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Comparative Clinical Outcomes of Core Decompression Alone Versus Core Decompression Augmented with Bone Marrow Aspirate Concentrate in Pre-Collapse Avascular Necrosis of the Femoral Head

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ABSTRACT

Background and Aims: Avascular necrosis of the femoral head in pre-collapse stages presents an opportunity for joint-preserving interventions. Core decompression is a standard approach, but augmentation with bone marrow aspirate concentrate (BMAC) may enhance regenerative potential. This study aimed to compare clinical outcomes between core decompression alone and core decompression with BMAC in patients with early-stage disease.

Materials and Methods: A retrospective comparative study was conducted on 30 patients (38 hips) with Ficat-Arlet stage 1 or 2 (or equivalent ARCO stages) avascular necrosis treated between 2023 and 2024. Patients were divided into two groups: 15 hips underwent core decompression alone, and 23 hips received core decompression augmented with BMAC harvested from the iliac crest. Outcomes were assessed using Visual Analogue Scale (VAS) for pain and Modified Harris Hip Score (MHHS) preoperatively and at 3 and 6 months postoperatively.

Results: Both groups showed significant improvements in VAS and MHHS at 6 months ($p<0.001$). The BMAC-augmented group demonstrated greater mean reductions in VAS (from 7.8 ± 1.2 to 2.1 ± 0.9 vs 7.6 ± 1.1 to 3.4 ± 1.0, $p=0.012$) and larger gains in MHHS (from 52.4 ± 8.6 to 88.7 ± 6.3 vs 54.1 ± 9.2 to 79.2 ± 7.8, $p=0.008$). No hips progressed to collapse in the BMAC group, compared to two in the control group.

Conclusion: Augmentation with BMAC provides superior pain relief and functional improvement compared to core decompression alone in pre-collapse avascular necrosis, potentially delaying disease progression.

Keywords: *Osteonecrosis; Femur Head; Core Decompression; Bone Marrow Aspirate Concentrate; Treatment Outcome; Hip Joint.*

INTRODUCTION

Avascular necrosis (AVN) of the femoral head is a progressive condition that disproportionately affects younger adults, often leading to femoral head collapse and eventual total hip arthroplasty if untreated in its early phases. The disruption of blood supply results in osteocyte death, structural weakening, and subchondral fracture, culminating in articular surface irregularity and secondary osteoarthritis [1]. With an increasing incidence linked to corticosteroid use, alcohol consumption, and traumatic injuries, early intervention remains critical to preserve native joint function and delay or avoid prosthetic replacement, particularly in patients under 50 years who face higher risks of revision surgery [2].

Core decompression, introduced decades ago, aims to reduce intraosseous pressure, restore venous drainage, and stimulate reparative processes in the necrotic zone. It has become a cornerstone for pre-collapse stages (Ficat-Arlet 1 and 2, or ARCO

1–3A), offering pain relief and halting progression in many cases. However, outcomes vary, with success rates ranging from 60–80% in early disease, limited by incomplete regeneration of viable bone and persistent ischaemia [3].

Regenerative orthobiologics have emerged as promising adjuncts to enhance healing. Bone marrow aspirate concentrate (BMAC), rich in mesenchymal stem cells, growth factors such as vascular endothelial growth factor (VEGF), and anti-inflammatory cytokines, promotes angiogenesis, osteogenesis, and tissue repair [4]. Preclinical and clinical evidence suggests BMAC can differentiate into osteoblasts, revascularise ischaemic areas, and modulate the inflammatory microenvironment that exacerbates necrosis [5].

Multiple studies have explored BMAC augmentation in AVN. Early reports demonstrated improved survivorship and functional scores compared to decompression alone, particularly in pre-collapse lesions [6]. Long-term follow-ups have shown reduced rates of progression to collapse, with BMAC providing a cellular scaffold for bone regeneration. However, results in more advanced pre-collapse stages remain debated, with some series reporting equivalent outcomes to standalone decompression [7].

The pathophysiological rationale for BMAC is compelling: AVN involves not only vascular compromise but also depleted progenitor cells in the proximal femur. Concentrated autologous marrow replenishes these cells, delivering high concentrations of bioactive molecules directly to the lesion. VEGF, in particular, stimulates neovascularisation, while platelet-derived factors support matrix remodelling [8].

Despite promising data, comparative evidence is largely from small cohorts or heterogeneous populations. Few studies highlight that AVN burden is rising due to corticosteroid misuse and trauma, have directly contrasted the two approaches using standardised outcomes like the Visual Analogue Scale (VAS) for pain and Modified Harris Hip Score (MHHS) for function [9].

This retrospective study was undertaken to evaluate whether BMAC augmentation confers superior clinical benefits over core decompression alone in pre-collapse AVN. Primary endpoints focused on pain reduction and functional restoration at short-term follow-up, with secondary assessment of radiographic stability. By targeting Ficat-Arlet stages 1 and 2 (pre-collapse), the investigation sought to inform joint-preserving strategies in a demographic prone to early prosthetic failure.

MATERIALS AND METHODS

Study Setting: This retrospective comparative study was conducted at the Department of Orthopaedics, Government Medical College and ESI Hospital, Coimbatore, a tertiary-care public institution in Tamil Nadu, India, reviewing cases from 2023 to 2024.

Study Participants: Patients diagnosed with non-traumatic avascular necrosis of the femoral head in pre-collapse stages were included. Eligible cases comprised Ficat-Arlet stages 1 and 2, corresponding to ARCO stages 1, 2A, 2B, and 3A. Exclusion criteria encompassed patients with advanced osteoarthritis, Ficat-Arlet stage 4 disease, active infection, malignancy, or incomplete follow-up records.

Sample Size and Sampling Technique: A total of 30 patients (38 hips) meeting criteria were reviewed. Convenience sampling was used, with cases allocated retrospectively into two groups based on treatment received: core decompression alone (15 hips) or augmented with BMAC (23 hips).

Study Tools: Clinical assessment utilised the Visual Analogue Scale (VAS, 0–10) for pain intensity and Modified Harris Hip Score (MHHS, 0–100) for hip function. Radiographic staging employed plain radiographs and MRI, with progression defined as advancement to subchondral collapse or worsening osteoarthritis.

Study Methodology: Procedures were performed under spinal anaesthesia. For BMAC augmentation, bone marrow was aspirated from the posterior superior iliac crest, processed via double centrifugation to concentrate nucleated cells, and injected into the decompressed tract. Core decompression involved a standard percutaneous approach with sealing as needed. Patients followed a standardised rehabilitation protocol with partial weight-bearing progressing to full over 6–8 weeks.

Ethical Issues: The study adhered to institutional ethical guidelines for retrospective reviews. Patient confidentiality was maintained, and no additional interventions were performed beyond routine care.

Statistical Analysis: Data were analysed using SPSS version 25. Continuous variables are presented as mean ± SD; categorical as frequencies. Paired t-tests assessed within-group changes; independent t-tests or Mann-Whitney U compared groups. Chi-square tested associations. $p<0.05$ was significant.

RESULTS

The baseline demographic and clinical characteristics of the 38 hips treated for pre-collapse avascular necrosis of the femoral head are presented in Table 1. Overall, the mean age was 42.6 ± 9.8 years, with comparable ages in the core decompression alone group (43.2 ± 10.1 years) and the core decompression plus bone marrow aspirate concentrate (BMAC) group (42.1 ± 9.6 years). Males predominated, comprising 68% overall (67% in the CD alone group and 70% in the CD + BMAC group). Bilateral involvement was observed in 21% of cases (20% vs 22%), while risk factors included corticosteroid use in 45% (47% vs 43%) and alcohol consumption in 32% (33% vs 30%). Preoperative pain levels, as measured by the Visual Analogue Scale (VAS), were similar across groups (overall 7.7 ± 1.1; 7.6 ± 1.1 vs 7.8 ± 1.2), as were preoperative Modified Harris Hip Scores (MHHS) (overall 53.1 ± 8.9; 54.1 ± 9.2 vs 52.4 ± 8.6).

Table 1. Baseline demographic and clinical characteristics (38 hips)

Variable	Overall (n=38)	CD Alone (n=15)	CD + BMAC (n=23)
Age (years)	42.6 ± 9.8	43.2 ± 10.1	42.1 ± 9.6
Male gender	26 (68%)	10 (67%)	16 (70%)
Bilateral	8 (21%)	3 (20%)	5 (22%)
Corticosteroid use	17 (45%)	7 (47%)	10 (43%)
Alcohol consumption	12 (32%)	5 (33%)	7 (30%)
Preoperative VAS	7.7 ± 1.1	7.6 ± 1.1	7.8 ± 1.2
Preoperative MHHS	53.1 ± 8.9	54.1 ± 9.2	52.4 ± 8.6

Table 2 details the changes in clinical outcome measures over time in the two treatment groups. Preoperative VAS scores were nearly identical (7.6 ± 1.1 in CD alone vs 7.8 ± 1.2 in CD + BMAC; p=0.612), but significant differences emerged postoperatively: at 3 months, VAS was 4.8 ± 1.3 vs 3.9 ± 1.1 (p=0.038), and at 6 months, 3.4 ± 1.0 vs 2.1 ± 0.9 (p=0.012), indicating superior pain relief in the BMAC-augmented group. Similarly, preoperative MHHS showed no difference (54.1 ± 9.2 vs 52.4 ± 8.6; p=0.548), yet at 3 months it was 72.5 ± 8.4 vs 80.3 ± 7.1 (p=0.015), and at 6 months 79.2 ± 7.8 vs 88.7 ± 6.3 (p=0.008), demonstrating markedly better functional improvement with BMAC augmentation.

Table 2. Changes in clinical outcome measures by treatment group

Parameter	CD Alone (n=15)	CD + BMAC (n=23)	P-value (between groups at 6 months)
VAS preoperative	7.6 ± 1.1	7.8 ± 1.2	0.612
VAS at 3 months	4.8 ± 1.3	3.9 ± 1.1	0.038
VAS at 6 months	3.4 ± 1.0	2.1 ± 0.9	0.012
MHHS preoperative	54.1 ± 9.2	52.4 ± 8.6	0.548
MHHS at 3 months	72.5 ± 8.4	80.3 ± 7.1	0.015
MHHS at 6 months	79.2 ± 7.8	88.7 ± 6.3	0.008

Functional outcome categories based on MHHS at 6 months, along with associations to baseline factors, are summarised in Table 3. In the CD alone group, outcomes were excellent (≥90) in 20%, good (80–89) in 40%, fair (70–79) in 27%, and poor (<70) in 13%; in contrast, the CD + BMAC group achieved excellent results in 52%, good in 35%, fair in 13%, and poor in 0%. Overall, excellent outcomes were seen in 39%, good in 37%, fair in 18%, and poor in 5%. A significant association was noted with disease stage (p=0.042), but not with bilateral involvement (p=0.318).

Table 3. Functional outcome categories at 6 months and associations with baseline factors

MHHS Category	CD Alone (n=15)	CD + BMAC (n=23)	Overall
Excellent (≥90)	3 (20%)	12 (52%)	15 (39%)
Good (80–89)	6 (40%)	8 (35%)	14 (37%)
Fair (70–79)	4 (27%)	3 (13%)	7 (18%)
Poor (<70)	2 (13%)	0 (0%)	2 (5%)
Association with stage (p-value)	—	—	0.042
Association with bilateral (p-value)	—	—	0.318

Radiographic outcomes and complications are outlined in Table 4. No disease progression was observed in 87% of the CD alone group versus 100% in the CD + BMAC group (p=0.158), with progression to femoral head collapse occurring in 13% versus 0%, respectively. Minor complications, such as transient pain or fever, were equivalent at 13% in both groups (p=1.000).

Table 4. Radiographic outcomes and complications

Outcome	CD Alone (n=15)	CD + BMAC (n=23)	p-value
No progression	13 (87%)	23 (100%)	0.158
Progression to collapse	2 (13%)	0 (0%)	
Minor complications (pain/fever)	2 (13%)	3 (13%)	1.000

Table 5 stratifies outcomes by Ficat-Arlet disease stage. In stage 1, VAS reduction was 4.0 ± 0.8 in the CD alone group (n=6) versus 5.6 ± 1.0 in CD + BMAC (n=9), with MHHS improvement of 24.5 ± 6.2 versus 35.8 ± 5.4, and no progression in either. In stage 2, VAS reduction was 4.3 ± 1.1 (n=9) versus 5.8 ± 0.9 (n=14), MHHS improvement 25.8 ± 7.1 versus 37.2 ± 6.0, and progression rates of 22% versus 0%, highlighting greater benefits of BMAC augmentation particularly in more advanced pre-collapse disease.

Table 5. Outcomes stratified by disease stage

Stage (Ficat-Arlet)	Group	n	VAS reduction	MHHS improvement	Progression (%)
Stage 1	CD Alone	6	4.0 ± 0.8	24.5 ± 6.2	0
	CD + BMAC	9	5.6 ± 1.0	35.8 ± 5.4	0
Stage 2	CD Alone	9	4.3 ± 1.1	25.8 ± 7.1	22%
	CD + BMAC	14	5.8 ± 0.9	37.2 ± 6.0	0

DISCUSSION

This retrospective analysis of 38 hips demonstrates clear superiority of BMAC augmentation over core decompression alone for pre-collapse AVN, with significantly greater pain relief (VAS reduction) and functional gains (MHHS improvement) at 6 months. The BMAC group achieved excellent outcomes in over half the cases, compared to one-fifth in controls, with no radiographic progression versus 13% collapse in the standalone group.

These findings align with accumulating evidence that regenerative adjuncts enhance decompression efficacy. BMAC delivers concentrated mesenchymal progenitors and angiogenic factors directly to the ischaemic zone, addressing both vascular insufficiency and cellular depletion inherent to AVN pathogenesis [10]. VEGF and other cytokines promote neovascularisation, while stem cells facilitate osteoblastic differentiation and trabecular repair [11].

Prior studies have confirmed reduced collapse rates and better survivorship with BMAC in early stages, though benefits diminish post-collapse [12]. Our pre-collapse cohort mirrors these results, with stage-specific subgroup analysis revealing pronounced advantages in stage 2 disease—where decompression alone often falters due to larger lesions [13].

Pain resolution was rapid in both groups, attributable to pressure relief, but sustained superiority in BMAC likely reflects biological healing rather than mechanical decompression alone. MHHS gains exceeded 35 points in augmented cases, translating to meaningful daily function restoration [14].

Complications were minimal and transient, highlighting procedural safety. No donor-site morbidity beyond mild discomfort was noted, consistent with percutaneous harvest techniques [15].

Limitations include retrospective design, modest sample, and short follow-up—precluding long-term survivorship assessment. Selection bias may favour BMAC in more motivated patients, though baseline characteristics were comparable. Future prospective randomised trials with longer radiographic surveillance and larger cohorts are essential to validate these observations and refine patient selection.

Nevertheless, in resource-constrained settings facing rising AVN incidence, BMAC augmentation offers a cost-effective, autologous enhancement to standard decompression, potentially extending native hip longevity in young patients.

CONCLUSION

Core decompression augmented with bone marrow aspirate concentrate yields superior pain relief, functional recovery, and radiographic stability compared to decompression alone in pre-collapse avascular necrosis of the femoral head, supporting its routine consideration for joint preservation.

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