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Efficacy of small-diameter core decompression with platelet-rich plasma in early osteonecrosis of the femoral head: a retrospective study

Haiwei Tang[1†], Yahao Lai[1†], Enze Zhao[1], Kai Zhou[1], Gang Chen[1*] and Zongke Zhou[1*]

Abstract

Background Osteonecrosis of the femoral head (ONFH) is a challenging condition, primarily affecting young and middle-aged individuals, which results in hip dysfunction and, ultimately, femoral head collapse. However, the comparative effectiveness of joint-preserving procedures, particularly in the early stages of ONFH (ARCO stage I or II), remains inconclusive. This study aims to evaluate the efficacy of a novel technique called small-diameter core decompression (CD) combined with platelet-rich plasma (PRP), for the treatment of early-stage ONFH.

Methods Clinical data of 40 patients (51 hips) with pre-collapse stage ONFH were retrospectively analyzed. Nineteen patients (23 hips) underwent small-diameter CD + PRP (group A) and 21 patients (28 hips) received conventional CD (group B) and follow-up was conducted every 3 months. Hip radiographs (X-rays and MRI) were evaluated using various ONFH staging systems (Preserved Angles, ARCO, JIC, and CHFJ stages). X-rays were performed at each follow-up to assess femoral head collapse and the rate of total hip arthroplasty (THA). Additionally, the Visual Analogue Scale (VAS), Harris Hip Score (HHS), Charnley score, SF-36, Athens Insomnia Scale (AIS), and State-Trait Anxiety Inventory (STAI) were used to evaluate hip pain, function, quality of life, and psychological status. These assessments were conducted both preoperatively and at each follow-up visit.

Results The mean follow-up duration in Group A was 11.57 months, with a femoral head survivorship of 82.61%. One hip underwent THA 14 months after the novel procedure. In Group B, with an average follow-up period of 11.32 months, femoral head survivorship was 60.71% ($p = 0.111$), and 2 hips required THA ($p = 0.999$). At the final follow-up, the VAS, stiffness, HHS and Charnley scores of Group A showed significant improvements compared to those in Group B. Quality of life, anxiety and insomnia were also significantly improved in the Group A compared to Group B.

Conclusion The application of PRP following CD results in significant pain relief, improved short-term functional outcomes, and enhanced quality of life compared to CD alone. However, whether it hinders disease progression in early ONFH and reduces the conversion rate to THA and femoral head collapse remains uncertain. Further research with larger sample sizes and extended follow-up is needed to validate these preliminary findings.

†Haiwei Tang and Yahao Lai contributed equally to this work.

*Correspondence:
Gang Chen
drchengang@hotmail.com
Zongke Zhou
zhouzongke@scu.edu.cn
Full list of author information is available at the end of the article

Keywords Osteonecrosis of the femoral head, Small-diameter drilling core decompression, Platelet-rich plasma

Introduction

Osteonecrosis of the femoral head (ONFH), also known as avascular necrosis (AVN) of the femoral head or ischemic necrosis, is characterized by local death of osteocytes and bone marrow components and leads to hip joint pain and dysfunction [1, 2]. As a prevalent and refractory orthopedics condition, ONFH imposes a significant economic burden globally [3–5]. Typically affecting males between the ages of 30 and 50, the disease progresses through localized necrosis and subsequent repair, resulting in structural changes to the femoral head that compromise its weight-bearing capacity and ultimately lead to collapse [6, 7]. Once collapse occurs, the efficacy of treatment diminishes, often necessitating total hip arthroplasty (THA) to alleviate pain and restore function [8]. Consequently, early diagnosis and intervention are crucial to preventing femoral head collapse and preserving hip function. The primary objectives in early-stage ONFH (ARCO stage I or II) are to relieve pain and slow disease progression. However, treatment options for ONFH remain varied and controversial. Conservative treatments include pharmacological approaches aimed at increasing calcium absorption, preventing bone resorption, anticoagulation, and vasodilation. Additionally, extracorporeal shock wave and hyperbaric oxygen therapy frequently employed for early-stage ONFH with small lesions frequently employed for early-stage ONFH with small lesions [9–11]. In contrast, surgical intervention has been extensively documented to impede disease progression [12–14]. Research indicates that femoral head collapse may occur within 1 to 4 years in approximately 80% of patients who do not undergo surgery in the early stages [15]. In patients undergoing hip preservation surgery, the femoral head survival rate significantly improves [9]. One study reported a survival rate of 93 out of 120 hips after five years of follow-up following multiple drilling [16]. Similarly, transtrochanteric rotational osteotomy achieved an 88% survival rate over four years for 113 hips [17]. Furthermore, for individuals with laterally located necrosis, which presents a high risk of collapse, early surgery to preserve the hip is recommended [8, 12]. In addition to delaying disease progression, surgical procedures can also relieve pain, enhance hip function and improve quality of life in patients with symptomatic early-stage ONFH [18, 19].

Core decompression (CD) is currently the most commonly utilized surgical procedure for hip preservation. The primary rationale is to alleviate intramedullary pressure and enhance blood circulation, thereby promoting revascularization and osteogenesis at the affected site, and has already demonstrated a certain level of efficacy. [20, 21]. It has been employed for more than 50 years and has proven to be more effective than conservative treatments [22, 23]. However, its long-term outcomes require further verified. In an early study involving 1206 hips CD patients, Mont et al. found that the necrosis continued to progress in 36% of the cases following CD alone [22]. A 2019 meta-analysis indicated that the overall success rate of CD was approximately 65%, and argued that mere CD is insufficient to halt the progression of ONFH [13]. Additionally, traditional CD has some inherent flaws. For instance, due to the limitation of a single channel, CD often results in an inadequate decompression range, potentially leading to surgical failure [24]. Moreover, traditional CD requires an entry hole in the lateral cortex of the femur, making it invasive for the patient and potentially increasing the risk of subtrochanteric fractures [25–27]. After decompression, the decompression channel lacks bony structural support, which may result in persistent pain or even premature collapse.

To improve the results, small-diameter CD is utilized to minimize invasiveness and achieve a more comprehensive decompression range. Additionally, regenerative medicine has garnered significant interest among researchers. Through the original channel of CD, various regenerative agents, including bone marrow aspirate concentrate (BMAC) and bone mesenchymal stem cells (BMSCs), are injected into the lesion site to improve bone regeneration and offer support after decompression, which has been report to show certain therapeutic effect [28–30]. However, BMAC is invasive for patients and its operation and preparation process are complex. Moreover, its quality is easily influenced by the donor's age and the extraction sites [31]. These drawbacks limit its widespread application. Platelet-Rich Plasma (PRP), an autologous derivative of whole blood generated by centrifugation, releases various cytokines and growth factors that promote cell proliferation and angiogenesis, enhancing the natural healing process upon activation. This may potentially improve the efficacy of CD [32]. Platelet-derived growth factor (PDGF), transforming growth factor-b (TGF-b), insulin-like growth factor (IGF), vascular endothelial growth factor (VEGF), hepatocyte growth factor, endothelial growth factor, and platelet factor-4 are among the bioactive substances derived from platelets that regulate cellular processes, like mitogenesis, chemotaxis, angiogenesis, differentiation, and metabolism, to improve tissue regeneration [33, 34]. Furthermore, research has demonstrated that in the presence of bone morphogenetic proteins (BMP), such as

BMP-2 or BMP-7, PRP can enhance the osteogenic differentiation of myoblasts and osteoblasts, thereby facilitating bone healing [35]. Compared with BMAC, PRP offers advantages of self-sufficiency, easier extraction and reduced trauma, making it widely applied in the treatment of chronic injury diseases [34, 36]. However, only few clinical studies have been published on the use of PRP in in ONFH, and no definitive conclusions can be drawn regarding the therapeutic effect of CD combined with PRP [37–43].

Therefore, the present study aimed to evaluate whether small-diameter CD combined with PRP could delay the progression of early-stage osteonecrosis of the femoral head. The primary objective included femoral head collapse rate, THA conversion rate, hip function and pain severity. Secondary observations included patients' quality of life, sleep, and anxiety. In addition, multiple small-diameter core decompression, a novel approach, were employed in this study to reduce invasiveness, achieve a more complete decompression range, and lower the risk of postoperative iatrogenic collapse [44–46]. We hypothesized that applying PRP after decompression would alleviate pain, improve functional outcome, and slow the progression of ONFH, thereby avoiding or delaying the need for THA.

Patients and methods

We analyzed a consecutive series of patients at least 18 years old but no older than 80 years who underwent multiple small-diameter drilling CD + PRP (group A) or traditional CD (group B) at our center between January 2022 and January 2024, who was diagnosed with early ONFH (ARCO stage I or II). The study was approved by the Ethics Committee on Biomedical Research of our medical center (Approval 2024–348) and designed in accordance with the Declaration of Helsinki, which waived the need for written informed consent because patients or their legal guardians, at the time of admission, signed written consent for patients' anonymized data to be analyzed and published for research purposes.

Inclusion criteria were: 1) patients with ARCO stage I or II of ONFH; 2) treatment with CD or multiple small-diameter drilling CD combined with PRP in our hospital; 3) age ranged from 18 to 80 years; 4) those willing and able to return for follow-up during at least 6 months after procedure. Exclusion criteria were: 1) participants with collapsed stage ONFH; 2) had undergone hip preservation surgery other than CD; 3) bone marrow suppression, comorbidities such as pregnancy, cancer, and immunosuppression; 4) ONFH due to joint inflammatory disease or trauma. Patient demographic data were recorded and all demographic data of the patients are included in Table 1. All patients underwent X-ray and MRI

Table 1 Characteristic data of the patients

Characteristics	Group A	Group B	*p*
Patients (Female/male)	19 (2/17)	21 (4/17)	0.664
Hips	23	28	-
Side (R/L)	13/10	14/14	0.780
Age (years)	46.58 (7.46)	45.19 (10.61)	0.638
BMI (kg/m^2)	24.19 (2.25)	23.96 (2.32)	0.752
Follow-up (months)	11.57 (4.66)	11.32 (5.56)	0.868
Etiology of necrosis			0.114
Alcohol abuse	6 (26.09%)	14 (50.00%)	
Corticosteroid use	3 (13.04%)	5 (17.86%)	
Idiopathic	14 (60.87%)	9 (32.14%)	
ARCO			0.999
Type-I	3 (13.04%)	4 (14.29%)	
Type-II	20 (86.96%)	24 (85.74%)	
2021ARCO			0.787
Type-1	1 (4.35%)	2 (7.14%)	
Type-2	6 (26.09%)	9 (32.14%)	
Type-3	16 (69.57%)	17 (60.71%)	
JIC			0.787
Type-A	1 (4.35%)	2 (7.14%)	
Type-B	/	/	
Type-C1	6 (26.09%)	9 (32.14%)	
Type-C2	16 (69.57%)	17 (60.71%)	
CHFJ			0.645
Type-C	1 (4.35%)	2 (7.14%)	
Type-L1	19 (82.61%)	20 (71.43%)	
Type-L2	/	/	
Type-L3	3 (13.04%)	6 (21.43%)	
LPA	52.56 (37.87)	49.23 (24.56)	0.711
VAS (move)	4.09 (0.90)	4.05 (0.86)	0.825
VAS (rest)	2.26 (0.75)	2.14 (0.96)	0.584
VAS (sleep)	2.00 (1.24)	2.10 (0.89)	0.629
Stiffness (wake up)	2.32 (0.89)	2.43 (1.12)	0.662
Stiffness (rest)	1.54 (1.22)	1.67 (0.73)	0.436
HHS	65.88 (8.01)	66.26 (7.36)	0.861
Charnley	12.69 (1.67)	12.81 (1.47)	0.713
SF-36			
PF	50.00 (12.85)	52.38 (14.11)	0.448
RP	40.91 (32.16)	42.86 (25.76)	0.828
BP	55.00 (16.80)	56.24 (13.44)	0.677
GH	60.27 (18.33)	62.43 (13.71)	0.479
VT	78.64 (7.78)	79.52 (8.79)	0.650
SF	60.61 (19.50)	62.04 (18.57)	0.790
RE	72.73 (29.14)	71.97 (18.14)	0.850
MH	67.64 (20.90)	66.48 (14.97)	0.725
HT	29.09 (10.44)	30.24 (11.45)	0.651
PCS	51.55 (17.92)	53.48 (19.35)	0.746
MCS	69.91 (18.23)	70.00 (16.37)	0.987
AIS	3.09 (2.43)	2.71 (1.76)	0.341

Table 1 (continued)

Characteristics	Group A	Group B	*p*
STAI			
S-AI	36.27 (6.59)	34.10 (6.34)	0.132
T-AI	32.27 (7.88)	31.62 (4.92)	0.551

BMI Body mass index, *VAS* Visual Analogue Scale, *HHS* Harris Hip Score, *SF-36* 36-Item Short Form Survey, *PF* Physical Functioning, *RP* Role-Physical, *BP* Bodily Pain, *GH* General health, *VT* validity, *SF* Social Function, *RE* Role-emotional, *MH* Mental Health, *PCS* Physical Component Summary, *MCS* Mental Component Summary, *AIS* Athens Insomnia Scale, *STAI* State-trait Anxiety Inventory, *S-AI* State Anxiety Inventory, *T-AI* Trait Anxiety Inventory

examinations preoperatively. Distinct staging criteria were employed for preoperative assessment based on the necrotic area and location of necrotic lesions observed on the coronal plane of the MRI (2019ARCO, 2021ARCO [47], JIC and CHFJ stage) by two specialists. If the opinions of two experts are different, we will intervene in the third expert's staging opinion, so as to complete the preoperative staging of patients. Moreover, we measured the Lateral Preserved Angle (LPA) of each hip on the X-ray, which weas defined by two lines extending from the center of the femoral head with the first passing through the lateral boundary of the necrotic lesion and the second passing through the point on the junction between the femoral head and the neck, and was considered as a simple method to predict collapse in early ONFH [8]. The details of staging systems and progression status were showed in Table 1. Before surgery and at each follow-up we used Visual Analogue Scale (VAS), Harris Hip score (HHS), Charnley score, SF-36, Athens Insomnia Scale (AIS) [48], and State-trait anxiety inventory (STAI) [49] to assess hip pain, function, quality of life, and psychological status of patients.

Procedure

Thirty-five ml blood was taken from the antecubital vein using an 21G needle. Afterwards, 5 ml of acid citrate dextrose solution containing 2.20-g sodium citrate dehydrate and 0.73-g sodium citrate anhydrous plus 2.45-g dextrose monohydrate was added as an anticoagulant. The PRP processing was done using a registered standard kit (PRP kits, WEGO Medical Polymer Co., Ltd., Shandong, China). Samples were put into four test tubes and centrifuged for 12 min at 1600 rpm (RPM) equal to 400 g based on relative centrifugal force in first stage as light spin, which resulted in three different layers. The lowest layer was RBC precipitate, the middle layer was white blood cell (WBC) s, and the upper layer was plasma. The plasma containing PLT, together with the buffy coat layer was slowly aspirated and transferred to two test tubes in order to be centrifuged in second stage at 3500 RPM (= 1900 g) for 7 min as heavy spin. In the final stage, after aspiration and disposal of PLT poor plasma, a sample of PRP sent for PLT and WBC counts, 5–6 ml of liquid PRP (around 3 ml in each tube) with at least 4 times of whole blood PLT count was approved for injection.

All the patients were operated by the same senior doctor in our hospital. In Group A, the patient laid flat with mild abduction and internal rotation of the affected limb and flexion, abduction and external rotation of the contralateral lower limb. After routine disinfection, a small incision (1cm) was made in front of the top of the greater trochanter of the hip on the affected side. After entering the joint, the arthroscopic channel was established by expanding the cannula step by step in order to more accurate operation under direct view. Combined with the results of preoperative X-ray and MRI, the location of the necrotic area was determined. A Kirchner needle with a diameter of 1.5mm (Tianjin Yutong medical equipment factory, Tianjin, China) was used and fan decompression was performed from the anterolateral part of the head and neck junction to the necrotic area for less invasion under the supervision of arthroscopy (arthroscopy kits, WEGO Medical Polymer Co., Ltd., Shandong, China), using multi-angle decompression to scrape away as much necrotic tissue as possible and release intramedullary pressure. After decompression, 5ml autologous PRP was injected along the decompression channel to enhance the ability of bone regeneration.

In Group B, under C-arm X-ray guidance combined with preoperative X-ray and MRI, the necrotic area was precisely localized and the drilling direction, position, and depth were meticulously determined. From 2 cm below the greater trochanter of the femur, an 8 mm diameter Mischelle trephine (WEGO Medical Polymer Co., Ltd., Shandong, China) was then drilling into the osteonecrotic region for decompression (Fig. 1).

After surgery, isometric exercises were performed immediately. Then, as soon as the pain is tolerable, both passive and active hip movements are performed. On the second day following surgery, all patients began using crutches to walk; first non-weight-bearing and then gradually fully weight-bearing after 4–6 weeks. All patients were first followed up 1 month after surgery and then every 3 months after surgery. MRI was performed during at least 6 months of follow-up and to reassess whether ONFH progress. The endpoint was defined as underwent THA or progressed to collapse. The results were then statistically analyzed.

Statistical analysis

SPSS (version 29.0.1.0) was used to analyze the data. All quantitative variables were estimated using measures of central location (mean and median) and measures of

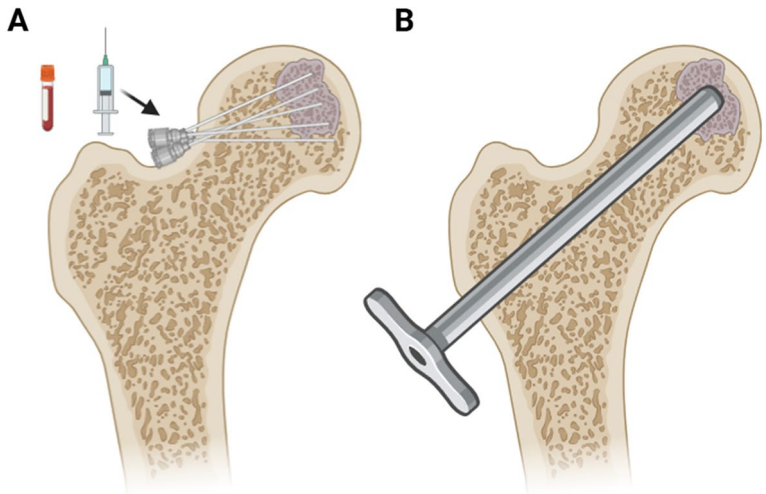

Fig. 1 **A** Schematic diagram of small-diameter CD combined with PRP: After 1.5 mm Kirchner needle fan decompression, 5 ml PRP was injected along the decompression channel; **B** Schematic diagram of traditional CD: From 2 cm below the greater trochanter of the femur, an 8 mm diameter Mischelle trephine was drilling into the osteonecrotic region for decompression. Created by Bioreder

dispersion (standard deviation [50] and standard error). Normality of data was checked by measures of skewness and Kolmogorov–Smirnov tests of normality. For normally distributed data, means were compared using Student t test for 2 groups. For more than 2 groups, analysis of variance was applied. For skewed data, Mann–Whitney test was applied. Intergroup differences in categorical variables were assessed for significance using the Pearson's chi-squared test. All statistical tests were 2-sided and performed at a significance level of $\alpha = 0.05$.

Results

There were 17 male and 2 female (23 hips) in Group A, and 17 male and 4 female (28 hips) in Group B ($p = 0.664$). An average age of the two groups were 46.58 (7.46) and 45.19 (10.61) respectively ($p = 0.638$). A total of 20 patients presented with a history of alcoholism, 8 patients had previously utilized cortisol, and 23 patients were classified as idiopathic. No statistically significant differences in etiology were observed between the two groups ($p = 0.114$). Furthermore, no significant differences in preoperative stage, hip function score, pain and SF-36 score between the two groups. The mean follow-up of the patients was 11.57 months in Group A and 11.32 months in Group B (Table 1). No mortality occurred, either in the postoperative period or during follow-up. No patient was lost to follow-up for any reason.

Radiologic result

In Group A, with a mean follow-up time of 11.57 months, 4 out of 23 hips collapse occurred at 6, 9, 12 and 14 months postoperatively, respectively. In the remaining 19 hips, no significant signs of disease progression on imaging, with the longest follow-up period was 14 months. Whereas in Group B, 11 hips progressed to collapse in the last follow-up ($p = 0.111$). None of the hip operated at stage I showed progression. Among the recognized high-risk types of collapse, such as 2021ARCO type 3 and JIC Type C2, 3 hips in group A and 8 hips in group B had collapsed at the last follow-up, but the difference was not statistically significant ($p = 0.141$). One hip underwent THA at 14 months in Group A and 2 hips in Group B underwent THA at 8 months and 18 months, respectively ($p = 0.999$). At the final follow-up, the mean LPA increased from 50.00 (37.16) to 50.57 (35.87) in Group A. In Group B the mean LPA decreased from 44.46 (20.62) to 40.47 (19.43). On comparing these two groups, there was no statistically significant difference in LPA ($p = 0.212$) (Table 2) (Fig. 2 and Fig. 3).

Clinical results

In terms of hip pain and functional scores, comparison of mean preoperative pain score, stiffness score and HHS between these two groups showed no statistically significant difference ($p > 0.05$). At the 6-month post-operation and final follow-up, VAS scores in Group A were significantly lower than those observed in Group B, with values of 2.05 (0.74) and 1.81 (0.51) for Group A compared to 2.57 (0.68) and 2.42 (0.72) for Group B ($p < 0.05$), respectively. This disparity was also significant when resting or sleeping at the last follow-up ($p < 0.05$). Similarity, there was a significant improvement in hip stiffness when, at the final follow-up, with

Table 2 Different stage of hips and progression in Group A and Group B

Classification system	Group A N (%) Postoperation 3m	Group B N (%) Postoperation 3m	*p*	Group A N (%) Postoperation 6m	Group B N (%) Postoperation 6m	*p*	Group A N (%) Last Follow-up	Group B N (%) Last Follow-up	*p*
Progress to collapse									
ARCO									
Type-I	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999
Type-II	0 (0)	2 (8.33)	0.493	1 (5.00)	5 (20.83)	0.198	4 (20.00)	11 (45.83)	0.111
2021ARCO									
Type-1	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999
Type-2	0 (0)	0 (0)	0.999	0 (0)	2 (22.22)	0.486	1 (16.67)	3 (33.33)	0.604
Type-3	0 (0)	2 (11.76)	0.485	1 (6.25)	3 (17.64)	0.601	3 (18.75)	8 (47.06)	0.141
JIC									
Type-A	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999
Type-B	/	/	/	/	/	/	/	/	/
Type-C1	0 (0)	0 (0)	0.999	0 (0)	2 (22.22)	0.486	1 (16.67)	3 (33.33)	0.604
Type-C2	0 (0)	2 (11.76)	0.485	1 (6.25)	3 (17.64)	0.601	3 (18.75)	8 (47.06)	0.141
CHFJ									
Type-C	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999
Type-L1	0 (0)	0 (0)	0.999	0 (0)	3 (15.00)	0.231	3 (15.79)	7 (35.00)	0.273
Type-L2	/	/	/	/	/	/	/	/	/
Type-L3	0 (0)	2 (33.33)	0.500	1 (33.33)	2 (33.33)	0.999	1 (33.33)	4 (66.67)	0.524
LPA	52.33 (37.34)	48.87 (25.42)	0.701	51.97 (38.72)	45.37 (21.78)	0.452	50.57 (35.87)	40.47 (19.43)	0.212
THA conversion rate	0 (0)	0 (0)	0.999	0 (0)	0 (0)	0.999	1 (4.35)	2 (7.14)	0.999

ARCO Association Research Circulation Osseous, *JIC* Japanese Investigation Committee, *CHFJ* China-Japan Friendship Hospital

values of 0.45 (0.67) and for Group A compared to 0.88 (0.58) for Group B ($p=0.020$), respectively. Regarding the HHS score, Group A demonstrated a significantly higher score compared to Group B at every postoperative follow-up. The scores recorded were 82.84 (11.36) and 76.17 (9.56) at 3 months follow-up ($p=0.042$), 85.88 (9.37) and 78.04 (5.14) at 6 months follow-up ($p=0.001$), and 87.76 (10.53) and 79.46 (7.13) at the last follow-up assessment ($p=0.002$). However, the Charnley score exhibited a consistent trend with HHS score only at 6 months follow-up [51] (Fig. 4 and Fig. 5).

In secondary outcomes, the SF-36 revealed statistically significant improvements in 6 of its 9 aspects (PF, BP, GH, SF, MH, HT) at 6 months post-operation and 5 of 9 aspects (BP, GH, SF, MH, HT) at the last follow-up. However, the Physical Component Summary (PCS) demonstrated statistically significant differences solely at the final follow-up, with values of 72.01 (11.47) compared to 64.99 (12.23) ($p=0.047$). In contrast, the Mental Component Summary (MCS) did not exhibit substantial difference at the last follow-up. During anxiety assessments, the S-AI and T-AI scores of Group A were significantly superior to those of Group B at the time point of our follow-up assessment. Out of all the aforementioned scale scores, only RE in the two groups does not meet the minimum clinically important difference (MCID) [52, 53], which means these two groups demonstrated improvements in pain, hip function, quality of life, and psychological status. And the PRP group showed greater effectiveness in these aspects (Table 3) (Fig. 6).

Discussion

ONFH is a refractory disease that currently lacks effective joint-preserving procedure. Over the past 30 years, core decompression (CD) has been employed in the early stages (stages I and II) of ONFH to prevent subsequent collapse of the necrotic femoral head. By drilling to reduce the pressure in the femoral head, it can not only alleviate pain but also enhance the blood supply to the necrotic site and enable the dead bone to communicate with the outside world, thereby facilitating the repair and regeneration of bone tissue [54]. However, whether it truly delay the nature course of ONFH remains a subject of long-standing debate. Recently, researchers have sought to integrate various regenerative agents with CD

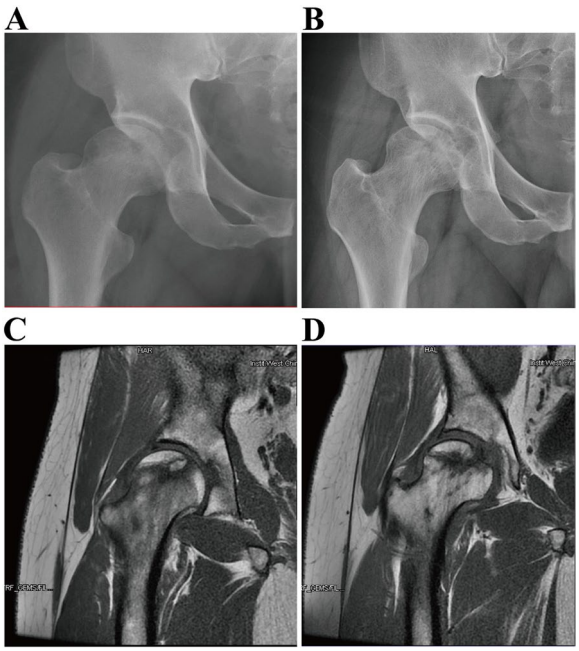

Fig. 2 **A**, **C** Preoperative hip X-ray and MRI indicated ARCO II stage of femoral head necrosis. **B**, **D** X rays and magnetic resonance imaging at final follow-up of 12 months showing no significant progression of ONFH

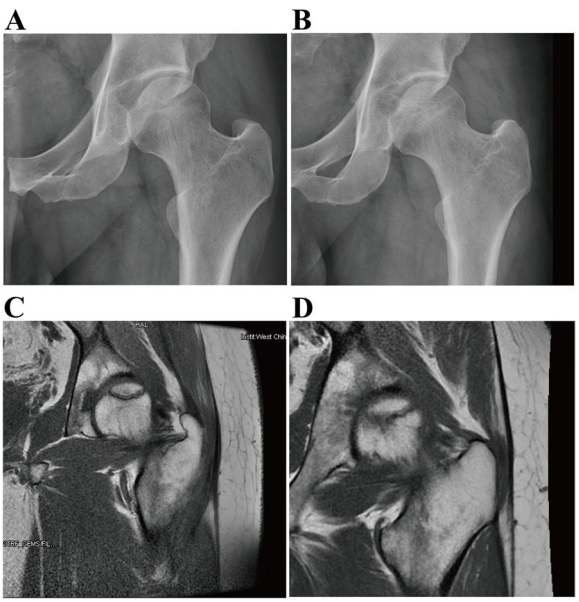

Fig. 3 **A**, **C** Preoperative hip X-ray and MRI indicated ARCO II stage of femoral head necrosis. **B**, **D** X rays and magnetic resonance imaging at final follow-up of 6 months showing no significant progression of ONFH

to enhance its efficacy. This study demonstrated limited evidence that CD combined with PRP could alter the natural course of ONFH, though it showed improved efficacy in pain relief, improved hip function and quality of life.

Traditional CD is performed from below the greater trochanter of the affected hip, with decompression achieved through puncture using a long needle. It not only relieves pressure within the femoral head but also removes necrotic tissue. However, its ability to slow disease progression remains controversial. Hua et al. analyzed 1,379 hip joints treated solely with CD and found an overall success rate of 65%, with significant variations across different stages [13]. Zhu et al. analyzed 768 patients who underwent CD alone, finding a disease progression rate of 36% [55]. Additionally, the relatively large diameter of the Kirschner needle used may increase the risk of subtrochanteric femoral fractures after surgery [26, 27, 56]. Smith et al. reported that the femoral neck fracture rate during surgery and the early postoperative period was as high as 13% [57]. Therefore, traditional CD techniques require further refinement.

One improved technique involves using small-diameter CD to reduce the fracture rate and expand the range of decompression [45]. Brown et al. demonstrated that small-diameter CD can improve femoral neck stability compared to single large-diameter CD procedures [44]. Mont et al. used 3 mm diameter fine needles for decompression in 45 hips, and after a mean follow-up period of two years, 32 hips (71%) showed good to excellent HHS results [58]. However, whether it truly alters the natural course of ONFH remains debate [13, 59, 60]. Mohanty et al. compared the efficacy of small diameter CD with autologous fibula grafting, and found that the three-year survival rate for the former was significantly lower than that for the latter [24]. To further enhance the femoral head survival rate in patients with, regenerative agents or cell therapies such as BMAC and BMSCs have garnered substantial attention. Li et al. analyzed 11 RCTS and 7 retrospective studies with a total of 1,257 hip joints, finding that stem cell therapy combined with CD was more effective in preventing collapse and radiological progression [61]. Piuzzi et al. reviewed the literatures to evaluate the benefits of cell-based therapy, concluding that suchcell therapies improves clinical outcomes [62]. However, due to the diversity of regenerative agents and the heterogeneity of studies necessitate further verification of their efficacy. Wang et al. performed a network meta-analysis to evaluate the efficacy of 6 different regenerative therapies for ONFH, finding that only BMAC and BMSCs delayed the disease's natural course [29]. Nevertheless, the varying therapeutic efficacy, optimal injection concentration, and the effectivenessof allogeneic MSCs

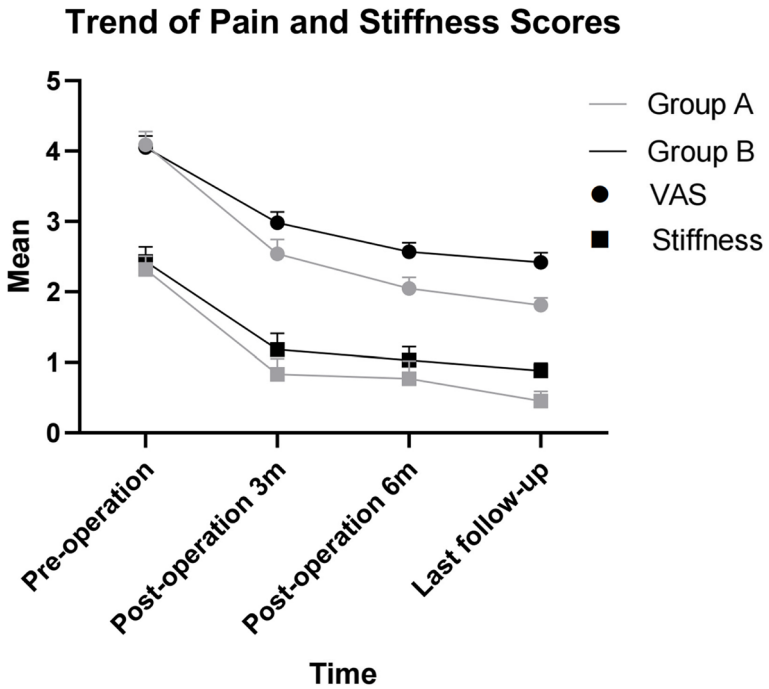

Fig. 4 Graph showing statistically significant improvement in pain and stiffness score in Group A as compared with Group B at 3 months (VAS: $p = 0.096$, Stiffness: $p = 0.303$), 6 months (VAS: $p = 0.021$, Stiffness: $p = 0.413$), and final follow-up (VAS: $\boldsymbol{p} = 0.002$, Stiffness: $\boldsymbol{p} = 0.020$)

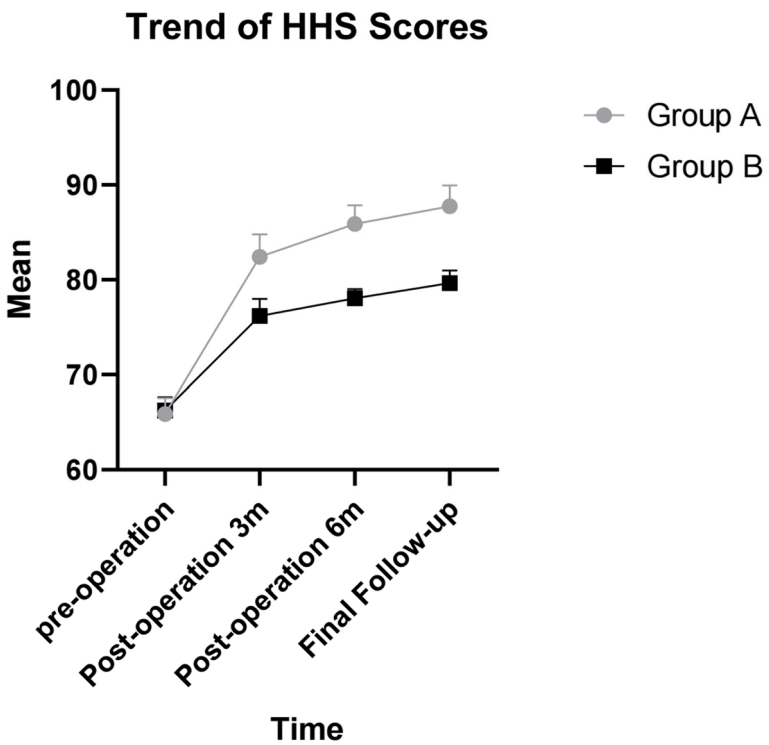

Fig. 5 Graph showing statistically significant improvement in HHS score in Group A as compared with Group B at 3 months ($\boldsymbol{p} = 0.042$), 6 months ($\boldsymbol{p} = 0.001$), and final follow-up ($\boldsymbol{p} = 0.002$)

Table 3 Score of different scales in Group A and Group B

Description	Post operation (3m) (Group A)	Post operation (3m) (Group B)	*p*	Post operation (6m) (Group A)	Post operation (6m) (Group B)	*p*	Post operation (Last Follow-up (Group A)	Post operation (Last Follow-up) (Group B)	*p*	MCID (Group A)	MCID (Group B)
VAS (move)	2.54 (0.98)	2.98 (0.83)	0.096	2.05 (0.74)	2.57 (0.68)	**0.021**	1.81 (0.51)	2.42 (0.72)	**0.002**	0.45	0.43
VAS (rest)	0.68 (0.76)	0.97 (0.82)	0.213	0.48 (0.60)	0.81 (0.68)	0.100	0.38 (0.50)	0.74 (0.56)	**0.024**	0.38	0.48
VAS (sleep)	0.62 (0.77)	0.95 (0.74)	0.136	0.57 (0.60)	0.91 (0.66)	0.070	0.43 (0.60)	0.82 (0.57)	**0.025**	0.62	0.45
Stiffness (wake up)	0.83 (1.07)	1.18 (1.23)	0.303	0.77 (1.19)	1.03 (1.01)	0.413	0.45 (0.67)	0.88 (0.58)	**0.020**	0.46	0.56
Stiffness (rest)	0.67 (0.77)	1.06 (0.92)	0.123	0.59 (0.80)	0.86 (0.77)	0.256	0.55 (0.91)	0.96 (0.75)	0.091	0.61	0.37
HHS	82.42 (11.36)	76.17 (9.56)	**0.042**	85.88 (9.37)	78.04 (5.14)	**0.001**	87.76 (10.53)	79.46 (7.13)	**0.002**	4.01	3.68
Charnley	14.73 (1.88)	13.89 (1.56)	0.094	15.13 (1.74)	14.23 (1.23)	**0.036**	15.44 (1.98)	14.41 (1.67)	0.054	0.84	0.74
SF-36											
PF	69.56 (13.87)	64.35 (13.27)	0.189	71.36 (14.51)	66.38 (12.11)	**0.047**	74.57 (13.24)	67.21 (12.39)	0.052	6.43	7.06
RP	58.38 (22.98)	54.28 (24.76)	0.557	59.09 (23.11)	56.65 (22.13)	0.703	62.33 (24.52)	55.28 (24.76)	0.327	16.08	12.88
BP	69.34 (7.72)	65.88 (8.36)	0.145	72.55 (6.27)	68.24 (7.38)	**0.031**	74.23 (7.83)	68.84 (8.54)	**0.028**	8.40	6.72
GH	77.53 (13.78)	69.72 (11.68)	**0.037**	78.32 (14.64)	70.83 (10.34)	**0.038**	76.89 (13.29)	68.61 (12.22)	**0.025**	9.16	6.86
VT	85.74 (5.63)	84.21 (6.68)	0.401	87.09 (6.25)	84.33 (8.79)	0.212	86.33 (8.34)	82.67 (9.87)	0.164	3.39	4.40
SF	75.88 (8.45)	71.31 (10.47)	0.108	78.75 (9.10)	73.91 (8.02)	**0.049**	79.83 (10.33)	72.31 (12.78)	**0.032**	9.75	9.29
RE	73.89 (18.64)	73.32 (19.23)	0.918	75.76 (26.21)	74.12 (17.88)	0.792	76.92 (22.98)	73.32 (19.23)	0.545	14.57	9.07
MH	80.87 (8.35)	73.22 (8.93)	**0.004**	84.00 (6.69)	77.13 (7.76)	**0.012**	85.33 (7.98)	79.26 (8.93)	**0.018**	10.45	7.49
HT	44.45 (10.57)	39.29 (9.67)	0.082	47.73 (12.32)	40.44 (12.12)	**0.039**	51.28 (13.58)	43.12 (12.94)	**0.038**	5.22	5.73
PCS	68.70 (15.66)	63.56 (14.97)	0.249	70.33 (14.28)	65.53 (14.78)	0.304	72.01 (11.47)	64.99 (12.23)	**0.047**	8.96	9.68
MCS	79.10 (11.53)	75.52 (12.92)	0.320	81.40 (13.98)	77.37 (11.39)	0.322	82.10 (13.53)	76.89 (13.72)	0.192	9.16	8.19
AIS	1.21 (1.15)	1.56 (1.33)	0.340	1.00 (1.09)	1.32 (1.21)	0.331	0.78 (1.17)	1.28 (1.05)	0.123	1.22	0.88
STAI											
S-AI	28.37 (3.28)	29.51 (4.18)	0.307	26.27 (3.17)	28.67 (3.22)	**0.010**	25.88 (3.42)	28.37 (4.18)	**0.031**	3.30	3.17
T-AI	25.79 (2.48)	27.12 (3.76)	0.166	23.09 (1.97)	25.12 (2.88)	**0.006**	22.78 (2.66)	24.87 (3.76)	**0.035**	3.94	2.46

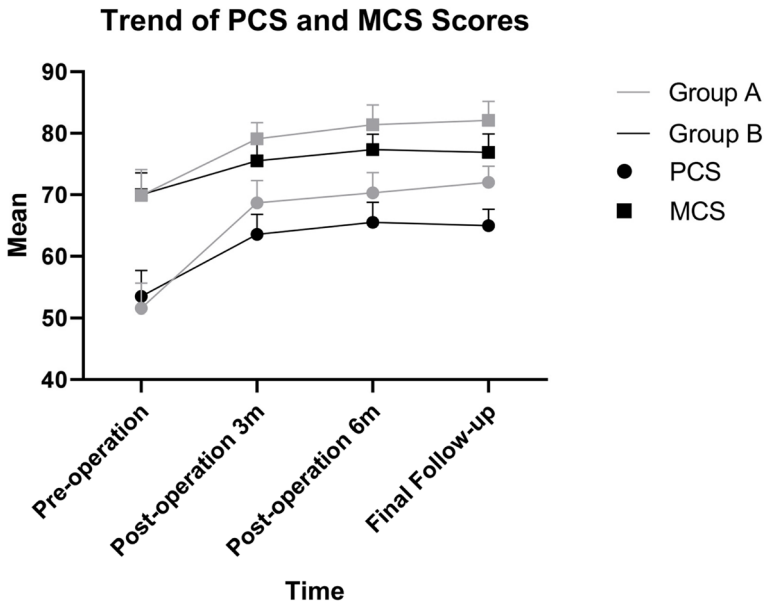

Fig. 6 Differences in PCS and MCS score between Group A and Group B at 3 months (PCS: $p = 0.249$, MCS: $p = 0.320$), 6 months (PCS: $p = 0.304$, MCS: $p = 0.322$), and final follow-up (PCS: $\boldsymbol{p = 0.047}$, MCS: $p = 0.192$)

remains unresolved [31, 63]. Additionally, the relatively huge trauma, difficult preparation process, and ethical concerns associated with BMAC and BMSCs limit their clinical application. Thus, regeneration agents that are easy to prepare, readily available, and have stable therapeutic efficacy are needed. Exosomes are small vesicles secreted by cells, with diameters ranging from 40 to 160 nm, capable of transferring various bioactive molecules, including nucleic acids, proteins, and lipids, from donor to recipient cells, thereby mediating intercellular communication and molecular transpor [64]. Compared with stem cells, exosomes offer advantages such as lower immunogenicity and greater abundance, making them a therapeutic potential for ONFH [65]. However, few studies have been conducted in the field of ONFH.

As an easily obtainable source of growth factors, PRP has attracted considerable attention within the medical community over the past two decades [66]. This regenerative agent has the potential to enhance regeneration of bone tissue, cartilage tissue, and vascular structures in necrotic regions through the localized secretion of various growth factors, including platelet-derived growth factor (PDGF), transforming growth factor-β1 (TGF-β1), vascular endothelial growth factor (VEGF), endothelial growth factor (EGF) etc. Furthermore, PRP significantly diminishes the expression of inflammatory cytokines and inhibits the inflammatory response, which reduces tissue damage caused by inflammation and alleviates pain [32, 67, 68]. In cases of glucocorticoid (GC)-induced ONFH, PRP also have a role of mitigating glucocorticoid-induced apoptosis [69]. Thus, it has been used as an augmentation during sugery and may serve as a useful adjuvant [34, 70, 71]. However, after an extensive review of the literature, only 7 studies were identified that focused on the use of PRP in the treatment of ONFH [37–43]. Three of these studies were case reports or case series [38, 40, 41]. Although these studies reported the potential benefits of PRP in patients with ONFH, they were considered to provide low-quality evidence due to the limited sample size. In other 3 studies, Houdek et al. assessed the efficacy of CD in combination with PRP and BMSCs [39], whereas D'Ambrosi et al. used synthetic bone grafts for the treatment of ONFH after administrering PRP and BMSCs after CD [37]. Samy reported the use of autologous bone graft combined with PRP after CD [42]. Although these studies have reported some efficacy of PRP, the specific role of PRP remains unclear due to the concurrent use of bone grafts and BMSCs. Only one RCT, conducted by Aggarwal et al., directly compared the efficacy between CD plus PRP (25 hips) with CD alone (28 hips). The rates of survivorship from femoral head collapse and THA was 84%/68% ($p < 0.001$) and 92%/78% ($p = 0.010$) in two groups, respectively, with a mean follow-up of 64 months, showing statistically significant results [43]. But the relatively small sample size of this study makes the role of PRP in the treatment of patients with early ONFH still unclear.

In this study, no definitive conclusion can be drawn regarding the ability of PRP to delay the natural progression of ONFH. The reasons for this may be as follows:

First, among these four collapsed hips, three were classified as 2021 ARCO type 3 or JIC type C2, with a mean LPA of 32.95°, indicating that the necrotic site involved weight-bearing areas, thereby presenting a high risk for collapse [8, 47]. In addition, in 3 of the 4 patients, the contralateral hip joint had already collapsed, which, according to a 2021 study, could be a contributing factor to the collapse. The study indicated that symptomatic hip collapse influences the progression of ONFH in the contralateral hip, suggesting a potential interplay between the conditions of both hips [72]. This evidence suggests that these patients may be at a high risk for collapse. Second, the average age of our patients was higher than in the Aggarwal's study, which may have contributed to the lower quality of the PRP [32, 34]. This also may be the potential reason for the different conclusions. Lastly, compared to the Aggarwal's study, the follow-up period of our study is relatively short and may not have been sufficient to reveal the role of PRP in ONFH. Thus, although the LPA in Group A was significantly higher than that in Group B at the final follow-up, we cannot definitively conclude that PRP is effective in delaying disease progression. Future randomized controlled trials with larger sample sizes and longer follow-up periods are requiredto elucidate the role of PRP in ONFH. Regarding pain, stiffness and hip function score, group A showed significantly improved outcomes at the final follow-up, including the 4 collapsed hips, all of which reached MCID, indicating that PRP have a "symptom-modifying" effect. Meanwhile, although no difference between the two MCS groups at the last follow-up, Group A performed significantly better than the Group B in PCS, further reflecting PRP's role in restoring physiological function. Furthermore, in Group A, 5 patients had sleep difficulties before surgery, but by the final follow-up, their sleep quality had improved. And following surgery, the patients' anxiety levels significantly decreased. The above illustrated the short term effect of this technology on symptom relief. Despite the benefits of PRP, there remain several challenges in its clinical application. PRP can be classified into leukocyte-rich PRP (LR-PRP) and leukocyte-poor PRP (LP-PRP) based on their leukocyte concentration [73]. However, the precise cellular and clinical implications of these different PRP preparations remain unclear. Moreover, the lack of data on experimental specifics or the precise composition of the PRP formulations used presents a major obstacle to interpreting the PRP studies published to date [74]. This creates challenges for the practical application of PRP in orthopedics.

There are several limitations in our study. Firstly, this was a retrospective study, which may introduce some bias and lead to inaccurate findings. Secondly, the short follow-up period of this study limit the reliability of the conclusions. Large sample RCTs are needed in the future to confirm the efficacy of PRP. Thirdly, during follow-up, we found that several patients in Group A continued smoking and drinking post-surgery, which led to postoperative pain and poorer imaging outcomes.. Therefore, postoperative behaviors should be standardized in future studies. Finally, the extent of necrotic borders varied throughout patients, even though only those with early ONFH were included. Individuals who have an excessively small LPA Angle, JIC type C2, or 2021ARCO type 3 are already more likely to collapse, which may have an impact on the results, and future studies need to consider the impact of this factor.

Conclusion

In conclusion, compared to traditional CD, PRP has been shown to significantly alleviate pain, improve hip function and enhance quality of life. However, due to the limited follow-up time and relatively small sample size it remains uncertain whether this combination can enhance CD and slow the progression of ONFH. Large-scale randomized controlled trials (RCTs) are still necessary in the future to validate the effectiveness of this therapy.

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Authors' contributions
Conceptualization: Haiwei Tang and Yahao Lai Investigation: Haiwei Tang, Enze Zhao and Yahao Lai Methodology: Gang Chen, Kai Zhou and Zongke Zhou Formal analysis: Haiwei Tang, Yahao Lai and Enze Zhao Writing – original draft: Haiwei Tang and Yahao Lai Writing – review & editing: Gang Chen and Zongke Zhou.

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Data availability
The datasets generated and analysed during the current study are not publicly available due to the privacy of patients data, but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee on Biomedical Research of West China Hospital (Approval 2024–348) and designed in accordance with the Declaration of Helsinki, which waived the need for written informed consent because patients or their legal guardians, at the time of admission, signed written consent for patients' anonymized data to be analyzed and published for research purposes.

Consent of publication
Consent for publication.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthopedics and Orthopedic Research Institute, West China Hospital, Sichuan University, Chengdu, People's Republic of China.

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