. 2009;27:442–6.
35. Alshameeri Z, McCaskie A. The role of orthobiologics in hip preservation surgery. J Hip Preserv Surg. 2015;2:339–54.
36. Hernigou P, Homma Y, Flouzat Lachaniette CH, et al. Benefits of small volume and small syringe for bone marrow aspirations of mesenchymal stem cells. Int Orthop. 2013;37:2279–87.
37. Hernigou P, Lambotte JC. Volumetric analysis of osteonecrosis of the femur: anatomical correlation using MRI. J Bone Joint Surg Br. 2001;83:672–5.
38. Andriolo L, Merli G, Tobar C, Altamura SA, Kon E, Filardo G. Regenerative therapies increase survivorship of avascular necrosis of the femoral head: a systematic review and meta-analysis. Int Orthop. 2018;42(7):1689–704.