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Original Research Article

ANALYSING THE OUTCOME OF AVASCULAR NECROSIS OF FEMORAL HEAD TREATED BY CORE DECOMPRESSION WITH PRP INJECTION AND BONE GRAFTING.

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Abstract

Background: Femoral head is the most common bone affected by avascular necrosis. Core decompression procedure, when done in the initial stages, before collapse, may arrest or reverse the progress of avascular necrosis and thereby may preserve the normal femoral head. Hence, we have analysed the clinical, functional and radiological outcome of core decompression with PRP injection and bone grafting in patients with Osteonecrosis of the femoral head (ONFH) upto stage IIB (Ficat & Arlet).

Materials and method: A study was undertaken at our institute from June 2017 to June 2020 wherein 15 patients (18 hips) of ONFH upto grade II B (Ficat & Arlet) were treated with core decompression and the outcomes were studied. Patients were subjected to core decompression of the affected hip. Patients were operated in supine position. In 16/18 hips, cancellous grafting was done after harvesting graft from the posterior iliac crest. In 2 patients cortical non-vascularised fibular graft was used. PRP injection in all patients.

Results: Functional outcome was assessed by Harris hip score, wherein 12 hips (67%) had good or excellent outcome; 1 hip (5.6%) had fair outcome, However 5 hips (27.8%) showed poor result. In stage I, 7/8 hips (87.5%) improved, whereas in Stage IIA, 4/7 hips (57.14%) showed improvement and in stage IIB only 1/3hips (33.33%) showed improvement. Less than 25% of the hips required a replacement or salvage procedure. Strict non weight bearing was compliant by 15 hips (83.33%), whereas 3 hips (16.7%) were not compliant.

Conclusion: Core decompression with bone grafting and PRP injection provide satisfactory outcome when patients are carefully selected in early stages of the disease.

Keywords- Osteonecrosis of femoral head(ONFH), Ficat & Arlet, PRP injection.

Introduction

Avascular necrosis (AVN) is defined as a cellular death of bone components due to interruption of blood supply. The bone structures then collapse, resulting in bone destruction, pain, and loss of joint function.[1] Certain bones have precarious blood supply; hence even a small vascular insult can result in avascular necrosis of the part supplied by it. The head of femur is the most common bone affected by avascular necrosis. Clinically the pain may be minimal at onset, but if no active intervention is done it may worsen gradually, affecting the activities of daily living.

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It affects young population and if not managed timely, leads to the collapse of femoral head eventually requiring hip arthroplasty.

Avascular necrosis of femoral head (ONFH) is associated with many etiological factors and usually one or more risk factors are present but approximately two-thirds of this is related to alcohol abuse and corticosteroid intake. Rest are mainly idiopathic.[2] The rationale for the use of core decompression is based on the concept that increased intra-medullary pressure is involved in the pathogenesis of avascular necrosis. Thus by core decompression, creeping substitution to the necrotic area occurs by bringing the blood supply through the drilled channels thereby decreasing the intra-medullary pressure. This may arrest or reverse the progress of avascular necrosis before the collapse occurs thereby avoiding articular collapse and its sequelae. Hence when acted, vigilantly at initial stages before collapse occurs, core decompression may preserve the normal femoral head.
In this study, we have analysed the clinical, functional and radiological outcome of core decompression and bone grafting in patients with ONFH upto stage IIB (Ficat & Arlet).

Materials and method
The current study was undertaken at our institution from June 2017 to June 2020 wherein 15 patients (18 hips) of AVN of femoral head upto grade II B (Ficat & Arlet) were treated with core decompression. Patients with sickle cell disease were excluded as these patients are expected to have recurrent vascular infarcts thereby nullifying the principle of core decompression.

The patients meeting the inclusion criteria were evaluated in terms of age, sex, occupation, pain with its detailed characteristics, limp, duration of symptoms, progression of symptoms, deformity, support required to walk or not, any history of trauma and history of other joint pain. History of risk factors like steroids and alcoholism was also noted. They were thoroughly examined for their pre-operative hip range of movement as well as their debility and their Harris hip score was noted. They were also investigated by routine blood investigations (complete hemogram, ESR, CRP, liver and kidney function tests) and radiologically by hip AP and Frog leg view X-rays and MRI of both hips to know the amount of involvement of the femoral head, stage the disease as well as to check the status of contralateral hip. It also helped to map out the affected areas of the hip.

Following adequate explanation about the procedure and necessary consent, patients were subjected to core decompression of the affected hip. Patients were operated in supine position and guide-wire was inserted through lateral cortex just below the base of greater trochanter under image intensifier. Based on primary mapping of the affected area in head and under image intensifier guidance, the guide pin was directed towards the affected area. Confirming position of the guide pins in both AP and lateral views (taken by keeping the leg in flexion, abduction and external rotation), serial reaming was done by DHS reamer to scrape out the necrotic sclerotic part.

The affected part being sclerotic was harder to scrape out as compared to the normal bone and this gives an indirect confirmation of the affected area. The margins of the core created were thereafter curetted till normal feel of the bone is achieved and confirmed under image intensifier. The core thus created was filled by bone grafts. In 16/18 hips, cancellous grafting

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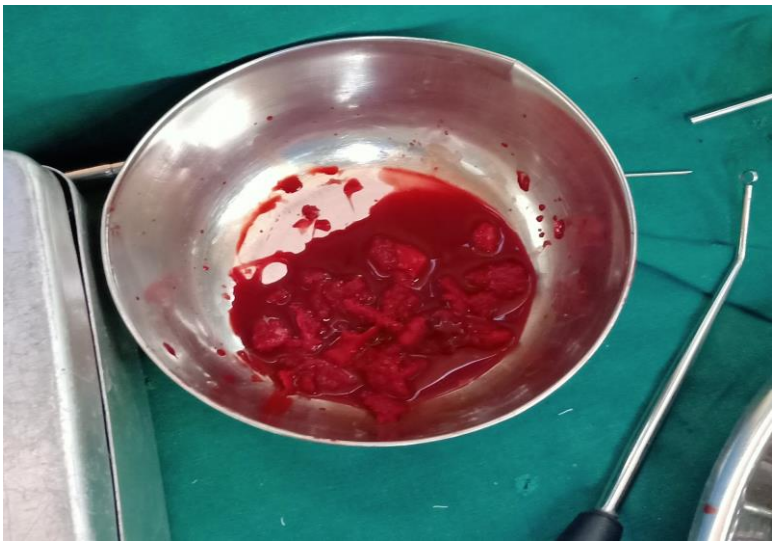
was done after harvesting graft from the posterior iliac crest. PRP injection was given to the patients.

Cancellous bone graft has both osteogenic as well as osteo- inducing properties, thereby facilitating the scaffold for new bone formation. However, in 2 patients cortical non-vascularized fibular graft was used to provide mechanical support. However, decision of the type of graft was purely surgeon based.

Patients were advised strict non weight bearing for atleast 3 months though hip range of movement exercises in bed were started from 2nd post-operative day as per pain tolerance.
The patients were followed at an interval of 1, 3 and 6 months post-operatively and at the latest follow up were re-evaluated clinic-radiologically by X-rays. Weight bearing was started after 3 months only after the void in the femoral head showed new bone formation. If patient agreed, a repeat MRI was done at 6 months or later to compare the outcome of core decompression. The outcomes were judged based on Harris hip score.

Patient placed supine on the fracture table in semi lithotomy position



Illac crest bone grafting

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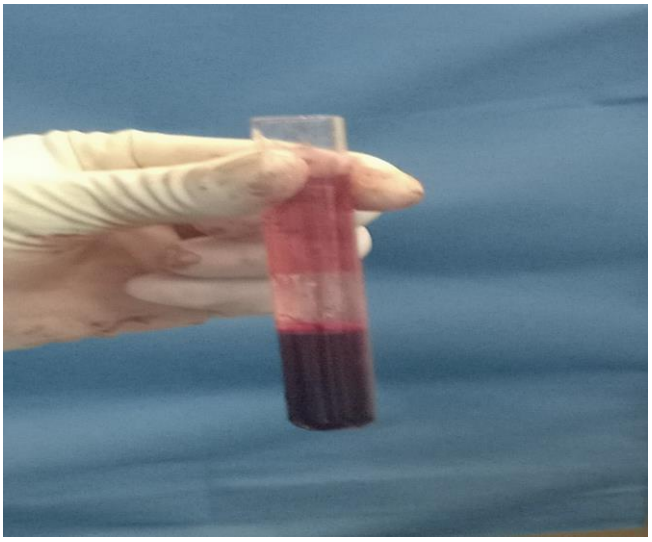

PRP prepared.

Results

There were 15 patients in our study, out of which 11 (73%) were with bilateral and 4 (27%) with unilateral involvement (total number of hips involved with ONFH were 24). 6 out of 24 hips with stage 3 or 4 ONFH were excluded, leaving 18 hips. Male (80%): Female (20%) ratio was 4:1. Majority of patients (60%) found in our series were chronic alcoholics. A majority of patients (53.57%) had encountered difficulties in daily living. There were 8 hips (44.44%) of Ficat & Arlet grade I, 7 hips (39%) of grade IIA and remaining 3 hips (16.7%) were grade IIB (Table 1).

Table 1 – Distribution of patients according to grade of ONFH.		
	X-ray	MRI
Normal	8 (44.44%)	
Grade I		8 (44.44%)
Grade II A	7 (38.89%)	7 (38.89%)
Grade II B	3 (16.67%)	3 (16.67%)
Total	18	18

The procedure adopted in 16 hips (89%) was core decompression and cancellous bone grafting. Remaining 2 hips (12%) were treated with core decompression and fibular grafting.

Alcohol consumption contributed in majority of patients 8/13 (62%) for AVN. 1 patient had AVN following long term steroid use and 1 had HIV infection (stage 3). Whereas, no contributing cause was found in 3/13 patients.

9/13 presented within 6 months of onset of pain. Majority of presenting patients had more restriction of cross leg sitting (8/13) and squatting (9/13) as compared to climbing stairs (6/13). 10/18 hips had flexion $>90^0$ but extension was restricted in >78% hips (14/18). Similarly, almost half of the hips (8 hips) had significant restriction of abduction (less than 30^0) and 14/18 hips had appreciable restriction in adduction (less than 20^0). Also two-thirds of the presenting hips had appreciable restriction in internal rotation, both in flexion (13/18) and

extension (12/18), which was less than 10^0 and 14/18 hips had appreciable restriction ($<30^0$) in external rotation in flexion and 12/18 had in extension (Table 2).
All 8 hips which were diagnosed as grade I in MRI appeared completely normal on X-ray. However AVN of higher grade II A and B had similar representation in both X-ray and MRI

Table 2 - Range of movements of hip.

Degree	On presentation				3 Months				6 Months				Final follow-up			
	F	E	AB	AD	F	E	AB	AD	F	E	AB	AD	F	E	AB	AD
0–"10		14		5		14		5		14	1	5		15	1	5
11–20		4	2	9		4	2	8		4	2	6		3	2	6
21–30			6	4			4	5			2	7			2	7
31–40			8				10				10				10	
41–50			2				2				3				3	
51–60					1				1				1			
61–70	3				2				2				2			
71–80																
81–90	5				5				5				5			
91–100	8				8				8				8			
101–110	1				1				1				1			
111–120	1				1				1				1			
Total	18	18	18	18	18	18	18	18	18	18	28	18	18	18	18	18

Table 3 - Range of internal and external rotation of hip.

Degree	On presentation				3 Months				6 Months				Final follow-u]			
	IR		ER		IR		ER		IR		ER		IR		ER	
	F	E	F	E	F	E	F	E	F	E	F	E	F	E	F	E
0–10	13	10	4	2	9	3	2	2	7	3	1	2	7	3	1	2
11–20	4	6	6	7	8	11	7	6	8	11	8	6	8	11	8	6
21–30	1	2	4	3	1	4	3	2	3	3	3	2	3	3	3	2
31–40			2	6			5	6		1	5	6		1	5	6
41–50			2				1	2			1	2			1	2
Total	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

16 hips were treated with core decompression with cancellous bone graft. However in 2 patients non-vascularised fibular strut graft was used instead of cancellous grafts. Both of them were of type II B. However the decision was solely surgeon based. 4 patients having grade 3 and 4 AVN in contralateral hip were treated with replacement surgery. Average follow-up of 13 patients was upto 11 months.
Majority of the patients (10) were immobilized for atleast 12 weeks. However, 3 patients being non-compliant started weight bearing earlier. Out of 18, 16 hips had pain relief immediately after operation. In follow-up at 3 months, 14 hips had complete pain relief and at 6 months and final follow-up 12 had no pain. So it suggests that majority of patients (67%) had pain relief after the procedure.

Out of 18 hips, though 17 hips had internal rotation (in flexion) of less than 20^0 at 3 months of follow-up, 4 patients showed appreciable improvement at final follow-up. Similar improvement was also seen in 3 hips having less than 10^0 internal rotation in extension at final follow-up. In 3 patients who had less than 30^0 of external rotation (in flexion) at 3 months

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improvement was seen at final follow-up. Appreciable improvement was also seen in 2 hips that had less than 30^0 of external rotation in extension (Table 3).
Out of 18 hips, 4 hips (22%) showed collapse at 3 months. 1 more hip worsened at 6 months follow-up. Thus at final follow-up 5 hips had collapse and worsening.
Out of 18 hips, though 12 hips had no complication, 5 hips showed further advancement of the disease resulting into arthritis. One hip had superficial infection initially which subsided after debridement According to Harris hip score, 12 hips (67%) had good or excellent outcome whereas 1 hip (3.57%) had fair outcome. However 5 hips (27.8%) showed poor result. For stage I, out of 8 hips, 7 hips (87.5%) improved, whereas for Stage IIA, out of 7 hips, 4 hips (57.14%) showed improvement and for stage IIB, out of 3 hips only 1 hip (33.33%) showed improvement (Table 4). Also 3 patients who had low pre-operative Harris hip score (<60), did not improve but worsened.

Table 4 – Harris hip score distribution.

Harris hip score	Pre-operative	Final follow-up
0–10		
11–20		2
21–30		
31–40		
41–50	1	1
51–60	1	0
61–70	10	3
71–80	4	1
81–90	2	6
91–100		5
Total hip	18	18

Strict non weight bearing was complied by 15 hips (83.33%),whereas 3 hips (16.7%) were not compliant. If we exclude non- compliant patients, our success rate was 87.50% for grade I, 100% for grade IIA and 33.33% for grade IIB.
Thus, based on Harris hip score system, overall out of 18 hips, 13 hips improved and average Harris hip score of those 13 hips was 71.18 (pre-operative) which was increased to 88.23 at final follow-up. Remaining 5 hips did not show improvement. Their score was 58.03 (pre-operative) and 47.68 at final follow- up, which showed deterioration (Fig. 1a–d).

Discussion

In our study, most of the patients were under the age group of 20–40 years (75%) while rest of them were from the age group 41–50 years (25%). From the above data, it suggests that almost all the patients are from young age group. Similar results were also found in various other studies.3–5 Males were more commonly affected (80%) as compared to females (M:F- 4:1). Similar results were also shown in the study of Babhulkar et al where 81.25% were males.[6]
In our study, out of 15 patients, 4 (27%) had unilateral involvement and rest 11 (73%) had bilateral involvement. According to Bradway JK and Kozinn, incidence of bilaterality ranges from 6 to 72%, where as Mankin and Brower report an incidence from 20 to 80%.[6] As the risk factors of alcohol abuse, steroids intake and HIV have systemic effect, there are comparatively more chances of bilateral involvement.

According to Shannon and Trousdale, most non traumatic cases of femoral head AVN, the disease is often bilateral, due to risk factors like long term corticosteroid use, alcohol abuse and

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sickle cell disease.6 Out of 24 hips, 6 hips were not considered as they had grade III & IV of AVN (FICAT & ARLET classification). So, only 18 hips were included in our study
In our study, 8 (61%) patients were alcoholic, out of whom 1 was HIV positive and other 1 was taking steroids (for skin disease), remaining 5 (39%) patients had idiopathic AVN. This also shows that chronic alcoholism contributes to development of AVN more than other risk factors. Correlating facts were also observed in Babhulkar et al where approximately more than half cases were related to alcohol abuse.[6]

Out of 15 patients, 11 patients (73%) had bilateral involvement. Out of 11 patients, 5 patients were asymptomatic clinically and were diagnosed only on MRI. Remaining patients had pain bilaterally.

Activity of daily living were affected in 10 (55.55%) out of 18 hips. Even in early stage of AVN the daily activities of the patients were affected. On the basis of overall review cross leg sitting and squatting is more difficult for patients as compared to stair climbing.
For the diagnosis and staging of AVN, X-rays and MRI were routinely performed. According to classification of Ficat and Arlet, in our study 8 hips (44.44%) were normal on X-rays but showed in MRI as grade I. Out of 18 hips 7 (38.9%) of them were graded as IIA on X-ray as well as on MRI. Remaining 3 hips (16.7%) were diagnosed as grade II B on X-ray as well as on MRI (Fig. 2a–d).

This clearly brings out the fact that X-ray may not be of much help in diagnosing AVN in Stage I. However it is at par with MRI as far as stage IIa and II b is concerned. MRI is more significant as compared to X-rays especially in diagnosing stage I AVN in normal looking contralateral hip on X-ray.
The minimum follow-up was 6 months whereas the maximum follow-up was of 24 months and our average follow-up was 11 months.

Core decompression procedures showed improvement in results in patients who had abduction more than 30^0 and adduction more than 10^0. Moreover it also showed more improvement for internal rotation (hip flexion and extension) in comparison with external rotation.
Out of 18, majority had pain relief immediately following operation but as time passed deterioration was seen. At 3 months, 14 hips (77.8%) had pain relief but only 12 hips (67%) had pain relief at final follow-up. So it suggests that majority of patients (67%) had pain relief after procedure. Out of 18 hips, 1 hips (5.26%) that had started early weight bearing before 3 months had mild pain. However our follow-up is not long enough to comment on long term pain relief. According to Babhulkar et al, 6 patients (19%) had residual pain around 24 weeks following surgery.[6] In literature, most of the authors have noted immediate pain relief after core decompression other than Saito et al.

As per our protocol, the common practice was to immobilize patient for 14 weeks in bed so that patient remains non weight bearing and compliant. However 3 hips did not comply with the requirement. 1 of them started weight bearing immediately after surgery whereas 1 started after 4 weeks and another at 6 weeks of surgery. Those 3 hips (16.67%) that were not immobilised adequately had collapse of femoral head. From the remaining 15 hips, 12 hips (80%) were successfully prevented from collapsing. This could be because once core decompression is done, the femoral head would require

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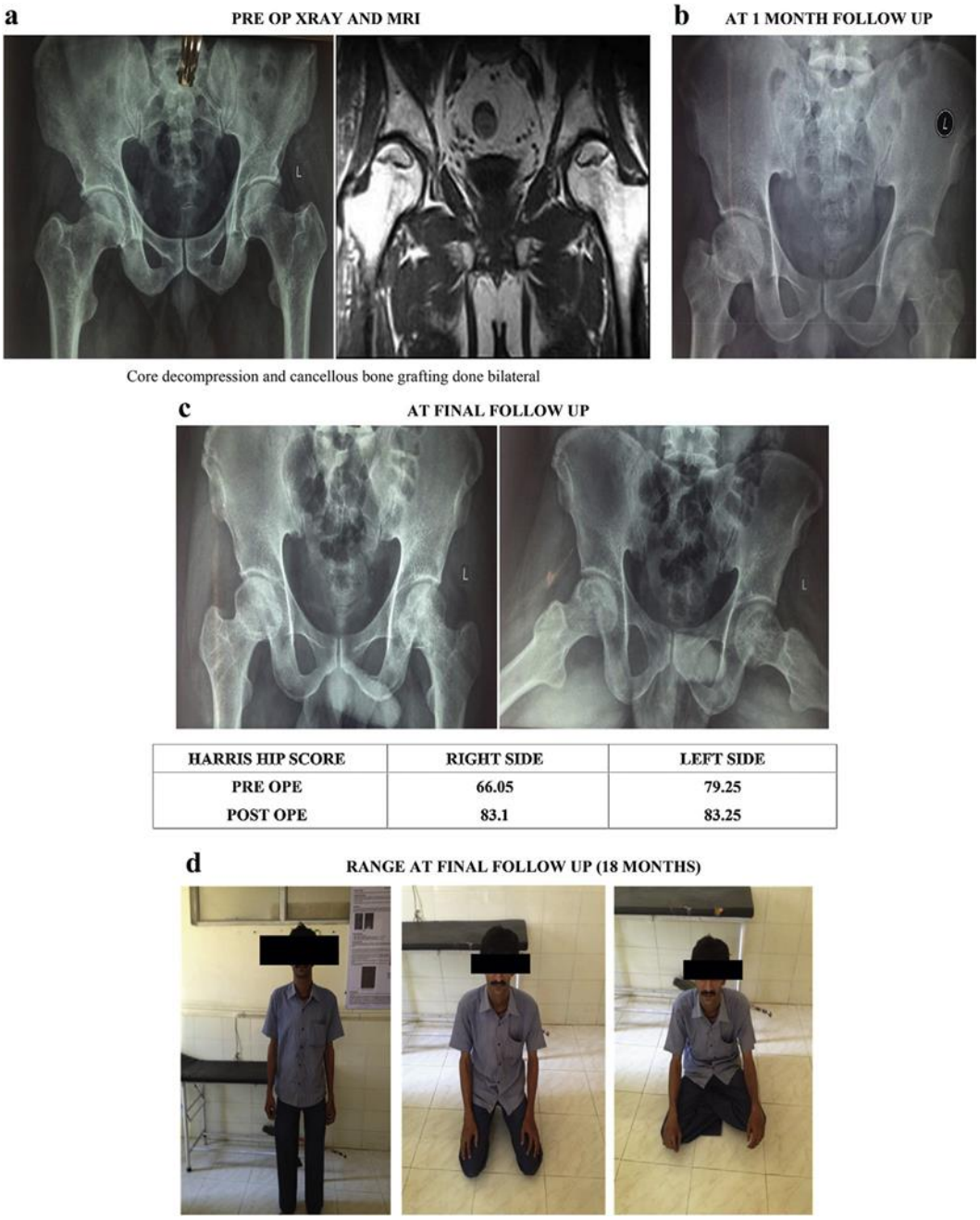

Fig. 1 – 32 yr/M/farmer/pain in Rt hip since 7 months, Lt hip asymptomatic/diagnosed as bilateral AVN grade IIA on Rt side and grade I on Lt side.

Adequate time for regeneration. Hence if weight bearing is started before adequate bone formation, it might lead to collapse of the femoral head under stress. Adequate immobilisation (at least 3 month post-operatively) for AVN patients treated with core decompression for incorporation of the graft and new bone formation is therefore suggested. Similarly, in study by Babhulkar et al, patients were allowed partial weight bearing after 10 weeks and full weight bearing after 14–16 weeks depending upon the incorporation of graft.[6]

Out of 18 hips, 4 hips (22.22%) showed the collapse at 3 months where as 14 hips didn't show any collapse. Whereas 2 more hips showed collapse at 6 months following initiation of weight bearing. Similar results were also found in study by Carlos et al wherein radiographic progression from pre- collapse to collapsed stage occurred in 21 hips (36.8%) out of 57 hips.[7]

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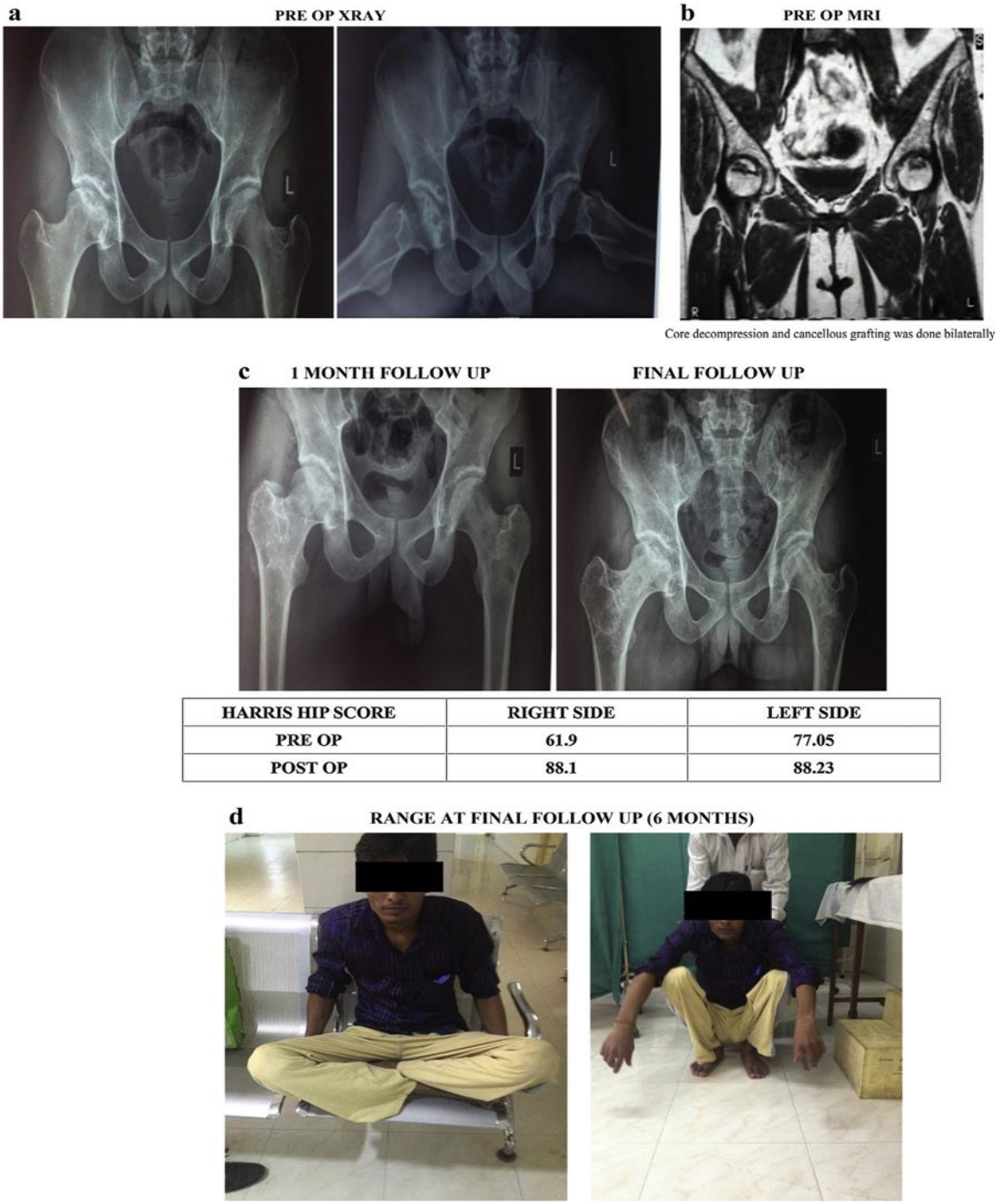
So it clearly suggested that if worsening occurs it occurs within 6 months only, thereafter no worsening ensues. However our follow-up was too short to comment on this observation.
Out of 18 hips, though 12 hips had no complication, 5 hips (27.78%) showed further advancement of the disease resulting into arthritis and 1 patient had superficial infection which subsided after thorough debridement. Out of 5 patients who had progressed to arthritis, 3 of them had started early weight bearing.



HARRIS HIP SCORE	RIGHT SIDE	LEFT SIDE
PRE OP	61.9	77.05
POST OP	88.1	88.23

Fig. 2 – 24 yr/M/farmer/pain on Rt hip since 1 year, Lt hip asymtomatic/diagnosed bilateral AVN on MRI (grade IIB on Rt side and grade I on Lt side).

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If we exclude 3 hips (all had stage IIA) which worsened due to non compliance, our outcome changes significantly. For stage I, out of 8 hips, 7 hips (87.50%) improved, whereas all 4 hips of Stage IIA, (100%) showed improvement. However in stage IIB, out of 3 hips only 1 hips (33.33%) showed improvement. Thus over all 5 hips (71.43%) were improved out of 7 hips of grade II.`

A Meta analysis of 24 reports analysing 1206 hips treated by core decompression with or without cancellous bone grafting revealed an overall clinical success rate of 63.5%. Less than 33% of the hips required a replacement or salvage procedure during the follow-up period.[8]

Ficat reviewed the results of core decompression in 133 patients with ON of the hip (average follow-up, 9 years, 6 months) and reported a successful clinical result in 90% with no radiographic progression in 79% of the patients.[9]

In 1986, Camp and Colwell reported the results of core decompression in 25 hips. At an average follow-up of 18 months, the success rate for stage I was 37.5% (3 of 8); for stage II, 45.5% (5 of 11); and for stage III, 0% (0 of 6).[10]

Smith et al 1995 reported their results in 114 patients (follow-up, 40 months) using the modified Ficat staging system. They reported a success rate of 84% (27 of 32) for stage I, 47% (18 of 38) for stage IIA (same as Ficat II), 20% (5 of 20) for stage IIB (crescent sign), and 0% (0 of 19) for stage III (collapse of the femoral head).11 Our results are similar to Ficat and Smith but differ from that of Camp and Colwell.

Conclusion

Although our series is small we suggest that MRI grading along with clinical features put together can give accurate prognosis for the outcome when treated with Core decompression with bone grafting and PRP injection that may provide satisfactory result when patients are carefully selected.

References

1. 1. Mont MA, Hungenford DS. Non traumatic osteonecrosis of the femoral head: ten year later-current consepts review. J Bone Joint Surg Am. 2006;88:1107–1129.
2. Bradway JK, Morrey BF. The natural history of the silent hip in bilateral atraumatic osteonecrosis. J ARTHROPLASTY. 1993;8:383–387.
3. Glimcher MJ, Kenzora JE. The biology of osteonecrosis of the human femoral head and its clinical implications: part III, discussion of the etiology and genesis of the pathological sequelae; comments on treatment. Clin Orthop RELAT Res. 1979;140:273–312.
4. Mankin HJ, Brower TD. Bilateral idiopathic aseptic necrosis of the femur in adults: a Chandler's disease. Bull Hosp Joint Dis. 1962;3:23.
5. Shannon BD, Trousdale RT. Femoral osteotomies for avascular necrosis of the femoral head. Clin Orthop RELAT Res. 2004;418:34–40.
6. Babhulkar di. Osteonecrosis of femoral head: treatment by core decompression and vascular pedicle grafting. INDIAN J Orthop. 2009;43:27–35.
7. Lavernia Carlos Jro, Sierra Rafael Jfe. Core decompression in atraumatic osteonecrosis of the hip. J ARTHROPLASTY. 2000;15:.
8. Mont MA, Carbone JJ, Fairbank AC. Core decompression vs. non-operative management for avascular necrosis of the femoral head. Clin Orthop RELAT Res. 1996;324:169–178.
9. Ficat RP. Idiopathic bone necrosis of the femoral head: early diagnosis and treatment. J Bone Joint Surg. 1985;67B:3–9.
10. Camp JF, Calwelf CW. Core decompression of the femoral head for osteonecrosis. J Bone Joint Surg Am. 1986;68:1313–1319.

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11. Smith SW, Fehning TK, Griffin WL, Beaver W. Core decompression of the osteonecrotic femoral head. J Bone Joint Surg Am. 1995;77:674.
12. Yan ZQ, Chen YS, Li WJ, et al. Treatment of osteonecrosis of the femoral head by percutaneous decompression and autologous bone marrow mononuclear cell infusion. Chin J Traumatol 2006;9:3.
13. Daltro GC, Fortuna VA, Salvino de Araújo SA, et al. Femoral head necrosis treatment with autologous stem cells in sickle cell disease. Acta Ortop Bras 2008;16:44.
14. Hernigou P, Poignard A, Zilber S, et al. Cell therapy of hip osteonecrosis with autologous bone marrow grafting. Indian Journal Orthop 2008;43:40.
15. Hernigou P, Habibi A, Bachir D, et al. The natural history of asymptomatic osteonecrosis of the femoral head in adults with sickle cell disease. J Bone Joint Surg Am 2006;88–12:2565.
16. Mitchell DG, Steinberg ME, Dalinka MK, et al. Magnetic resonance imaging of the ischemic hip: alterations within the osteonecrotic, viable and reactive zones. Clin Orthop Relat Res 1989;244:60.
17. Koo KK, Dussayult RG, Kaplan PA, et al. Fatty marrow conversion of the proximal femoral metaphysis in the osteonecrotic hips. Clin Orthop Relat Res 1995;361:159.
18. Hernigou P, Beaujean F, Lambotte JC. Decrease in the mesenchymal stem-cell pool in the proximal femur in corticosteroid-induced osteonecrosis. J Bone Joint Surg Br Vol 1999;81:349.
19. Tzaribachev N, Vaegler M, Schaefer J, et al. Mesenchymal stromal cells: a novel treatment option for steroid-induced avascular osteonecrosis. IMAJ 2008;10:232.
20. Song S, Zhu S, Sun C. Treatment of avascular necrosis of femoral head by periosteal cell transplantation: an experimental study. Zhonghua Yi Xue Za Zhi 1998;52:8.
21. Sen RK, Tripathy SK, Aggarwal S, et al. Early results of core decompression and autologous bone marrow mononuclear cells instillation in femoral head osteonecrosis: a randomized control study. J Arthroplasty 2012;27(5):679.
22. Lim Young Wook, Kim Yong Sik, Lee Jong Wook, et al. Stem cell implantation for osteonecrosis of the femoral head. Exp Mol Med 2013;45:61