Research Square

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The Long-Term Outcome of Autologous Peripheral Blood Stem Cell Transplantation Combined with Core Decompression and Allogeneic Fibula Grafting for Osteonecrosis of the Femoral Head

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Research

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Abstract

Objective: The aim of this study was to determine long-term clinical and radiographic results of patients with early stage osteonecrosis of the femoral head (ONFH) who received autologous peripheral blood stem cells (PBSCs) transplantation combination with core decompression and allogeneic fibula grafting.

Methods: This was a retrospective study. Between February 2012 and February 2013 10 patients with ONFH (ARCO II) received PBSCs transplantation combination with core decompression and allogeneic fibula grafting. All cases received PBSCs mobilization by recombinant human granulocyte colony-stimulating factor（rhG-CSF）subcutaneous injection(5μg/kg/d) and astragalus injection intravenous drop (20ml/d) for 3-4 days preoperatively. In the next morning after mobilization hemanalysis was performed, if WBC count was more than $30X10^9$/L, PBSCs were collected by COM. TEC (Fresenius, Germany) for 15ml and prepared to infusion into decompression channel in the femoral head and femoral neck following core decompression and allogeneic fibula grafting . If white blood cell (WBC) count on the 4th day was less than $30X10^9$/L, PBSCs mobilization continued more 1 day and PBSCs were collected and translated on the 5th day. WBC count and CD34+ cell count were recorded pre- and post-operatively. Visual analog scale (VAS) pain scores, and Harris hip score (HHS) were recorded to assess the clinical outcome; X-ray was used to evaluate radiographic progression; failure was defined as patients underwent total hip arthroplasty (THA) or HHS less than preoperative level at the last follow-up.

Results: The mean follow-up was 89 months (82-96 months). All patients were followed up except one who suffered from early hip infection postoperatively. 7 cases received mobilization for 3 days and 3 cases for 4 days. After mobilization by rhG-CSF and astragalus injection for 3-4 days, WBC and monocytes increased from 6.61(5.04-8.94) X 10^9/L and 0.50(0.32-0.88) X 10^9/L to 45.71(35.73-79.73) X 10^9/L and 2.78(1.12-4.87) respectively. The concentration of CD34+ cells was 0.87(0.64-1.1) $X10^8$/ml. The mean VAS score decreased from 5.29±1.1 (4–7) to 0.57±0.53 (0–1). HHS were significantly improved from 63.43±5.41 (58-74) to 94.57±2.99 (93-98). 1 patient progressed from IIB to ARCO IIIA, 5 patients improved from IIC to IIB. There was no change in 2 patients with IIC and 1 patients with IIB. No patient underwent THA.

Conclusions: RhG-CSF combination with astragalus injection had synergistic action on PBSCs mobilization. The time and dose of exposure to rhG-CSF were reduced with less trauma and lower cost, without any side effect. Autologous PBSCs transplantation combined with core decompression and allogeneic fibula grafting could gain better long-term clinical and radiographic outcomes. This option was suitable for patients with early stage ONFH.

Introduction

Osteonecrosis of the femoral head (ONFH) is a disease in which cells (bone marrow cells, osteocyte and adipocyte) death leads to collapse of the femoral head and results dysfunction of the hip joint. Its pathogenesis is unclear with different theories. There are many different therapeutic options, but none of

which is able to cure all cases with ONFH. The treatments can be categorized as Nonsurgical treatments and Surgical treatment, the later also can be divided into hip-preserving surgery and total hip arthroplasty. Hip-preserving surgery includes core decompression, osteotomy, and (non)vascularized bone transplantation, which are suitable for patients in the early (ARCO 0–1) or mid-stage (ARCO 2–3 B) of ONFH and with a necrotic volume of more than 15%[1]. Core decompression is a classical surgery which can effectively reduce the pressure in the femoral head, improve local blood circulation and relieve hip pain. 91.9% hips achieved excellent clinical efficacy (HHS ≥ 80),it was indicated for early-stage ONFH resulted from only venous stasis without artery blood supply insufficiency[2]. However, the side effect was postoperative fracture and further collapse of the articular because of increasing strains of the bone in the vicinity of the bone tunnel after core decompression, which was more pronounced in the bone with necrotic material properties in the femoral head, whatever the the number, location and diameter of the drilling holes[3, 4]. When core decompression with other artificial bone substitute refilling in the hole, the applied maximum compression force that caused the fracture did not significantly reduced, daily activities (normal walking and walking downstairs) are not risky for femoral fracture[5, 6, 7]. Autogenous bone, allograft bone and bone graft substitute can be available for filling the decompression channel to increase the proximal femur strength. Free (non)vascularized fibular grafting was widely utilized for supporting and preventing collapse of the femoral head, the clinical outcome was better than core compression alone because of improvements in femoral head vascularity and the potential for bone revitalization[8].

Ischemia and hypoxia was the critical pathology of femoral head[9, 10],which led to the death of bone cells and abnormal bone marrow composition[11].The ability to differentiate into bone of Mesenchymal Stem Cells(MSCs) in patients with ONFH decreased[12].It was reported that steroid- and alcohol-induced osteonecrosis was accompanied by widespread apoptosis of osteoblasts and osteocytes[13]. So recently increasing number of studies have focused on cell therapy which was a promising treatment to improve the therapeutic effects. Autologous BMSCs implantation had a good therapeutic effect on ONFH, resulting in beneficial clinical outcomes[14]. Autologous BMSCs implantation combined with core decompression had a better pain relief and clinical outcomes than core decompression alone in the treatment of ONFH, which could delay the collapse of the femoral head more effectively[15, 16]. The conversion rate to THA reduced but ARCO stage was not improved [17]. In addition, the harvest of BMSCs was invasive and may cause pain at the donor site. Autologous peripheral blood stem cells (PBSCs) are located in peripheral blood and can be mobilized by rhG-CSF [18, 19]. Those cells have mesenchymal phenotype by expression of specific markers (CD90, CD105, and CD73) and absence of CD45 marker, and differentiate into osteoblasts and adipocytes [20]. So PBSCs have been used for treatment of ONFH combined with other option, such as core decompression[18],biomechanical support treatment (porous tantalum rod implantation)[21].

This was a retrospective study,from February 2012 to February 2013 ten cases with early stage ONFH underwent autologous PBSCs transplantation combined with core decompression and allogeneic fibula grafting. This was the first report and long-term outcomes of this treatment. We hypothesized that

autologous PBSCs transplantation combined with core decompression and allogeneic fibula grafting can obtain a better clinical outcomes and survivorship.

Methods

Study design and patients

Following approval by our institutional review board, a retrospective study was conducted at the First Affiliated Hospital of Guangzhou University of Chinese Medicine between February 2012 and February 2020. Inclusion criteria: (1) Diagnostic criteria met the Guidelines for clinical diagnosis and treatment of ONFH in adults (2019 version)[1]. (2) ARCO staging system was ARCO IIA-C. (3) Japanese Investigation Committee (JIC) classification was C1 [22]. Exclusion criteria:(1) Patients had adverse reactions to rhG-CSF.(2) The hips had received operation before.(3) Females who were pregnant, breastfeeding or preparing for pregnancy.(4)Patients with neurosis, psychosis, cardiovascular, cerebrovascular, liver, kidney, hematopoietic, endocrine system or other serious diseases.(5)Patients who refused long-term clinical follow-up or participation in the clinical trial. All cases reviewed clinical and radiographically fellow-up at 3,6,9, 12 month postoperatively and once a year after that. The mean follow-up was 89 (range 82–96) months. The failure was defined as patients with severe hip pain and progression of radiography, or received total hip arthroplasty (THA).

PBSC mobilization and collection

All patients received PBSC mobilization by subcutaneously injection with rhG-CSF (Beijing sihuan Bio-Pharmaceutical Co., LTD. Beijing, China) 5 μg/kg/d and astragalus injection (Zhengda Qingchunbao Medicine Co. LTD, Hangzhou, China) intravenous drop (20 ml/d) for 3–4 days preoperatively. In the 4th morning hemanalysis was performed, if WBC count was more than 30×10^9/L, PBSCs were collected by COM. TEC(Fresenius,Germany) for 15 ml and prepared for graft. If WBC count on the 4th day was less than 30 × 109/L, PBSCs mobilization continued more 1 day and PBSCs were collected and translated on the 5th day. A total of 15 ml blood containing PBSCs was collected. Flow cytometry was used to calculate the number of CD34 + cells.

Allogeneic cancellous bone granule and fibula preparation

Before implantation allogeneic cancellous bone granule and non-vascularized allogeneic fibula with diameter 12 mm (AoRui Technology Co., LTD. Shanxi,China). were soaked in gentamicin solution (80 mg in 100 ml NS) for 5 min. The fibula was drilled holes with 1 mm kirschner wire to make bone ingrowth easier and an oblique plane was made at either tip with an osteotribe (Fig. 1).

Surgical procedure

Operation was scheduled on the next day after PBSC mobilization. Patients lay on the back after spinal anesthesia. The lateral hip incision went from the most prominent point of the great trochanter extended

distal with length of 6 cm. The skin, subcutaneous tissue and fascia lata were incised (Fig. 2). The vastus lateralis muscle was blunt separated to expose the proximal side of the femur. A guide needle was located at 2 cm below the trochanter and drilled into the femoral head which was confirmed by anteroposterior and frog X-ray views (Fig. 3,4). The tip of the guide needle was located at the center of the necrotic area in the femoral head about 5 mm away from subchondral bone. A 4 mm diameter trephine was inserted followed manual reamer with diameter of 6–12 mm was inserted to perform core decompression（Fig. 5,6）. Allogeneic cancellous bone granule was impaction bone grafting followed the prepared allogeneic fibula was implanted with the oblique plane toward the anterolateral of the femoral head through the decompression channel (Fig. 7).

PBSC implantation

The operation bed was turned to the contralateral side of the operative hip about 30°and then the operative hip was lift.10 mm blood containing PBSCs was infused into medullary cavity of the fibular and then flowed directly into necrotic area of the femoral head. The distal hole at the proximal side of the femur was enclosed by bone wax.

Postoperative management

Patients lay on the back with the operation hip lift about 30°for 24 h and received routine antibiotic prophylaxis consisted of one intravenous preoperative dose of 2 g cephazolin, or 0.4 g Clindamycin in patients with allergy to beta-lactams. All patients received thromboembolic prophylaxis consisting of rivaroxaban oral for 6 weeks since the second day postoperatively. All patients were instructed to be non-weight-bearing for 6 months.

Clinical and radiographical evaluation were performed preoperatively, and 3,6 ,12months postoperatively and annually thereafter. VAS and Harris score were used for clinical evaluation. ARCO staging was evaluated by standard anteroposterior and frog radiographs of the hip. The failure was defined as severe hip pain or conversion to THA.

Statistical analysis

SPSS software 16.0 was used for statistical analysis. Qualitative data were compared using the chi-square test and quantitative data were compared with the t test. Kaplan-Meier survival curves with 95% confidence intervals were calculated. The results were assessed using the log-rank test to compare the Kaplan-Meier curves. The level of significance was $p<0.05$.

Results

Between February 2012 and February 2013, 10 patients (10 hips) were included. One patient suffered from early hip infection and received surgery and systemic antibiotic therapy. Debridement and removal of the allogeneic fibula were performed. At last 9 cases (9 hips) were followed until July 2020 and used for results analysis. The mean follow-up was 89 months (82–96 months). Patients' preoperative

demographic data are summarized in Table 1. 7 patients received PBSCs mobilization by injection RhG-CSF and astragalus injection intravenous drop for 3 days, 3 patients for 4 days. WBC and monocytes increased after mobilization and decreased after PBSCs collection (table 2 and Fig. 9). The concentration of CD34 + cells were 0.87 (0.64–1.1) $X10^8$/ml. VAS score decreased and Harris scores increased (table 3). 1 patient progressed from IIB to ARCO IIIA, 5 patients improved from IIC to IIB,2 patients remained IIC and 1 patients remained IIB as preoperation (table 3). No patient underwent THA. The representative case is shown in Figs. 10 and 11.

Survivorship

There were 1 patient progressed and had the femoral head collapsed during follow-up time, who had a good condition and the pain can be controlled by reducing weight bearing and taking celecoxib if necessary. No patient underwent THA. The success rate of 89 m was 88.9%.

Discussion

Main findings

This was the first report and long-term outcome of autologous PBSCs transplantation combination with mechanical support for treating ONFH. A latest clinical study reported intra-arterial infusion of auto-PBSCs for treating ONFH,the follow-up time was 53.96 ± 21.09 months (ranged from 8 to 84 months), which was the longest one [23]. The implantation of PBSCs and operation were different from this study. The main findings of our study as follow,1. Autologous PBSCs transplantation improved the results of treatment ONFH with core decompression and allogeneic fibula grafting; 2. The autologous PBSCs were rich in peripheral blood and could be was mobilized by rhG-CSF and astragalus injection which reduced the time and dose of exposure to rhG-CSF; 3. It was easy to reach a high enough concentration of PBSCs for collection with less trauma and lower cost; 4.The combination option for treating ONFH was safe and efficacious.

Core decompression and allogeneic fibula grafting

The option for treatment of ONFH was categorized into nonoperative and operation. There were many nonoperative treatments available for ONFH, most with limited supporting data[24]. Operation including hip-preventing surgery and THA was appropriate for most ONFH except for asymptomatic hip with small, medially located lesions[25]. THA was indicated for advanced-stage osteonecrosis in older patients or those who have failed joint-preserving treatment with excellent results in terms of pain relief and survivorship [24]. However ONFH often occurs in young patients who will receive revision THA in future if received THA too earlier. For young patients with early stage ONFH hip-preventing surgery was eligible. Core decompression was the first hip-preventing surgery and has beneficial results, bur the mechanical properties of the bone was inferior after core decompression [25]. It aimed to improve blood flow to the femoral head by decreasing intraosseous pressure [23] and the prognosis in bone healing[26].It was indicated for early-stage ONFH resulted from only venous stasis without artery blood supply insufficiency

[2].Postoperative fracture and further collapse of the articular occasionally occurred because of increasing strains of the bone in the vicinity of the holes, which was more pronounced in the bone with necrotic material properties in the femoral head, whatever the number, location and diameter of the drilling holes[3, 4] .Early study reported that the collapse rate was 78% at 24 months postoperatively, it had no greater value than conservative management in preventing collapse in early osteonecrosis of the femoral head[27]. In order to prevent femoral head collapse by providing structural support, different material such as autogenous bone, allograft bone and bone graft substitute were utilized to filling the defect to increase the proximal femur strength[28, 29, 30, 31]. Core decompression and allogeneic fibular grafting has been used in our hospital for many decades, the mid-long term outcome was excellent[32, 33]Modified non-vascularized allogeneic fibula grafting combined with core decompression and bone grafting also was an effective and cost-effective treatment on early femoral head necrosis with satisfactory survivorship and could improve the clinical outcomes, delay the disease progression, and enhance the quality of life for patients[34].The fibular allograft procedure had favorable biomechanical efficacy and biological repair ability, it can prevent the necrotic femoral head from collapse in a certain extent and improve the survival rate,and its clinical effect is obviously better than pure conservative treatment even as good as vascularized fibular grafting[35].

Bone marrow stem cells transplantation

Stem cells are a group of cells with the ability to self-renew and differentiation into target cells. In adult, mesenchymal stem cells (MSCs) were the main stem cells which consist in bone marrow called bone marrow stem cells (BMSCs) and adipose tissue called Adipose-derived MSCs (aMSCs). A study in vitro found that aMSCs outperform BMSCs in growth rate and bone differentiation potential in the setting of osteonecrosis, suggesting they may provide a more-potent regenerative therapeutic strategy in ONFH[36]. Autologous aMSCs transplantation improved osteogenesis and the microstructure of vascular deprivation-induced osteonecrotic tissue in rabbit[37]. However aMSCs was seldom utilized for treating ONFH clinically [38]. BMSCs had been used for treating ONFH in 1990 combined with core decompression[39]. The safety and biodistribution of BMSCs in bone had been confirmed by an animal research[40]. Recently several reviews reported that autologous BMSCs combination with core decompression had better pain relief and clinical outcomes compared with core decompression alone in the treatment of early-stagy ONFH, which can delay the collapse of the femoral head more effectively[17, 41, 42]. Another matched pair case-control study suggested that implantation of MSCs into the femoral head at an early stage of ONFH lowered the THA conversion rate, however ARCO stage progression is not affected by this treatment[43]. The aforementioned studies did not fill the defect followed core decompression to provide structural support, this may influence the outcome. Tao Wang,et al performed a thorough debridement of all necrotic lesion, pack autogenous cortical and cancellous bone which were harvested from the ipsilateral iliac crest tightly into the femoral head, implanted bone-marrow mononuclear cells containing mesenchymal stem cells into the necrotic lesion for patients with ARCO II-III ONFH, the overall clinical success rate is 80% without infection, femoral neck fracture or other complications[44]. Dewei Zhao described a modified technique using bone marrow mesenchymal stem cells (BMMSCs) associated with porous tantalum rod implantation combined with vascularized iliac

grafting for the treatment of end-stage ONFH, the outcome showed that Harris hip score improved significantly from 38.74 ± 5.88 points (range 22–50) to 77.23 ± 14.75 points (range 33–95) and the joint-preserving success rate of the entire group was 89.47% for ARCO stage IIIc and 75% for ARCO stage IV, which suggested than this intervention was safe and effective in delaying or avoiding total hip replacement for end-stage ONFH[45].

However, a considerable number of patients who received BMSCs transplantation did not achieve a satisfactory outcome in terms of repair of the femoral head necrotic area. One reason was that the success of hip joint preserving depended on the stage and amount of osteonecrotic lesion[46].Patients with a large sized lesion or medium sized laterally located lesion achieved poor outcomes[43]. Another reason may be associated with the quality of implanted stem cells, which decided the ability of differentiation into bone[12, 47]. Whereas cellular activity and ability to differentiate into bone of BMSCs in patients with Corticosteroid-Induced ONFH have decreased, which may be a factor in why patients with corticosteroid-induced ONFH treated with autologous iliac crest bone marrow grafting progress to collapse [12]. Other cell sources need consider.

Peripheral Blood Stem Cell Mobilization

Under steady-state conditions less than 0.05% of the white blood cells (WBC) are PBSCs, mobilization of CD34 + cells from the bone marrow into the peripheral blood was necessary [48, 49] .G-CSF was the most commonly used with few side effects and high mobilization efficacy[50]. If PBSCs were poor mobilization in patients with hematological malignancies, plerixafor could be added to enable rapid and efficient mobilization[51] ,which was a salvage strategy in dose of 0.24 mg/kg to haploidentic healthy donors[50].There were no consensus about the optimal time and dose of G-CSF to mobilize PBSCs. In the early study period, leukapheresis for PBSC collection was performed for 2–3 days in 75 (37.9%) patients, 4–5 days in 60 (30.3%) patients, and 6–11 days in 63 (31.8%) patients[52]. At present 4–5 days mobilization was commonly used[19, 50, 53, 54].The dose of rhG-CSF was 10–16 μg/kg/day with low rates of short-term serious side effects and no potential long-term complications[50].

In our study patients received rhG-CSF (5ug/kg/d) subcutaneous injection and astragalus injection intravenous drop for 3–4 days. On the third day WBC count was test. when the WBC count > 30 × 10e9/L the mobilization stopped, if ≤30 × 10e9/L, the mobilization continue more 1 day. Autologous PBSCs were collected by COM. TEC(Fresenius,Germany) on the next day. 70% patients can avoid one more day of G-CSF exposure and its potential side effects. The dose we used was lower than current literature reports, astragalus injection intravenous drop maybe the reason. Astragalus polysaccharide was the main component of astragalus, which enhanced the secretion of granulocyte-macrophage colony stimulating factor (GM-CSF) in vitro[55, 56].However the synergistic effect of both was unclear, need further research.

Cell volume was important for success of PBSCs transplantation, higher dose of CD34 + PBSCs is associated with better survival. Generally, the minimum quantity of PBSCs for one transplant is defined as 2.0×10^6 CD34 + cells/kg bodyweight [57].Optimal dose of CD34 + cell for autologous and allogeneic

was 5 × 10e6 and 4.5 × 10e6/kg respectively [58]. The forementioned cut-off was intravenous graft for multiple myeloma or leukemia. Local graft was commonly performed for treating ONFH. It was reported that stem cell therapy for treating ONFH, the injection of 10^6 to 10^9 cells may be reasonable, however, the optimal number still needs to be investigated[59]. Mao Q et al infused 1.71 ± 0.7 × 10^6 PBSCs into the femoral head through the medial circumflex artery[21]. In this study we infused 0.87 (0.64–1.1) X10^8/ml CD34 + PBSCs 10 ml into medullary cavity of the fibular and then flowed directly into femoral head.

So PBSCs in peripheral blood (PB) must be enough before leukapheresis. Some factors had been used to predict mobilization. CD34 + cell level at baseline was the most used. The basal CD34 + either ≤ 2 cells/μL or ≥ 3 cells/μL well predicted the levels of CD34 + on day 4, which determine whether mobilization should be attempted or not[53]. Whereas in adult it was set that PB-$CD34^+$ count > or = 15 CD34(+) cells/microL and ≥ 20 cells/μL were the best predictor to begin the apheresis procedure [60, 61]. However sometimes the number of CD34 + cells in PB may be persistently lower than the threshold at which PBSCs collection begins in poor mobilizers, and therefore, it was difficult to decide the timing to start PBSC collection[62]. In addition CD34 + cells test was expensive. Many institutions still consider WBC count in PB as one of valid surrogates. However, the optimal WBC count in PB to start PBSC collection has not been systematically tested. Sung KW et al proposed that WBC count in PB exceeded 4,000/μL predicted a higher CD34 + cell yield in Children with high-risk solid tumors[62]. Lydon H et al found that the mean WB count of 16.1 ± 5.0 × 106 /ml was sufficient for apheresis in ovine model[63]. In our study we set the cut-off of WBC as or = 30 × 10^9/L, and collected sufficient PBSCs.

PBSCs transplantation

PBSCs are mononuclear cells enrich in peripheral blood, which was not fully accepted until 2004, when Valenti MT,et al found that human PBSCs circulated among mobilized peripheral blood[64].PBSCs had similar characteristics and chondrogenic differentiation potential to BMSCs[65], also can differentiate into osteoblasts and adipocytes [19, 66], neuron-like cells[67]. In clinical practice, intracoronary infusion PBSCs improved cardiac function and promoted angiogenesis in patients with myocardial infarction[68]. Animal experiment and clinical study had demonstrated that PBSCs also could be used for treating ONFH[20, 69, 70]. The possible mechanism were that PBSCs improved blood supply of the femoral head[69]and enhanced the bone regeneration by up-regulating BMP-2 expression and down-regulating PPAR-γ expression, both of which were the most typical and closely relative genes in bone regeneration[70] .

To our knowledge this was the first report of clinical outcome study of a combinational treatment for ONFH with autologous PBSC transplantation combination with core decompression and allogeneic fibula grafting. Mao Q reported a randomised controlled clinical trial in which tantalum rod implantation in combination with targeted intra-arterial infusion of PBSCs was utilized for treatment of ONFH[21]. There was some difference from our study. Firstly the porous tantalum rod was utilized for mechanical support, secondly PBSCs were infused through medial circumflex femoral artery into femoral head. There was no comparative study on porous tantalum rod and allogeneic fibula grafting. In Mao Q' s study PBSCs were

intra-arterial infused, the fate of PBSCs after transplantation was not examined, the cell homing was unclear. In our study PBSCs were infused into medullary cavity of the fibular and then flowed directly into femoral head, which could existed in the bone tunnel after core decompression for 6months[71] when PBSCs differentiated into osteoblasts[20] and endothelial progenitors with angiogenic properties containing in the PB mononuclear cells (MNCs) promoted MSCs produce proangiogenic factors as well as differentiate into mural pericytes[72]

Limitations

There were some limitations of this study. Firstly this was a retrospective study, not a prospective randomised controlled clinical trial. Secondly the case number was small, we only included patients between February 2012 to February 2013.Thirdly how PBSCs playing a part in the repair of ONFH was not investigated, but other research explained the possible mechanism. Forth the synergistic effect of rhG-CSF and astragalus injection was unclear, need further research.

Conclusion

Autologous PBSCs transplantation combination with core decompression and allogeneic fibula grafting was utilized for treating ONFH. The clinical and radiographic results were significantly improved. In our study 70% patients received rhG-CSF subcutaneous injection and astragalus injection intravenous drop can avoid exposure time and dose to G-CSF and its potential side effects.

Abbreviations

ONFH: Osteonecrosis of the femoral head; MSC: Mesenchymal stem cell; PBSCs: peripheral blood stem cells; rhG-CSF: recombinant human granulocyte colony-stimulating factor; WBC: white blood cell; THA: Total hip arthroplasty; ARCO: Association Research Circulation Osseous; VAS: Visual analogue scale.

Declarations

Acknowledgments

Not applicable.

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Because of the retrospective study design, a formal consent was not required. The protocol of this study was approved by the first affiliated hospital of Guangzhou university of Chinese Medicine institutional review board (approval number: 2020-08-1).

Consent for publication

Informed consent was obtained from all individual participants included in the study.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contribution

Jianchun Zeng and Yiyong Zeng designed this study and finished operation. Jianchun Zeng finished the manuscript. Feilong Li and Yueguang Fan harvested data. Keliang Wu finish data analysis. Hai Lan, Zhiying Liu and Zhongqi Yang engaged in PBSC mobilization and collection. All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work were appropriately investigated and resolved.

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Tables

Table 1

Preoperative demographic data

Parameters	Mean (range)
Age (years, range)	37.7(27–45)
Gender (M/F)	7/3
Left/right	6/4
Risk factors	
- Idiopathic	1
-Glucocorticoid	2
- Alcoholism	4
- trauma	2
-Dysbaric	1
ARCO stage	
IIA	0
IIB	6
IIC	4
Follow-up (months)	89 (82–96)

Table 2

Change of peripheral WBC and monocyte (X 10^9/L)

Parameters	Pre-mobilization	Post-mobilization	1 day postoperative	2 day postoperative	3 day postoperative
WBC	6.61 ± 1.68(5.04–8.94)	45.71 ± 16.63 (35.73–79.73)	12.50 ± 5.77(7.08–24.66)	8.98 ± 2.52(5.15–12.44)	4.86 ± 1.71(2.51–7.83)
monocyte	0.50 ± 0.20 (0.32–0.88)	2.78 ± 1.32(1.12–4.87)	1.77 ± 1.33(0.74–4.3)	0.86 ± .30(0.54–1.32)	0.47 ± .176(0.31–0.78)

Table 3
clinical and radiographic results

	Pre-	Post-	P value
VAS	5.29 ± 1.1 (4–7)	0.57 ± 0.53 (0–1)	P<0.001
Harris score	63.43 ± 5.41 (58–74)	94.57 ± 2.99 (89–98)	P<0.001
ARCO stage			
IIA	0		0
IIB	3		6
IIC	6		2
IIIA			1

Figures

Figure 1

The fibula was drilled holes with 1 mm kirschner wire and an oblique plane was made at either tip with an osteotribe

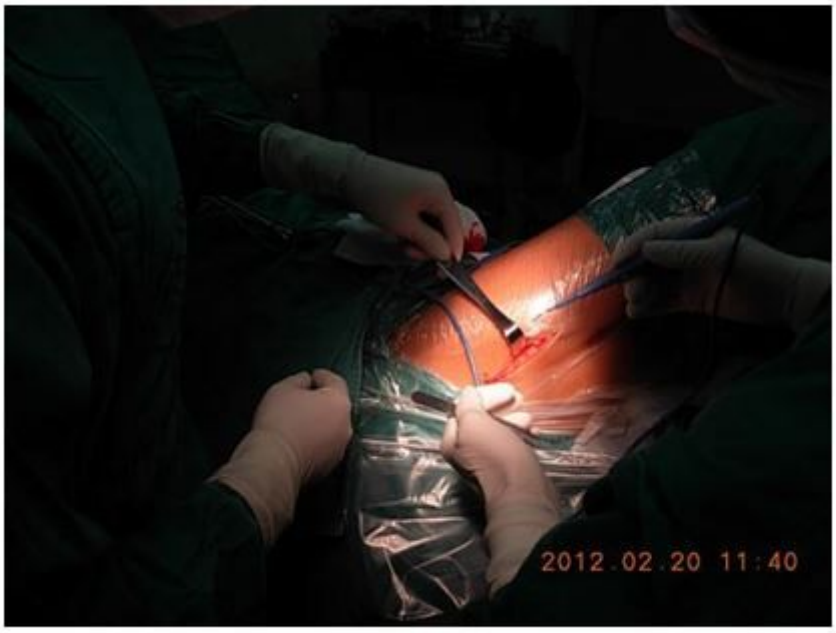

Figure 2

Skin incision

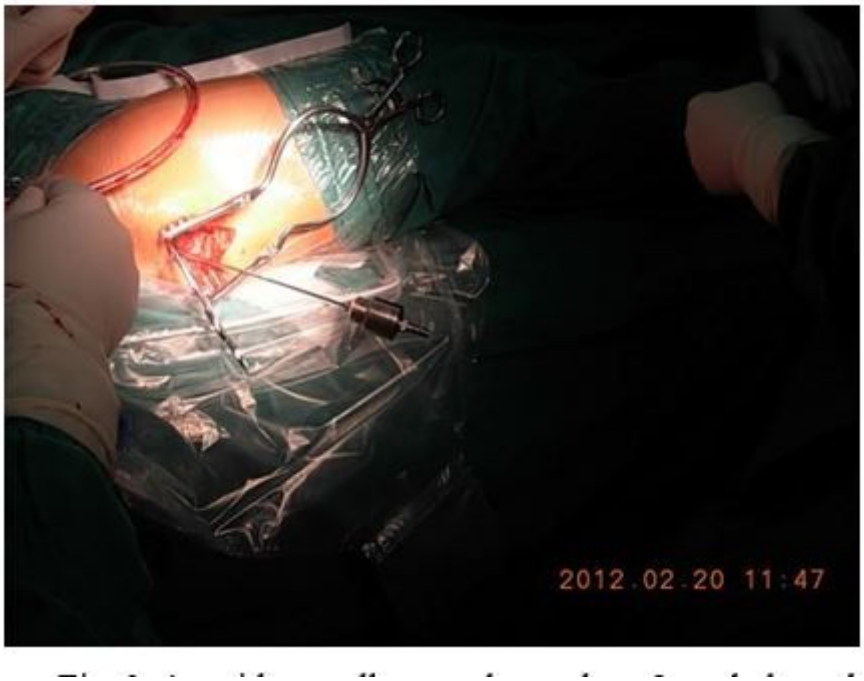

Figure 3

A guide needle was located at 2cm below the trochanter and drilled into the femoral head

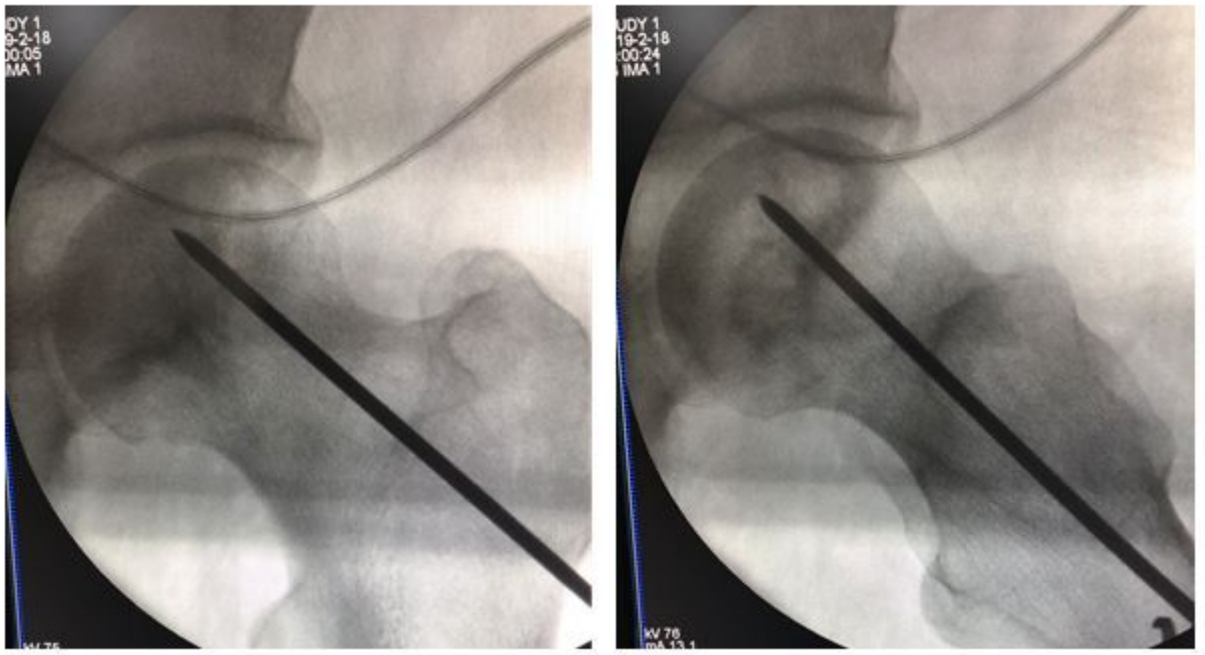

Figure 4

Position of guide needle was confirmed by anteroposterior and frog X-ray views

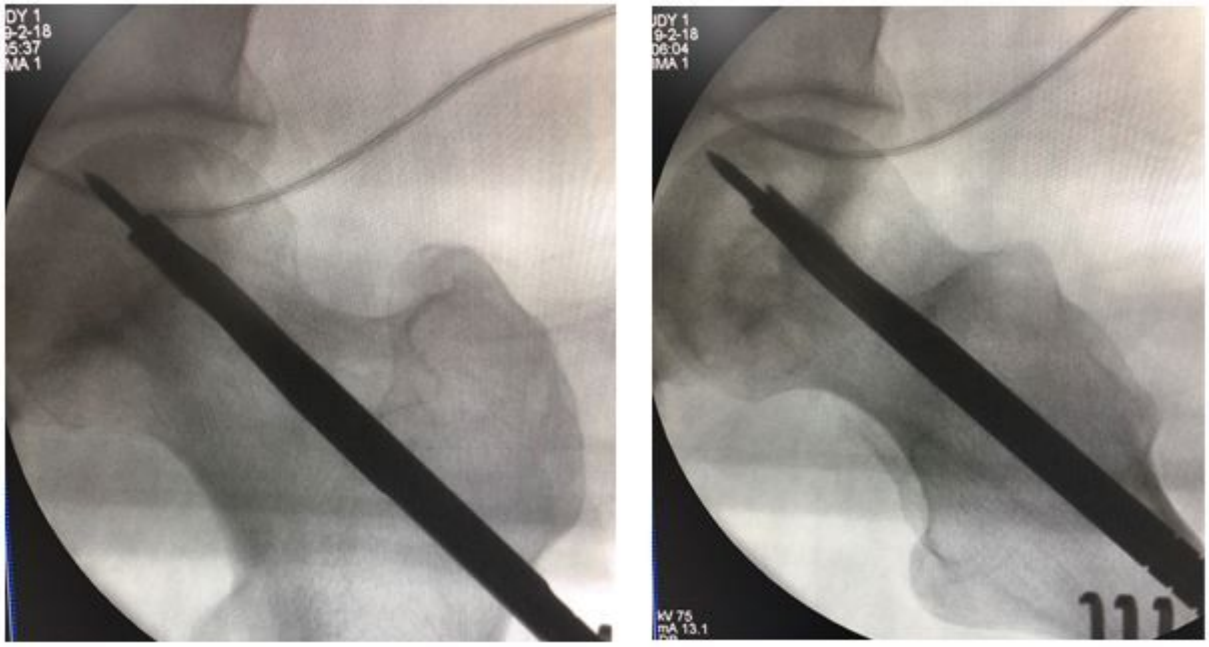

Figure 5

A 4mm diameter trephine was inserted

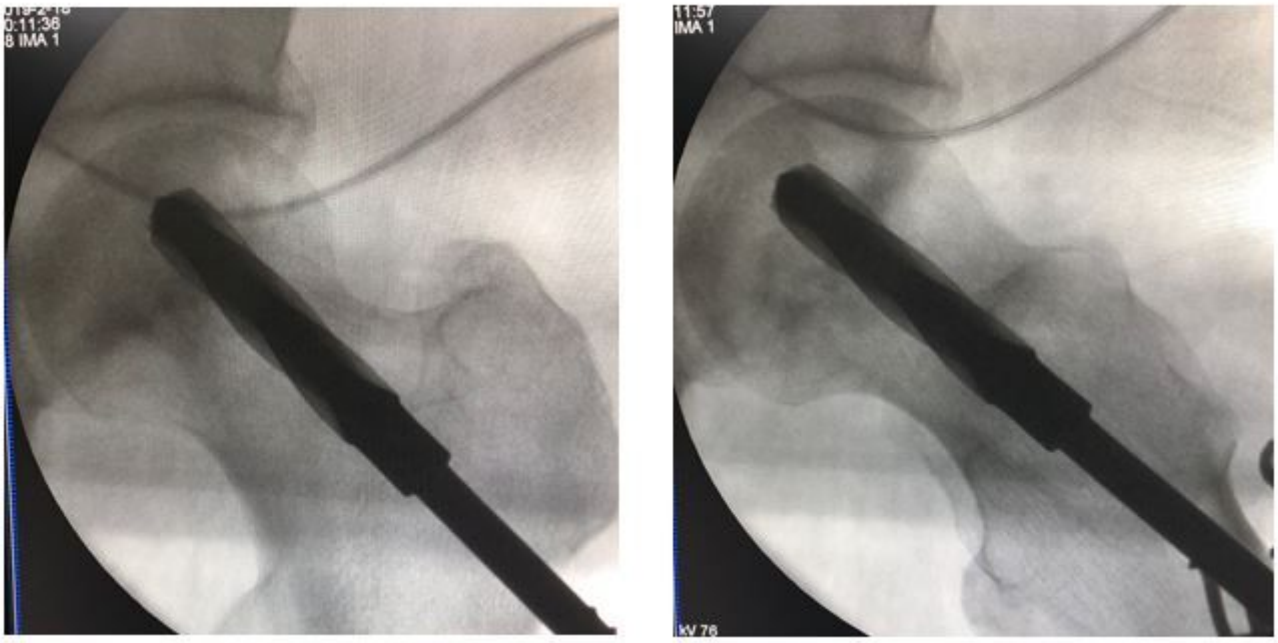

Figure 6

core decompression was perform by manual reamer with diameter of 6-12mm

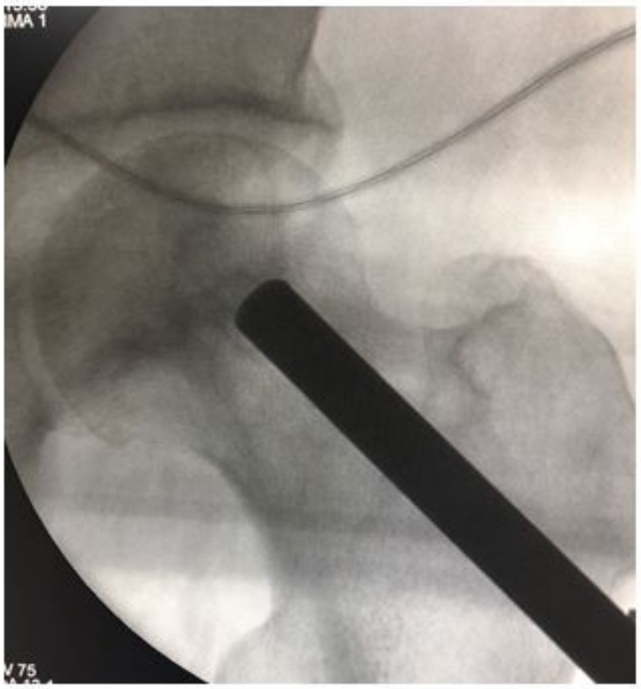

Figure 7

Impacting bone graft with allogeneic cancellous bone granule with a metal bar.

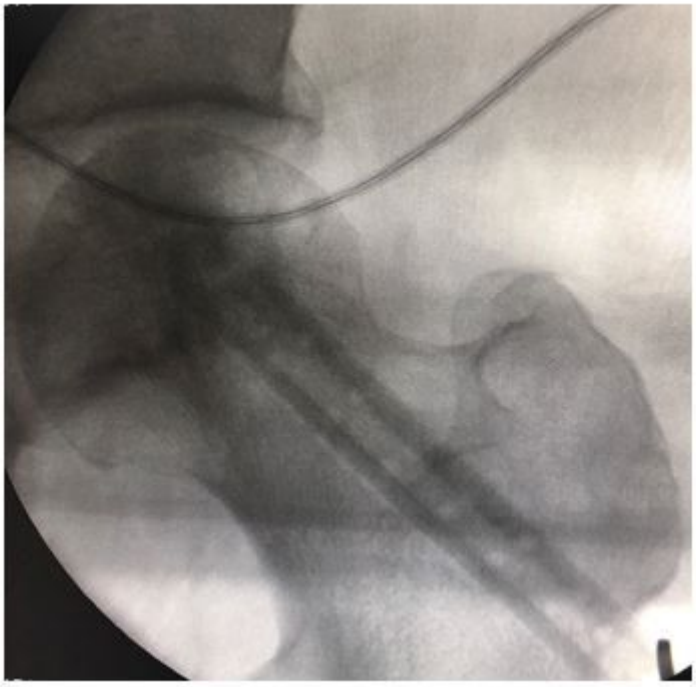

Figure 8

The prepared fibula was implanted with oblique plane toward the anterolateral of the femoral head through the decompression channel

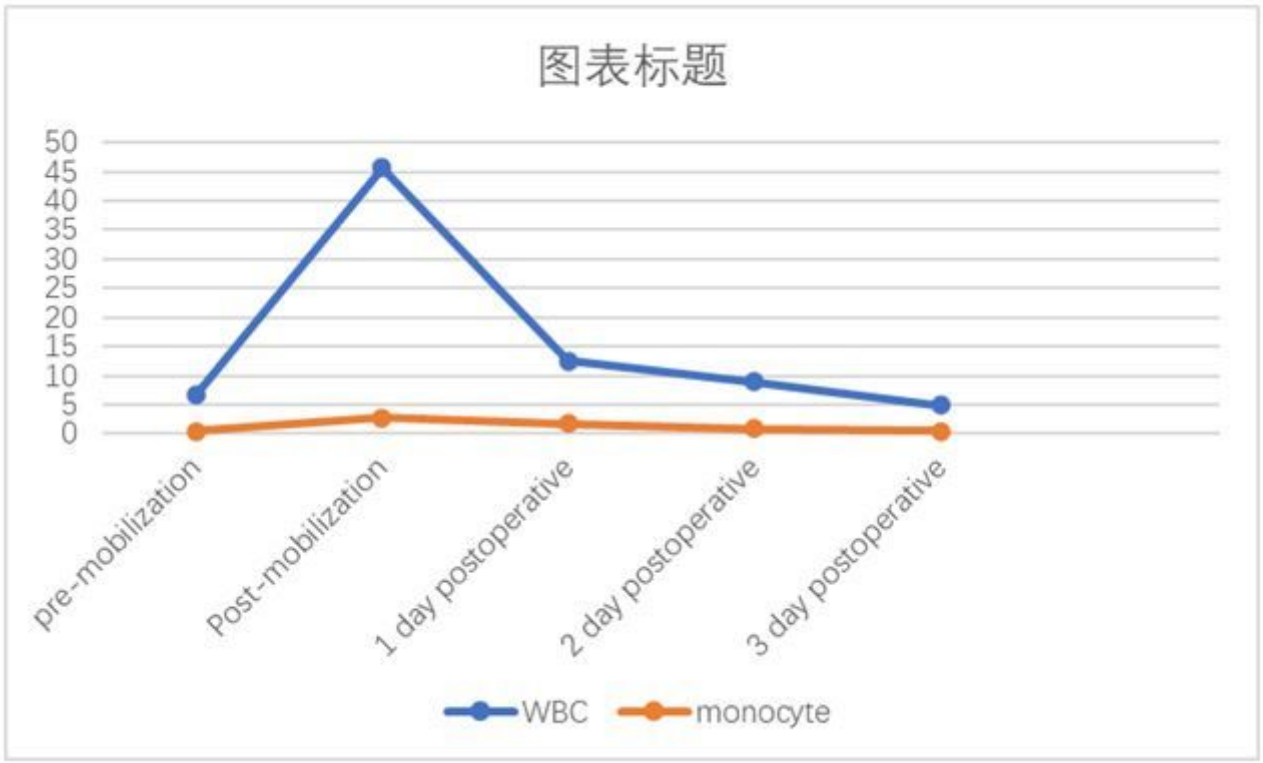

Figure 9

Change of peripheral WBC and monocyte (X 109/L)

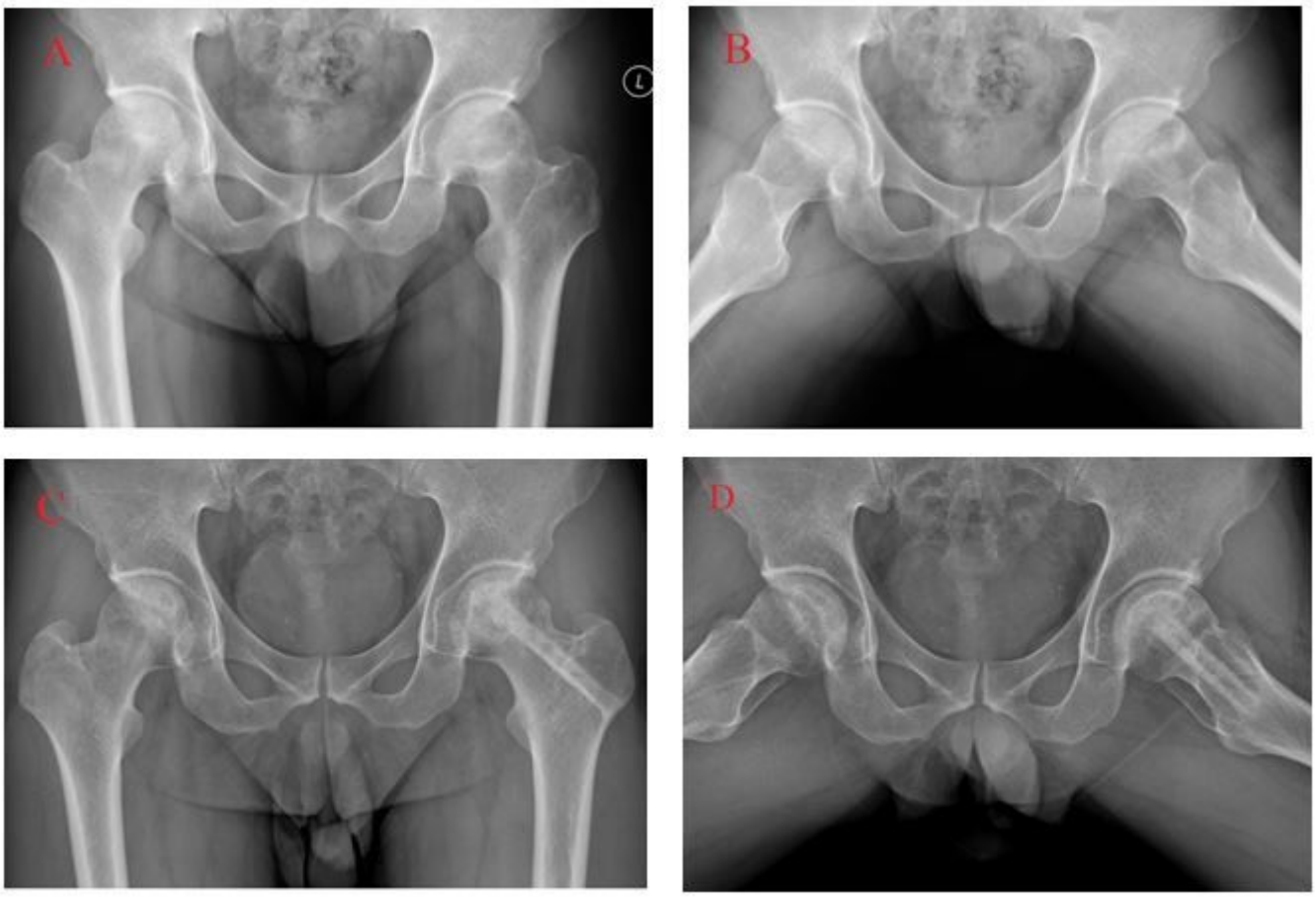

Figure 10

The radiographic outcomes of a 30-year-old man was diagnosed as both idiopathic ONFH, the left side was ARCO IIC and JIC C1 which underwent autologous PBSCs transplantation combined with core decompression and allogeneic fibula grafting. Fig A , B were preoperative and C,D were followed at 96m postoperative with ARCO IIB.

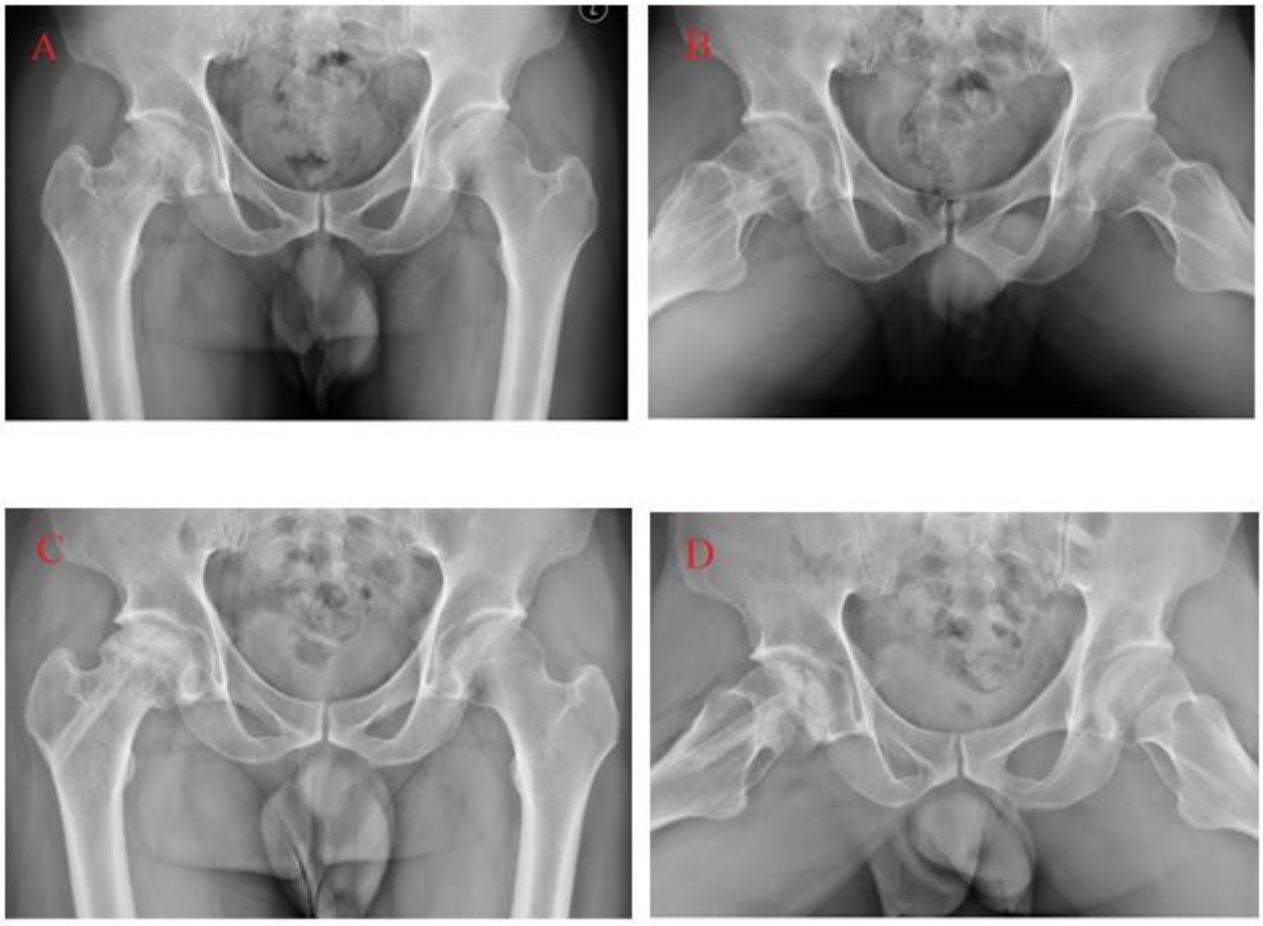

Figure 11

The radiographic outcomes of a 45-year-old man was diagnosed as right post-traumatic ONFH, it was ARCO IIB and JIC C1 who underwent autologous PBSCs transplantation combined with core decompression and allogeneic fibula grafting. Fig A , B were preoperative and C,D were followed at 34m postoperative with ARCO III A.