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HIP

Arthroscopic management and platelet-rich plasma therapy for avascular necrosis of the hip

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Abstract
Purpose The purpose is to describe a noninvasive arthroscopic procedure as an alternative to open surgery for avascular necrosis of the hip.
Methods Patients with grade I or IIA avascular necrosis of the hip are treated by core decompression performed by drilling under fluoroscopic guidance. Liquid platelet-rich plasma (PRP) is delivered through a trocar, saturating the necrotic area. In more severe conditions, the necrotic bone is decompressed and debrided, through a cortical window at the head–neck junction. A composite graft made of autologous bone and PRP is delivered by impactation through the core decompression track. Fibrin membranes are applied to enhance healing of the head–neck window and arthroscopic portals. Platelet-rich plasma is infiltrated in the central compartment.
Results This arthroscopic approach aids in making diagnosis of the labrum and articular cartilage and permits intra-operative treatment decisions. Visual control permits the precise localization and treatment for the necrotic area allowing cartilage integrity to be preserved.
Conclusions Arthroscopic management of avascular necrosis of the femoral head is viable and has significant advantages. Clinical studies should justify the theoretical additional benefits of this approach.

Keywords Avascular necrosis · Hip · Arthroscopy · Core decompression · Bone graft · Platelet-rich plasma

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Introduction

During the last decade, the management of hip pathologies has progressed toward earlier and less invasive approaches due to outstanding advances in both diagnostic magnetic resonance imaging (MRI) and arthroscopy. Likewise, improved understanding of healing mechanisms and platelet-rich plasma (PRP) therapies has provided opportunities for combining mechanical and biological concepts to treat compromised clinical conditions such as avascular necrosis (AVN) of the femoral head. Because AVN typically presents in young patients and most often progresses to collapse [8] and arthritic changes, any intervention for joint preservation should be considered in order to avoid hip replacement.

Avascular necrosis is not a specific disease; rather, it is the final common pathway of various pathological processes. The treatment is independent of causative factors—idiopathic conditions, high stress trauma, high-dose corticosteroid administration, or alcohol abuse—that activate the biological process. However, the choice of treatment is dictated by the stage of the disease and the size of the lesion, which are stratified by various classification systems based on MRI and radiography [15]. Although commonly treated with open hip surgery, in view of the morbidity and risks associated with such surgery, referral to less invasive arthroscopic procedures enhanced with PRP therapies might be an effective approach to slow and possibly reverse the effects of AVN.

An arthroscopic approach, for early intervention of AVN at Pennsylvania stages I-IIA-C, is described [21]. Diagnosis and treatment for necrosis and associated pathologies are performed by arthroscopic access to both the central compartment and necrotic area using approaches consistent with current practice [14]. Additionally, the

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entire process is enhanced by applying PRP therapies that aim to avoid progressive collapse of the vulnerable hip joint.

Arthroscopic technique and biological therapy

PRP preparation

Before inducing anesthesia, 90 cc of peripheral venous blood was withdrawn into 9 cc tubes containing 3.8% (wt/vol) sodium citrate. Platelet-rich plasma is prepared by single spinning at 580 g for 8 min at room temperature (PRGF®, Vitoria, Spain). The plasma fraction located above the sedimented red blood cells, and buffy coat was collected in sterile tubes and carried to the operating theater, ready for use. When PRP is used in the liquid form, 10% calcium chloride is added just before application. This plasma contains a moderate enrichment in platelets (1.5–2-fold the platelet count of peripheral blood), without leukocytes.

Arthroscopy

The patient is placed in a supine position on a fracture table for hip distraction. General anesthesia is used, and the labrum and the acetabular and femoral cartilage are examined in moderate traction. In the case of damaged joint patterns, labrum fixation or resection and/or cartilage debridement by vaporization are performed intra-operatively. The femoral head is probed to assess the areas of necrosis under both fluoroscope and intra-articular vision.

Symptomatic hips, classified as grade I or IIA [21], were treated by core decompression [14], which is performed by accessing the femoral head through the base of the head with the hip flexed to 10–15° and with neutral abduction and moderate traction. Depending on the location of the necrosis, flexion or extension, and internal or external rotation may be needed to reach the necrotic area. Drilling is performed with a 3.2-mm Steinmann pin inserted through the anterior portal or via an ancillary portal in the direction of the center of the femoral head, under fluoroscopic guidance (Fig. 1). Once the pin properly oriented into the anterior half of the femoral neck, several 3.2-mm holes are made precisely, by drilling at various angles (Fig. 2), surpassing the sclerotic rim and advancing to within a few millimeters of the subchondral plate under arthroscopic control. Then, a trocar is advanced through the perforation hole and 10 cc of liquid PRP are delivered, saturating the necrotic area. The injected biomaterial did not wash away, since a platelet-rich fibrin develops within the pre-collapse site, releasing growth factors and cytokines into the area.

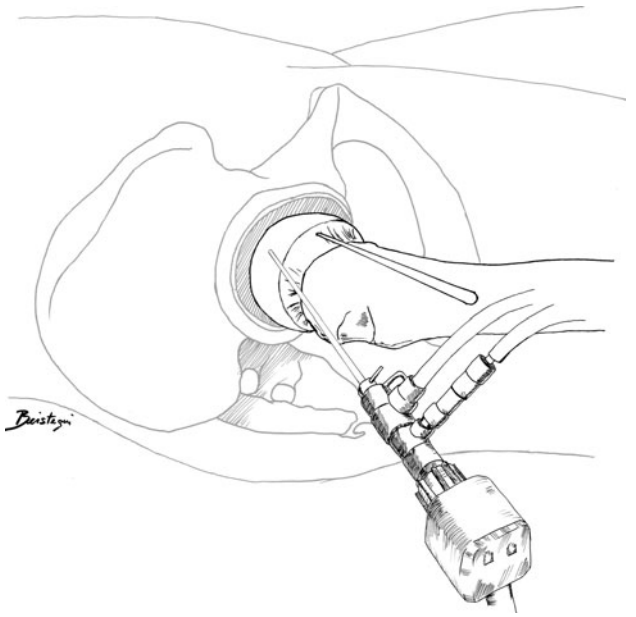

Fig. 1 Diagram depicting the position of the Kirschner pin, which is advanced into the necrotic area through an ancillary portal (the insertion point is just medial to the greater trochanter and anterior to the central axis of the femoral neck)

Alternatively, patients at stage IIB and IIC, with moderate or severe cystic and sclerotic changes, require full debridement of the necrotic tissue and subsequent bone grafting. To achieve full debridement, the "light bulb" approach is used [22]. After opening a cortical window at the level of the head–neck junction, the necrotic area is approached using a Kirschner pin and the proper trajectory for the trephine drill is confirmed by fluoroscopy (Fig. 3). The 9-mm cannula is adjusted, and the 8-mm trephine drill is advanced through the cortical window into the necrotic niche (Fig. 4). The core healthy bone is recovered for subsequent grafting, while the necrotic bone is removed with either burrs or curettes. The bone graft is introduced—ideally ipsilateral iliac cancellous bone combined with PRP—through the trephine drill track, as described below. Otherwise, to avoid donor site morbidity, using other grafts such as morselized bone allograft or demineralised bone may be considered, all of them combined with PRP.

Bone graft + PRP

At first, the bone graft is mixed with activated liquid PRP and incubated for several minutes, allowing development of a 3-D fibrin scaffold, which agglutinates bone particles. The composite (bone +PRP) is arranged within the trephine, passed through the core track and packed by impaction; in so doing, a good fit within the deep femoral head is achieved.

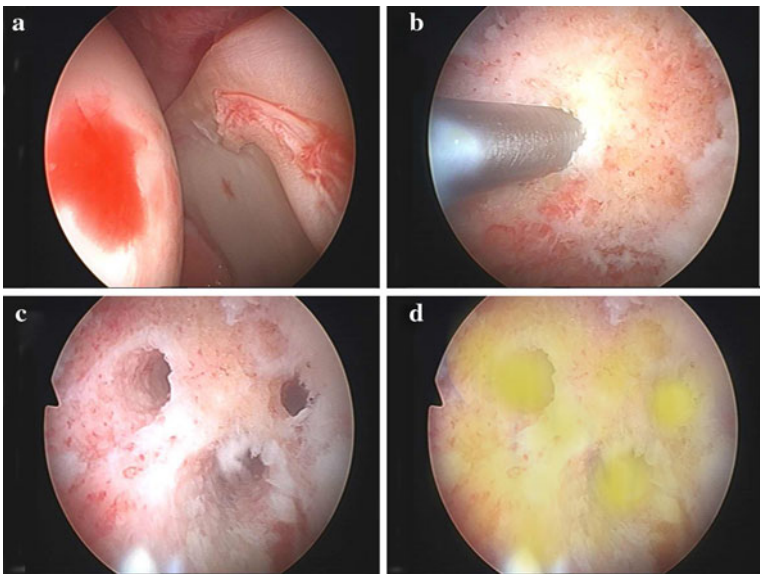

Fig. 2 Intra-articular views showing core decompression assisted by PRP therapy. **a** Diagnostic of the labrum and the cartilage of the central compartment. **b** The tip of the Steinman pin is positioned for core decompression. **c** Several perforations through the necrotic area have been performed at different angles to control core depth. **d** The perforations are filled with activated PRP, which delivers growth factors and cytokines throughout the entire area after clotting

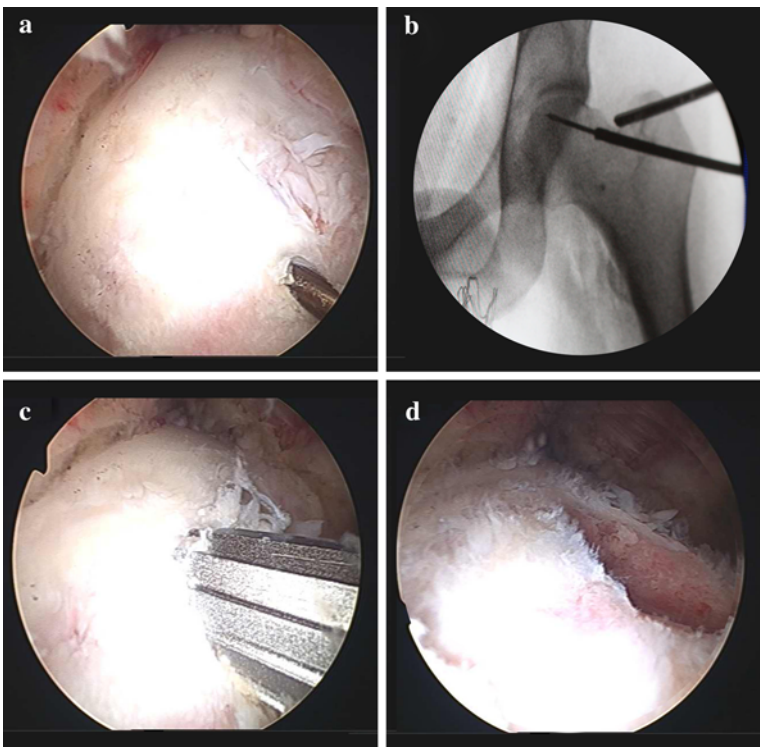

Fig. 3 **a** Kirschnner pin is inserted and properly oriented. **b** The position is verified by intra-operative fluoroscopy. **c** An 8-mm cannulated burr is used to create an opening through the cortical wall, and then the necrotic area is attained using an 8 mm trephine. **d** Cortical window at the level of the head–neck junction

Fibrin membranes

Hemostasis and enhanced healing can be obtained by placing autologous fibrin membranes over the cortical window opened in the base of the femoral head. In addition, the defect created in the donor iliac crest may be filled with fibrin membranes. In order to prepare the autologous fibrin membrane, 15–20 cc of the plasma located at the top of the tubes are activated with calcium chloride and incubated for 30–40 min in a glass bowl, for ex vivo fibrin formation.

Before finishing the surgery, any free body is aspirated via the outflow cannula. Finally, after flushing out all arthroscopic fluid, the joint is infiltrated with 8 ml of activated PRP.

Our experience is limited to 1 patient with Grade IIA AVN and 3 patients with Grade IIB AVN. Two of the patients with grade IIB were diagnosed of labral tears during arthroscopy and followed debridement. The average follow-up was 14 months. Every patient reported a clinically significant reduction in pain intensity ($\geq$60%),

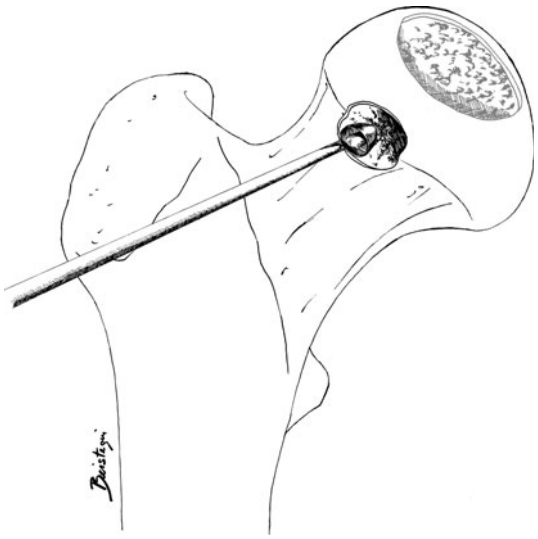

Fig. 4 Drawing depicting the light bulb procedure, in which necrotic bone is removed through the window created at the junction of the femoral head and neck

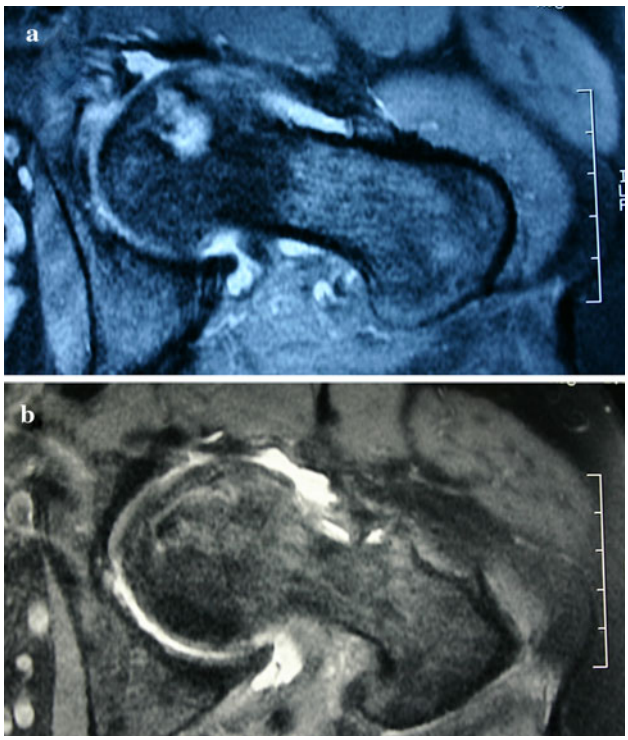

Fig. 5 MRI appearance of stage IIB AVN before and after PRP-assisted arthroscopic management. **a** axial T2-weighted image before surgery; **b** Postoperative (20 weeks) MRI findings on axial T2-weighted image

measured with 100-mm visual analog score and went back to a regular style of life by the fifth month. While a significant clinical improvement was seen relatively early in the follow-up (3 months), the image changes appeared later on. Representative MRI findings before and after treatment are shown in Fig. 5.

Discussion

The most important preliminary finding of the present study was the viability of core decompression and bone grafting through arthroscopy in patients with AVN of the hip avoiding any open surgery. The optimal joint-preserving procedure for AVN should be predictable and should provide core decompression, sufficient support and cues for revascularization of the necrotic area. Accordingly, the purpose of this management is fourfold: (1) to improve overall diagnostic accuracy by detecting labrum degeneration or other associated pathologies not evident in MRI or plain radiography; (2) to achieve core decompression and precise debridement of the necrotic area with visual control to preserve cartilage integrity; (3) to graft the necrotic area/bone cysts; and (4) to enhance overall arthroscopic management with PRP.

Currently, most surgeons perform grafting by open surgery using two distinct techniques: (1) the "trapdoor" technique [14], involving an elevated trapdoor through articular cartilage or (2) the "light bulb" approach [17], which involves grafting through a window at the femoral neck junction. Using the latter approach and autologous iliac bone grafting, Rosenwaser et al. [17] demonstrated a high clinical success rate (87%) at long-term follow-up (10–15 years). More recently, Wang et al. [22] reported survivor rates of 85% in stages IIA and IIB and 60% in stages IIIA and IIC at 25.37 months. Taken together, these results suggest that bone grafting through the light bulb approach may be a predictable preservation approach in the pre-collapse stage. The present arthroscopic adaptation of the light bulb technique, when compared with open procedures, has well-described benefits of muscular preservation, decreased recovery times, lower infection rates, and reduced postoperative pain. Overall, arthroscopy as compared with conventional open surgery is associated with substantial increases in both diagnostic sensitivity and accuracy in drilling the necrotic area; moreover, specificity in determining the condition of cartilage and labrum facilitates intra-operative decisions regarding further treatment. Arthroscopy can improve the condition of the hip joint by scavenging pain-producing substances, removing cartilage chips caused by cartilage stress or pathology, and correcting internal environment disorders.

Arthroscopic surgery may be enhanced by the application of PRP in several ways. First, the area is grafted with trabecular bone mixed with PRP to induce angiogenesis and enhance cell survival and function. The hundreds of soluble proteins released from both plasma and platelets include VEGF-A, PDGF, FGF, EGF, HGF, and IGF. These angiogenic activators collectively promote vessel wall permeability and recruitment, growth and proliferation of endothelial cells [4]. Studies have confirmed that the local

application of PRPs is especially important in pathological conditions in which bone healing is weakened, due to an inadequate blood supply such as that observed in atrophic nonunion fractures. Both percutaneous injection and surgical augmentation with freshly prepared PRP normalized fracture callus [3, 19, 20]. These findings are consistent with those seen in diabetic patients with a Charcot foot who showed improved healing and fewer complications after ankle fusion treated with fresh PRP [9]. In contrast, previously frozen, thawed PRP supplementation in long bone nonunions treated with external fixation failed to prove clinical usefulness [13]. Other biologic augmentation, i.e., rhBMP7 has shown superior clinical and radiographic efficacy than PRP [5].

Platelet-rich plasma is also applied within the intra-articular space aiming to improve the conditions of synovial cells, chondrocytes, and subchondral osteoblasts. Recently, Cenni et al. [6] have reported that the concentrations of growth factors in PRP releasates and lysates from patients with idiopathic or secondary osteonecrosis of the hip were similar to those of healthy subjects. This provides a biological basis for the use of PRP in the treatment for osteonecrosis. In a laboratory study, PRP application can improve the quality of synovial fluid by inducing endogenous secretion of hyaluronic acid by synovial cells [1]. In a retrospective cohort study, Sánchez et al. [18] reported decreased pain and enhanced function after intra-articular injection of activated PRP in knee OA as compared with intra-articular injection of hyaluronic acid. Corroborating these findings in a case series, Kon et al. [12] reported reduced pain and improved function in young patients with a low degree of articular degeneration.

Our preliminary experience is limited to hardly any patient; thus, any conclusions about the effectiveness of this procedure are dependent on future clinical studies. Prospective investigations should be conceived to determine the efficacy of the present arthroscopic procedure. Given the limited clinical experience, a step forward would be to explore the analgesic and anti-inflammatory effect of PRP when it is used to treat AVN of the hip. Additional potential benefits including blood loss, shorter hospital stay, and faster recovery time should be investigated as well.

Abundant experimental data suggest a role for various constituents of PRP in the regulation of bone formation. So far in orthopedic trauma, there are few clinical studies and no conclusions can be made. However, in some clinical conditions, the development of newly grown bone may be a realistic target if PRP is applied with cells or scaffolds. When 9 patients with solitary bone cysts were treated with allogenic grafts and PRP, the cysts were filled with newly formed bone at 12 months [16]. In a randomized control trial among people undergoing a medial, opening-wedge osteotomy of the proximal tibia the use of allograft plus PRP showed better radiographic osseointegration at all stages of follow-up [7]. Encouraging results were observed in clinical studies exclusively concerning children. For instance, in the distraction of long bones, Kitoh et al. [10] reported less complications in children treated with PRP plus mesenchymal stem cells (MSCs) than children that did not receive PRP and MSCs augmentation. The same authors reported an enhanced healing index in a controlled case series of children with achondroplasia or hypochondroplasia undergoing limb-lengthening procedures [11]. Within the foot and ankle literature, the clinical utility of PRPs still lack the support of randomized controlled trials, but most studies have shown favorable outcomes with acceleration in bone healing [2]. Even so achieving control of bone healing is difficult and the challenges associated with PRP therapies are enormous, extending beyond the present knowledge.

Clinical relevance

Avascular necrosis of the femoral head may be an indication for arthroscopic surgery reducing discomfort, pain, and potential for disability and morbidity associated with open surgery. Moreover, lesions such as labral tears or loose bodies can be diagnosed and treated simultaneously reducing associated pain.

Conclusions

The activity level and survival of the hips of patients with AVN represent challenges for the orthopedic surgeon. In the early stages of treatment, current practice may be improved by arthroscopy with PRP therapy but clinical studies should justify the theoretical additional benefits of this noninvasive and biological approach.

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Conflict of interest The authors state no conflict of interest.

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