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Efficacy study of platelet-rich plasma combined with core decompression and bone grafting in the treatment of early-stage avascular necrosis of the femoral head: a retrospective study

Rong-Da Xu[1†], Si-Yu Duan[1†], Hai-Rui Liang[1], Ming Sun[1], Hang Wen[1], Xue-Ting Zhou[1], Han-Fei Liu[1] and Zhen-Cun Cai[1,2*]

Abstract

Objective This study aimed to evaluate the effectiveness of combined core decompression (CD), bone grafting (BG), and platelet-rich plasma (PRP) in treating early-stage avascular necrosis of the femoral head (ANFH).

Methods A retrospective study was conducted on 74 patients (85 hips) with Ficat-Arlet stage I-II ANFH who were treated at our hospital between May 2015 and May 2018. The control group (20 patients, 22 hips) received symptomatic treatments, including weight-bearing reduction and oral analgesics. The CD + BG group (29 patients, 34 hips) underwent CD and β-tricalcium phosphate bone grafting. The PRP combination group (25 patients, 29 hips) received PRP injections in addition to CD and BG. Patients were followed up for five years to assess the necessity for total hip arthroplasty (THA). Data analysis was performed on those from the CD + BG and PRP groups who did not require THA. Clinical outcomes were evaluated using the Visual Analog Scale (VAS), Harris Hip Score (HHS), and the proportion of patients not accepting THA.

Results At the five-year follow-up, the rate of THA in the control group was 68.18% (15/22), while in the CD + BG group and the PRP combination group, the rates were 17.65% (6/34) and 10.34% (3/29), respectively. There was no statistically significant difference between the CD + BG group and the PRP combination group ($P = 0.441$), but both differed significantly from the control group ($P < 0.001$). Kaplan-Meier survival analysis showed that over time, the proportion of patients in the PRP combination group who did not require THA was consistently higher than that in the CD + BG group. Among patients who did not undergo THA, the proportion of Ficat-Arlet stage I-II patients in the PRP combination group was 88.46% (23/26), which was higher than the 64.29% (18/28) in the CD + BG group, showing a significant difference ($P = 0.038$). VAS score and HHS were compared between the two groups at 6 months, 12 months, and the last follow-up point, with patients in the PRP combination group showing better scores than those in the CD + BG group ($p < 0.05$) in both metrics.

†Rong-Da Xu and Si-Yu Duan contributed equally to this work.

*Correspondence:
Zhen-Cun Cai
sychczc@163.com
Full list of author information is available at the end of the article

Conclusion The combination therapy of CD, BG, and PRP demonstrates significant advantages in improving symptoms and delaying disease progression in early-stage ANFH.

Keywords Avascular necrosis of the femoral head, Platelet-rich plasma, Core decompression, Bone grafting

Introduction

The development of avascular necrosis of the femoral head (ANFH) is a progressive pathological process typically influenced by various factors. Its primary characteristic is the interruption of blood circulation to the femoral head, leading to the gradual necrosis of bone cells within the femoral head, thereby compromising the structure and function of the bone tissue [1, 2].As the disease progresses, the femoral head may collapse, resulting in decreased hip joint function and loss of normal joint mobility. Eventually, joint replacement surgery may be necessary to alleviate pain and restore joint function. Therefore, early detection and treatment of ANFH are crucial for preserving joint function in patients. Joint-preserving surgeries in the early stages of ANFH have garnered significant attention, with core decompression (CD) being the most commonly used procedure. Its primary goal is to alleviate pressure within the femoral head, improve blood supply, and thus delay or halt the progression of the disease [3, 4].

However, performing CD alone may lead to some issues, such as slow postoperative bone repair and insufficient support, which can result in inadequate structural integrity of the bone after surgery, increasing the risk of collapse or fracture of the necrotic area [5, 6]. Therefore, in cases where CD serves as the primary treatment, it often requires combining various adjunctive therapies, including bone transplantation, recombinant bone morphogenetic protein, autologous bone marrow stem cells, etc., to improve bone repair outcomes and postoperative stability [7, 8].

In recent years, to enhance the efficacy of joint-preserving surgeries, Platelet-rich Plasma (PRP) has been used in conjunction with various procedures for early-stage ANFH [9, 10]. PRP is plasma with a higher concentration of platelets obtained through centrifugation of whole blood, containing a high proportion of various growth factors and cytokines. These components not only activate cell proliferation but also promote angiogenesis, modulate immune responses, and accelerate tissue repair and regeneration processes [11, 12]. In studies on PRP treatment for ANFH, it is important to consider the impact of similar blood supply issues on other critical bones, such as the astragalus and the carpal scaphoid. Due to their unique and relatively insufficient blood supply, these bones are particularly vulnerable during the healing process of bone injuries or necrosis. Peng et al.'s [13] meta-analysis results indicate that PRP, whether used alone or in combination with other treatment modalities, is both safe and effective for cartilage repair in patients with talar cartilage injuries. Namazi et al. [14] investigated the efficacy of intra-articular PRP injections in patients with scaphoid fractures. They found that PRP injections significantly reduced resting pain and effectively improved functional difficulties, including both specific activities and daily living activities.These research results suggest that PRP may have a beneficial role in the repair and regeneration of bones facing issues of inadequate blood supply.

Systematic research on combined treatment strategies for early-stage ANFH is still limited. Most existing studies focus primarily on single treatment methods or explore the effects of PRP in isolation. In contrast, this study innovatively combines CD, BG, and PRP injection. The growth factors in PRP contribute to the repair of bone cells and soft tissues, while CD and BG provide essential structural support and pressure relief. This synergistic effect is expected to further enhance treatment outcomes and achieve more sustained efficacy.Therefore, our research team will investigate whether combining local PRP injections with the standard treatment of CD and BG in early-stage ANFH can significantly improve postoperative pain relief and enhance hip joint function.Our preliminary hypothesis is that the combination of CD, BG, and PRP injection will significantly reduce pain levels (as assessed by the VAS) in patients with early-stage ANFH, enhance hip joint function (based on the HHS), and effectively decrease the likelihood of ultimately requiring THA.

Materials and methods

Participants

A retrospective analysis was conducted on 126 patients with early-stage ANFH treated at the Orthopedic Department of Central Hospital Affiliated to Shenyang Medical College from May 2015 to May 2018. Using the G.Power software program to calculate the sample size, sample analysis was conducted for the primary outcomes of the study (VAS and HHS) based on previous research findings. Considering the significant reduction in the mean difference of VAS scores and the significant increase in the mean difference of HHS scores, it was determined that at least 22 hips per group are required to detect

these differences. The sample size calculation is based on a significance level of 0.05 and a test power of 80%.

All subjects were classified using the modified Ficat-Arlet classification system [15].The Ficat-Arlet classification system is a commonly used method for ANFH. However, the clinical progression of ANFH is influenced not only by the severity of necrosis but also by the size and location of the lesions. Therefore, this study also incorporates the Japanese Investigation Committee (JIC) classification system [16] as a supplement to more accurately assess lesion characteristics and further highlight the effectiveness of the treatment regimen. Inclusion criteria are as follows: (1) Patients aged between 18 and 60 years old; (2) Diagnosed with stage I-II ANFH according to the Ficat-Arlet classification; (3) No history of trauma to the acetabulum, femoral neck, or intertrochanteric region; (4)Complete follow-up data available. Exclusion criteria include: (1) Ficat-Arlet stage III-IV classification; (2) Previous history of hip joint surgery on the operated side; (3) History of developmental dysplasia of the hip, osteoarthritis of the hip joint, rheumatoid arthritis, or similar conditions; (4) Concurrent use of steroids for other medical conditions; (5) Nonsteroidal anti-inflammatory drugs combined with hyaluronic acid are selected to treat patients with early-stage ANFH and mild activity limitations.

Based on the inclusion and exclusion criteria, a total of 84 patients were enrolled in this study. To ensure data integrity and reliability, we conducted a rigorous selection process, excluding all patients with incomplete data. Based on the patients' treatment protocols, those receiving symptomatic treatment, such as using crutches to reduce weight-bearing and oral analgesics, were defined as the control group. Patients treated with CD combined with BG were defined as the CD + BG group. Patients treated with CD, BG, and PRP injection were defined as the CD + BG + PRP group. In the control group, 25 patients were initially enrolled; however, during the follow-up period, 5 patients did not attend their scheduled visits and were excluded due to incomplete data. In the CD + BG group, 31 patients were enrolled, with 2 patients excluded for incomplete data. Similarly, in the CD + BG + PRP group, 28 patients were enrolled, but 3 patients were excluded due to incomplete data. Data including gender, age, BMI, mechanism of necrosis, and classification of femoral head necrosis were recorded for all three groups.This paper is a retrospective study. During the case selection process, we compared the general characteristics of the patients in each group, including age, gender, BMI, etiology, hip involvement, Ficat staging, and JIC classification. The results showed that the baseline characteristics of each group were comparable. This study has obtained approval from the Medical Ethics Committee of Central Hospital Affiliated to Shenyang Medical College (Approval No: 2015024, Approval date: 20 March 2015). All patients provided written informed consent.

Surgical procedure

Control Group: Patients in this group received symptomatic treatment during the therapy period, including using crutches to reduce weight-bearing and taking oral analgesics. They also underwent regular follow-up visits during the follow-up period.

CD + BG Group: Patients underwent spinal or general anesthesia and were positioned supine on a traction table. Under C-arm fluoroscopic guidance, a guide pin was drilled into the femoral head and neck region, ensuring proper placement in anteroposterior and lateral views at the lesion site of femoral head necrosis (Fig. 1a-b). A hollow drill was used along the guide pin to create an operational channel (Fig. 1c). After removing the hollow drill, a decompression sleeve was inserted along the guide pin (Fig. 1d). After removing the guide pin, a expandable reamer was used through the decompression sleeve into the lesion site of femoral head necrosis (Fig. 1e).The reamer was rotated to scrape the lesion, gradually expanding it until the lesion was completely removed. After removing the reamer, under C-arm fluoroscopy, a curette should be used to scrape and remove any remaining necrotic lesions in all directions (Fig. 1f), decompressing the femoral head. Physiological saline was used to flush the lesion through the sleeve, and then the lesion area was filled and compacted with β-TCP (Beijing Xinkangchen Medical Technology Development Co., Ltd., China) (Fig. 1g).

CD + BG + PRP Group: The core decompression procedure is identical to that of the CD + BG group. PRP was prepared using the WG-YLJ-I centrifuge from Weigao Company (China). Initially, 5 ml of sodium citrate was injected into a 50 ml syringe to thoroughly lubricate the inner wall. Within 5 min, 45 ml of blood was drawn from the patient's median cubital vein, ensuring thorough mixing with the sodium citrate. The blood mixture was transferred to a centrifuge tube, and an equal weight of physiological saline (52–54 ml) was added to a balancing tube for the first centrifugation (Fig. 2a). After the first centrifugation, plasma was extracted down to 1 mm below the cone (Fig. 2b). Following balancing again, a second centrifugation was performed (Fig. 2c). After the second centrifugation, the supernatant was extracted to leave 5–6 ml in the tube (Fig. 2d), which was gently shaken clockwise to obtain PRP. Post bone grafting, the prepared PRP was injected along the sleeve into the necrotic area of the femoral head (Fig. 1h). To ensure consistency in the intervention, all surgical procedures

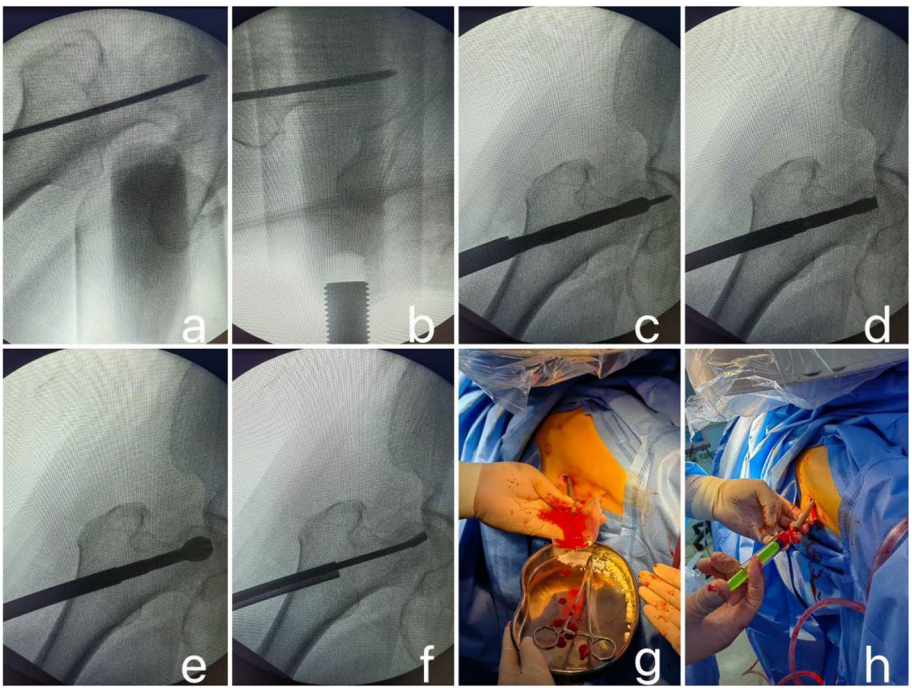

Fig. 1 **a**-**b** Under C-arm fluoroscopic guidance, a guide pin was drilled into the femoral head and neck region, ensuring proper positioning in both anteroposterior and lateral views. **c** A hollow drill was used along the guide pin to create an operational channel. **d** After removing the hollow drill, a decompression sleeve was inserted along the guide pin. **e** An expandable reamer was inserted into the lesion site, and rotated to gradually scrape the lesion, progressively expanding the reamer until the lesion was completely removed. **f** Under C-arm fluoroscopy, a curette was used to scrape and remove any remaining necrotic lesions in all directions. **g** The lesion area was filled with β-TCP and compacted. **h** Post bone grafting, the prepared PRP was injected along the sleeve into the necrotic area of the femoral head

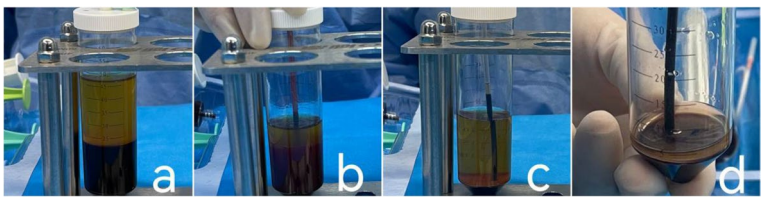

Fig. 2 **a** Blood and physiological saline of equal weight are injected into centrifuge tubes and placed in a centrifuge for the first centrifugation to obtain the product; **b** After the first centrifugation, the plasma layer is extracted to 1 mm below the cone; **c** After balancing again with equal weight physiological saline, a second centrifugation is performed to obtain the product; **d** After two centrifugations, extract the supernatant to leave 5–6 ml in the tube, where the interface between the supernatant and the blood cell layer is the PRP. After gentle clockwise agitation, activated PRP is obtained

for both the CD + BG group and the CD + BG + PRP group were performed by the same experienced surgeon. A typical case of the CD + BG + PRP group is shown in Fig. 3.

Postoperative management

During the postoperative bed rest period, instruct patients to perform ankle pump exercises, quadriceps strengthening exercises, and joint range of motion exercises. Patients undergoing unilateral hip joint surgery can start non-weight-bearing walking with crutches within 2 weeks postoperatively, while those undergoing bilateral hip joint surgery should refrain from weight-bearing for at least 6 weeks postoperatively. Both groups can gradually transition to weight-bearing after 6 weeks, with full weight-bearing allowed by 3 months. All patients should gradually progress from partial weight-bearing to full weight-bearing based on postoperative reassessment results. During follow-up visits, hip joint X-ray examinations should be conducted monthly for the first 3 months postoperatively, and then every 3 to 6 months thereafter. If patients experience worsening pain symptoms or

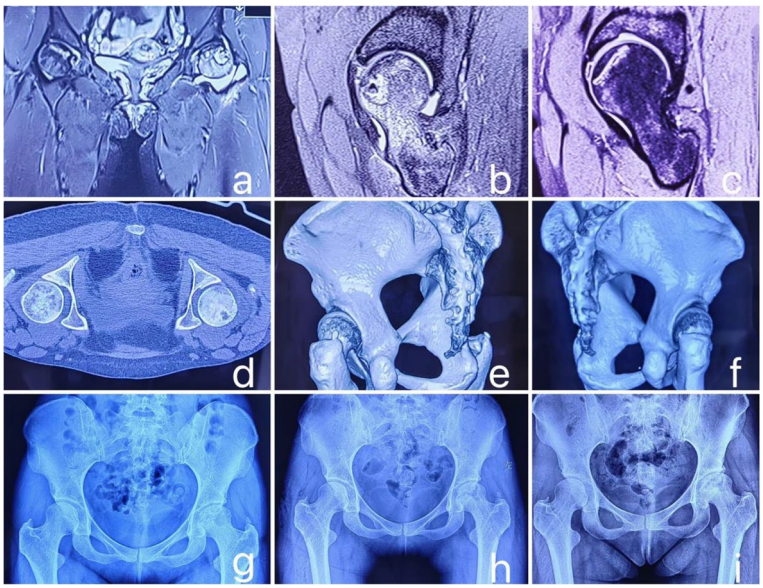

Fig. 3 A 32-year-old female patient with bilateral avascular necrosis of the femoral heads (Ficat-Arlet stage II on the left side and stage I on the right side), who underwent simultaneous core decompression with bone grafting combined with PRP injection on both sides. **a**-**c** Preoperative MRI images of both hip joints show disrupted internal structure of the femoral heads and localized cystic changes. **d**-**f** CT scans and 3D reconstruction data of both hip joints. **g** Preoperative X-ray. **h** X-ray on the first postoperative day. **i** X-ray at 12 months postoperatively, demonstrating a gradual reduction in the necrotic area

significant joint restriction, CT or MRI scans should be performed.

Clinical assessment

The visual analogue scale (VAS) and harris hip score (HHS) were used to assess pain relief and hip joint function at preoperative, 6 months postoperative, 12 months postoperative, and at the final follow-up. The endpoint was defined as the need for THA. The Kaplan-Meier survival curves were utilized to display the proportion of patients in each treatment group who had not undergone THA over various time periods.

Statistical analysis

Statistical analysis was performed using SPSS 27.0 software. Categorical data were represented by case numbers and analyzed using the chi-square test. Continuous data were expressed as mean ± standard deviation. The Kolmogorov-Smirnov test was first used to check for normal distribution of continuous data. Continuous variables following a normal distribution were analyzed using the independent samples t-test, while those not following a normal distribution were analyzed using the Mann-Whitney U test. The Kaplan-Meier survival curves were used to display the proportion of patients in each treatment group who had not undergone THA at various time points, and statistical significance was determined using the log-rank test. In these analyses, a P value of less than 0.05 was considered statistically significant.

Results

Baseline demographic characteristics

The study initially enrolled 84 patients, but during follow-up, patients with incomplete data were excluded. The control group included 20 patients (22 hips), with 5 patients excluded due to loss to follow-up. The CD + BG group included 29 patients (34 hips), with 2 patients excluded due to loss to follow-up.The CD + BG + PRP group included 25 patients (29 hips), with 3 patients excluded due to loss to follow-up. Therefore, a total of 74 patients (85 hips) were included in the final analysis. There were no statistically significant differences among the three groups in terms of age, gender, BMI, etiology, affected side of the hip joint, Ficat stage, and JIC classification($P > 0.05$) (Table 1).

Follow-up outcomes

Using the need for THA as the endpoint event for the three patient groups. In this study, the criteria for recommending THA may include the following: (1). Persistent or increasing pain in the hip joint that affects the quality of daily life; (2). Imaging studies show significant collapse of the femoral head or joint surface irregularity, indicating progression to Ficat-Arlet stage III-IV of

Table 1 Baseline demographic characteristics of patients

	Control group (*n* = 20)	CD + BG group (*n* = 29)	CD + BG + PRP group (*n*=25)	*P* value
Age (years)	42.15 ± 11.59	44.66 ± 10.98	41.72 ± 11.48	0.593
Gender				0.976
Male	13	18	16	
Female	7	11	9	
BMI(kg/m^2)	22.10 ± 2.05	22.55 ± 2.49	22.08 ± 2.77	0.736
Etiology				0.494
Steroid	9	14	10	
Alcohol	4	5	8	
Traumatic	7	5		
Idiopathic	5	2		
Hip involved				0.754
Unilateral	18	24	21	
Bilateral	2	5	4	
Total number	22	34	29	
Ficat stage(hips)				0.883
Stage I	9	15	11	
Stage II	13	19	18	
JIC classification(hips)				0.987
Type A	3	3	2	
Type B	6	10	10	
Type C1	11	18	15	
Type C2	2	3	2	

Table 2 Comparison of THA incidence at end of follow-up

Group	Total number		Hip preserved		THA	
	Individuals(*n*)	Hip joints(hips)	Individuals(*n*, %)	Quantity(hips, %)	Individuals(*n*, %)	Quantity(hips, %)
Control group	20	22	6(30%)	7(31.82%)	14(70%)	15(68.18%)
CD + BG group	29	34	24(82.76%)	28(82.35%)	5(17.24%)	6(17.65%)
CD + BG + PRP group	25	29	22(88%)	26(89.66%)	3(12%)	3(10.34%)

avascular necrosis; (3). A significant reduction in hip joint range of motion and severe functional impairment that impacts normal walking and daily activities; (4). Symptoms have not shown significant improvement despite treatments such as CD, BG, and PRP therapy, with ongoing deterioration of the condition.At the final five-year follow-up, the proportion of patients in the control group who underwent THA was 68.18% (15/22). In contrast, the hip replacement rates for the CD + BG group and the CD + BG + PRP group were 17.65% (6/34) and 10.34% (3/29), respectively. There was no statistically significant difference between the CD + BG group and the CD + BG + PRP group ($P = 0.441$), while both groups showed a significant difference when compared to the control group (both $P < 0.001$) (Table 2). Due to the higher number of hips that underwent THA in the control group, subsequent comparisons focused on the hips in the CD + BG group and the CD + BG + PRP group that did not undergo THA.

To further explore the impact of PRP on delaying the time to THA treatment, our study conducted Kaplan-Meier survival analysis (Fig. 4). The green curve represents the proportion of hip joints in the CD + BG + PRP group that did not undergo THA, while the blue curve represents the proportion for the CD + BG group. The green curve consistently higher than the blue curve indicates that the CD + BG + PRP group has a lower rate of hip replacement as time progresses. This suggests that

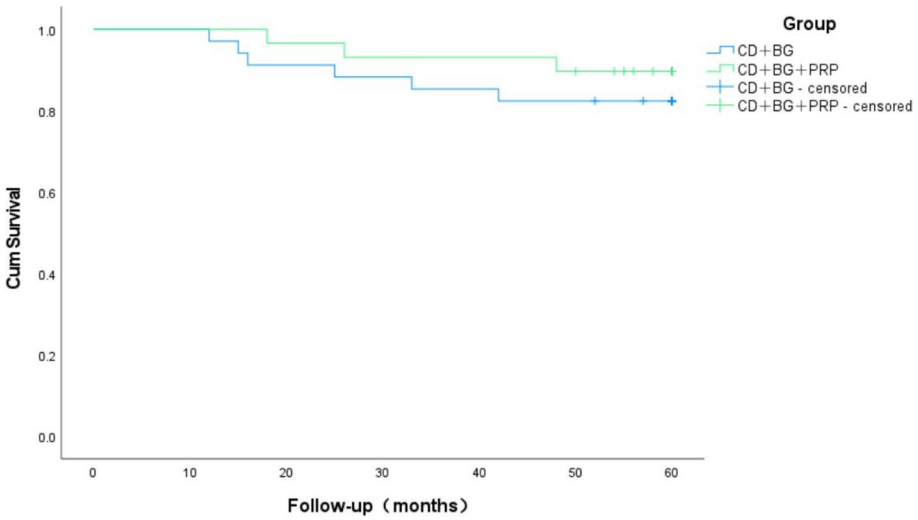

Fig. 4 Cumulative proportion of patients not accepting THA treatment during follow-up

Table 3 The Ficat stage distribution in patients not accepting THA at final follow-up

Group	Number of hip joints	Stage I	Stage II	Stage III	Stage IV	*P* value
CD + BG group	28	11 (39.29%)	7 (25%)	6 (21.43%)	4 (14.29)	0.038
CD + BG + PRPgroup	26	13 (50%)	10 (38.46%)	2 (7.69%)	1 (3.85%)	

Table 3 displays the number of hip joints in each Ficat stage among patients who did not undergo THA treatment at the end of follow-up. Since all included hip joints in this study were Ficat stages I-II, the hip joints in the table are categorized into two groups: one group for the total number of Ficat I-II stage hip joints, and the other for the total number of Ficat III-IV stage hip joints. We performed a 2 × 2 contingency chi-square test to compare the number of hip joints between the two groups, which showed a significant difference ($P = 0.038$)

PRP combined therapy may have a certain effect in delaying the time to THA treatment, but the difference between the two groups did not reach statistical significance (log-rank test, $P = 0.389$).

At final follow-up, the CD + BG + PRP group demonstrated a more significant advantage in delaying the progression of Ficat stages. The proportion of patients in stages I-II was 88.46% (23/26), higher than the CD + BG group at 64.29% (18/28), with a statistically significant difference ($P = 0.038$). Some patients in both groups progressed to Ficat stages III-IV but did not undergo THA treatment because post-surgical pain symptoms were alleviated, thereby delaying the need for THA (Table 3). The JIC classification distribution in patients not accepting THA at final follow-up is detailed in Table 4.

In terms of adverse events or complications, the CD + BG group experienced 1 case of postoperative infection, 1 case of lower limb deep vein thrombosis, and 8 cases of femoral head collapse (cumulative 6 unilateral

Table 4 The JIC classification distribution in patients not accepting THA at final follow-up

Group	Number of hip joints	Type A	Type B	Type C1	Type C2	*P* value
CD + BG group	28	4 (14.29%)	9 (32.14%)	11 (39.29%)	4 (14.29%)	0.029
CD + BG + PRP group	26	7 (26.92%)	15 (57.69%)	3 (11.54%)	1 (3.8%)	

Table 4 displays the number of hip joints in each JIC classification among patients who did not undergo THA treatment at the end of follow-up. The p-value of 0.027 can be obtained through the chi-square test

Table 5 Preoperative and postoperative functional outcomes

	CD + BG group	CD + BG + PRP group	*P* value
VAS Scores			
Preoperative	6.05 ± 1.20	5.84 ± 1.21	0.56
6 months postoperative	5.05 ± 1.36	4.11 ± 1.10	0.04
1 year postoperative	3.81 ± 1.17	2.42 ± 0.96	< 0.001
Final follow-up	3.38 ± 1.36	1.74 ± 0.73	< 0.001
HHS			
Preoperative	66.95 ± 7.33	65.42 ± 6.97	0.50
6 months postoperative	69.14 ± 10.79	75.95 ± 9.17	0.04
1 year postoperative	75.24 ± 10.69	84.74 ± 8.44	0.004
Final follow-up	80.14 ± 11.47	89.47 ± 8.72	0.01

and 2 bilateral), with a total complication rate of 41.67% (10/24). The PRP combined group experienced 1 case of postoperative infection, 1 case of rejection reaction, and 3 cases of femoral head collapse (all unilateral), with a total complication rate of 22.73% (5/22). Except for femoral head collapse, all other adverse reactions resolved within 1 week post-treatment. There was no statistically significant difference in the overall complication rates between the two groups ($P = 0.17$).

Functional outcomes

We analyzed patients in the CD + BG group and the PRP combined group who did not undergo THA at the end of follow-up. We compared the treatment outcomes between the two groups using VAS scores and HHS scores at preoperative, 6 months postoperative, 12 months postoperative, and final follow-up assessments. Patients in the PRP group showed superior VAS and Harris scores compared to the CD + BG group at different postoperative time points ($p < 0.05$) (Table 5).

Discussion

Despite CD being a common treatment for early-stage ANFH, traditional CD has several limitations. These include insufficient debridement of the necrotic area, lack of effective mechanical support in the decompressed region, and uncertainty regarding postoperative recovery outcomes [17, 18]. Similarly, Andronic et al. [19] found that CD provides only short-term clinical improvement and partial or complete pain relief, which may be related to temporarily reduced weight-bearing during the rehabilitation phase. Given these limitations, there is a need to explore more comprehensive and effective treatment options in clinical practice.

Given the regenerative properties of PRP, we introduced PRP injections following CD surgery to further enhance the effectiveness of the surgical treatment. Theoretically, the combination of CD and PRP for the treatment of early-stage ANFH is considered an ideal therapeutic approach. The advantage of this combined treatment lies in the integrated use of two different but complementary mechanisms. Firstly, CD improves the local environment by mechanically reducing pressure within the femoral head, thereby enhancing blood circulation and nutrient supply, which creates a favorable environment for bone tissue growth [4, 20]. Secondly, PRP, through the release of biological factors, can effectively promote the process of bone tissue regeneration [21, 22]. By combining these two mechanisms, the treatment not only improves the local environment from a mechanical perspective but also promotes tissue regeneration through biological factors, resulting in a more comprehensive and effective therapeutic outcome. Many studies have found that PRP has a positive therapeutic effect on early-stage ANFH, particularly in reducing pain and improving hip joint function. Xian et al. [23] in their study employed CD, autologous bone grafting combined with PRP treatment for 24 cases of traumatic femoral head avascular necrosis, and found through a 3-year follow-up that the treatment group using PRP demonstrated superior outcomes in terms of HHS, hip preservation success rate, and VAS pain score. Martin et al. [24] used concentrated bone marrow aspirate and PRP during minimally invasive decompression of the femoral head for osteonecrosis. With an average follow-up of 17 months, they ultimately found that significant relief of pain symptoms was achieved in 60 patients (86%), while 16 hips (21%) showed progression according to Ficat staging. The findings of this study are consistent with those of most existing research. It is worth noting that in this study, the comparison of VAS and HHS was based on patients who had not yet undergone THA at the end of the follow-up. This approach effectively excludes potential confounding factors introduced by the receipt of THA, allowing for a more accurate assessment of the effects of CD, BG, and PRP treatment for early-stage ANFH. However, some studies have reached contrary conclusions. For instance, Hernandez et al. [25] conducted a study using CD combined with implantation of autologous bone marrow concentrate and tricalcium phosphate. The results showed improvements in modified HHS, but the combined approach did not halt the radiographic progression of early hip osteonecrosis. The variability in this treatment approach is primarily attributed to the diversity inherent in the PRP combined with CD procedure, particularly in the differences in PRP preparation methods and surgical techniques of CD. Additionally, ongoing risk factors

among patients, such as corticosteroid use and alcohol consumption, further complicate the research outcomes. Moreover, variations in individual biological responses and postoperative rehabilitation compliance pose significant challenges to the evaluation and comparison of the treatment's effectiveness. Collectively, these factors may have a considerable impact on the overall assessment of this treatment strategy.Therefore, more rigorous clinical studies are needed to validate its effectiveness and reliability in different patient populations.

The results of this study demonstrate that patients in both surgical treatment groups showed higher VAS scores and HHS at different postoperative time points compared to pre-treatment, confirming the feasibility of both surgical approaches in treating early-stage ANFH. However, notably, patients in the PRP combined group consistently exhibited higher VAS scores and HHS at various postoperative time points compared to those in the CD + BG group and the control group. This may be related to the complementary mechanisms produced by the combination therapy. Kaplan-Meier survival analysis revealed that, over time, the cumulative proportion of patients in the PRP combination group who did not undergo THA was higher during the follow-up period. The application of PRP may promote the integration of grafted bone and the formation of new bone in the necrotic area of the femoral head, thereby effectively reducing the risk of collapse in the necrotic region and ultimately decreasing the need for THA.However, the difference between the groups did not reach statistical significance (log-rank test, $P=0.389$). Possible reasons include: Firstly, the small sample size may limit the power of statistical tests. Secondly, there could be individual variability in treatment outcomes, with PRP treatment responses differing significantly among patients. Such variability may impact the overall assessment of treatment efficacy and lead to uneven treatment effects. Regarding the delay in Ficat stage progression, the final proportion of patients in stages I-II was 88.46% in the PRP combined group, which was higher than the 64.29% in the CD + BG group ($P=0.038$).Furthermore, the comparison of JIC classification also revealed statistically significant differences($P=0.029$).In terms of adverse events or complications, there was no statistically significant difference in the overall complication rates between the two groups ($P=0.17$).

This study has several limitations. Firstly, this study employed a retrospective analysis method and was non-randomized, meaning that patient allocation was based on specific clinical decisions rather than randomization. This study design may introduce selection bias, which could affect the generalizability and reliability of the results. To address this limitation, future research should consider using a prospective randomized controlled trial (RCT) design. RCT can randomly assign patients to different treatment groups, thereby reducing selection bias and providing higher-quality evidence. Secondly, not all postoperative patients underwent MRI examinations in this study, which may impact the accuracy of Ficat staging. MRI is the gold standard for assessing the degree of early femoral head necrosis, and the lack of systematic MRI examinations may lead to inaccurate assessments of disease progression, thereby affecting the evaluation of treatment outcomes. Future studies should ensure standardized MRI examinations for all patients to improve the accuracy of Ficat staging and the evaluation of treatment efficacy. Lastly, the sample size in this study was relatively small, which may affect the statistical significance of the results and the generalizability of the conclusions. A small sample size may lead to result instability and potential chance findings. Future research should involve larger sample sizes in a prospective randomized controlled trial to enhance the reliability and generalizability of the conclusions.

In addition, future studies should adopt uniform treatment standards, including standardized PRP preparation methods and marrow CD surgical techniques, to improve the consistency of treatment protocols and the comparability of results. It is also recommended to consider individual differences as research variables and conduct stratified analyses to understand the responses of different patient groups to the treatment. By implementing these improvements, future research will be able to more comprehensively validate the efficacy of PRP combined with CD and BG, and provide stronger evidence for the treatment of early-stage ANFH.

Conclusion

PRP combined with CD and BG can significantly alleviate patients' pain symptoms and promote recovery of hip joint function in the short term. This combined approach is a safe and effective treatment option, demonstrating effectiveness in managing early-stage ANFH.

Abbreviations

PRP	platelet-rich plasma
CD	core decompression
BG	bone grafting
ANFH	avascular necrosis of the femoral head

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Authors' contributions

Z-CC designed the study and interpreted the data. HW, X-TZ and H-FL collected the data. H-RL and MS analyzed the data. R-DX and S-YD wrote the paper. All authors have read and agreed to the published version of the manuscript.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available due to limitations of ethical approval involving the patient data and anonymity but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study has obtained approval from the Medical Ethics Committee of the Central Hospital Afliated to Shenyang Medical College (Approval No: 2015024, approval date: 20 March 2015). All patients provided written informed consent.

Consent for publication
Informed consent for publication has been obtained from all participants.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthopedics Surgery, Central Hospital Affiliated to Shenyang Medical College, 5 Nanqi West Road, Shenyang, Liaoning 110024, China. [2]Liaoning Province Key Laboratory for Phenomics of Human Ethnic Specificity and Critical Illness, Shenyang Key Laboratory for Phenomics, Shenyang Medical College, Shenyang, Liaoning, China.

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