Modified technique of percutaneous core decompression with flexible reamers and percutaneous iliac bone graft harvesting for treatment of femoral head osteonecrosis

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Abstract
Avascular necrosis of the femoral head (ANFH) is a debilitating disease most commonly affecting young and middle-aged people. Most often leading to a significant articular disability ultimately needing total hip replacement. Early diagnosis and effective joint-preserving surgical treatments are urgently needed for patients with early stage ANFH. We would like to report a minimally invasive modified technique of percutaneous core decompression using flexible reamers and percutaneous iliac bone graft harvesting for treatment of early stage of femoral head osteonecrosis.

Keywords: Osteonecrosis of the femoral head, avascular necrosis hip, flexible reamer for core decompression, percutaneous bone graft with hollow mill

Introduction
Avascular necrosis of the femoral head is a destructive condition most commonly affecting young and middle-aged people. This often progresses to femoral head collapse and often requires total hip arthroplasty [1, 4]. Even though exact etiology is still unclear, the risk factors have been well documented in the literature and they are chronic corticosteroid administration, chronic alcohol ingestion, smoking, and various chronic diseases (renal disease, hematological disease, inflammatory bowel disease, post organ transplantation, hypertension, and gout) [5, 6].

Clinically early stages of AVN are painless which on progression will result in severe groin associated with limitation of hip movement and collapse of femoral head ultimately leading to hip arthritis [5, 6]. There are many treatment options in early stages of disease before head collapses including nonsurgical, pharmacological and surgical treatments. However, there is little evidence on supporting nonsurgical treatment when the condition is identified in the early stages. Non weight bearing is often used for symptom relief but does not seem to alter disease progression [7, 8].

Pharmacologic treatments of AVN consist of bisphosphonates, anticoagulants, vasodilators, statins, and biophysical modalities like ESWL, ultrasound were also reported [9]. Bisphosphonates are indicated up to the stage of early collapse. They inhibit the osteoclastic activity in the osteonecrotic lesion site, thus promoting bone healing and preventing collapse or fracture of subchondral bone [10, 11]. Commonly studied bisphosphonate is oral alendronate, and is reported to be effective in reducing the collapse rate over 50% compared to the placebo groups at doses of 10 mg/day or 70 mg/wk [12]. The current state of nonsurgical treatment options for ANFH is still in experimental stage.

The most common surgical treatment is core decompression for early stage disease. Of late core decompression with bone grafting (with or without adjuvants) is being followed. THA is the main stay of treatment for advanced stage of ANFH and in whom conservative or joint-preserving surgical treatments have failed. THA has excellent outcomes in terms of pain relief, survivorship and quality of life [2, 4, 13]. However, young patients with ANFH who has undergone THA are most likely to experience implant loosening and revision surgery in their lifetime [14]. Therefore, the most suitable time to intervene is the early stage of the disease.
ARCO classification stage 1 and 2. The ideal goal of early stage treatment is to postpone or stop the progression of the disease before the mechanical failure of the subchondral bone and collapse of femoral head. A consensus has been reached that joint preserving surgeries should be followed for early stage and arthroplasty for advance stage [15].

Core decompression is a joint-preserving surgical treatment that aims to improve blood flow and decrease intraosseous pressure for relieving pain. It promotes early healing prior to collapse, thereby potentially postponing or avoiding THA [4,16]. But studies have shown that the femoral head after simple decompression alone may not provide structural support and as a result, the risk of femoral head collapse increases [17,18]. Core decompression combined with bone grafting has been used to treat ONFH since the mid-twentieth century to prevent femoral head collapse by providing structural support and establishing a stable environment for the growth of new bone [19]. The clinical outcome of core decompression with bone grafting for early stage of ONFH has been confirmed [3]. Kong et al. [20] studied the outcome of percutaneous core decompression with bone grafting on ANFH. They concluded that this method can be used to effectively treat the early stage of ANFH. This treatment modality can also significantly relieve symptoms, improve movement of hip, and postpone or stop femoral head collapse. Zalavras et al. [3] treated 17 hips in 15 patients with core decompression with autologous bone graft, and allogenic fibula perfused with human bone morphogenetic protein and noncollagenous proteins. Through a mean follow-up of 53 months, 14 of 15 hips (93%) had relief of outcomes and no radiographic progression.

The aim of this article is to introduce a minimally invasive modified surgical technique of core decompression using flexible reamers and percutaneous iliac bone graft harvesting for early stage ANFH.

**Materials and Methods**

The clinical data of 23 patients and 23 hips diagnosed with ANFH were included in the study and treated with the procedure called percutaneous core decompression and percutaneous bone graft technique at santhiram general hospital from july 2017 to march 2021. All were prospectively analyzed; the follow-up ended in December 2021. The followup period was 2 yrs.

**Inclusion criteria**

1. All patients with the stage II of the ARCO classification system (figure 1), confirmed by MRI.
2. The boundary of avascular necrosis in the femoral head was clear
3. Good hip range of motion in order to maintain the requirements of intraoperative position.

**Exclusion criteria**

1. AVN following Trauma and metabolic diseases were excluded. 2. Bilateral AVN

The outcome was evaluated by the Harris hip score (HHS), visual analogue scale (VAS), radiography changes preoperative and postoperative.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Finding</th>
<th>Techniques</th>
<th>Sub-classification</th>
<th>Quantitization</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>All present techniques normal or nondiagnostic</td>
<td>X-ray; CT; Scintigraph; MRI: Quantitation on MRI</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>I</td>
<td>X-ray and CT are normal, at least one of the blew mentioned is positive</td>
<td>Scintigraph; MRI; Quantitation on MRI</td>
<td>LOCATION</td>
<td>Area involvement (%): minimal A: &lt; 15%; moderate B: 15%-30%; extensive C: &gt; 30%</td>
</tr>
<tr>
<td>II</td>
<td>No crescent sign, X-ray abnormal: Sclerosis, osteolysis, focal osteoporosis</td>
<td>X-ray; CT; Scintigraph; MRI; Quantitation on MRI and X-ray</td>
<td>central</td>
<td>Length of crescent (%): A: &lt; 15%; B: 15%-30%; C: &gt; 30%</td>
</tr>
<tr>
<td>III</td>
<td>Crescent sign or collapse on the X-ray and/or flattening of articular surface of femoral head</td>
<td>X-ray; CT; Quantitation on X-ray</td>
<td>lateral</td>
<td>Collapse and Dome depression: A: &lt; 15% / &lt; 2 mm; B: 15%-30% / 2-4 mm; C: &gt; 30% / &gt; 4 mm</td>
</tr>
<tr>
<td>IV</td>
<td>Osteonecrosis joint space narrowing, acetabular changes, joint destruction</td>
<td>X-ray</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

**Informed consent statement:** All participants provided written informed consent

**Surgical technique**

All surgeries were performed by single surgeon (author) with the patient supine on a traction table under spinal anesthesia. Best Entry point was determined under image intensifier guidance. A 2 cm skin incision given. Entry point was always above level of lesser trochanter. A 2.5 mm rigid guide wire drilled into the lesion area and confirmed in AP and Lateral views. Initially reaming done with 4 mm rigid reamer till top of lesion. serial reaming with 6, 7, to 8 mm reamers done till the base of the lesion only. Now the ACL (anterior cruciate ligament) femoral guide (stryker) introduced into the tunnel and flexible guide wire drilled into superior and lateral portion of lesion till top border of the lesion. Later serial reaming done with versitomic flexible reamer (stryker USA) starting from 4 mm till 9 mm depending on the size of the lesion. Now the ACL guide is reintroduced into inferior and medial direction and similar procedure is followed till almost entire sclerotic necrotic bone is removed. Residual sclerotic necrotic bone from edges of lesion can be curetted with 15 degree curette. All these steps must be performed under C-arm fluoroscopy in both AP and lateral views to make sure that the instruments were placed in the best possible position without damaging the articular cartilage and retaining the healthy bone as much as possible. The drilling channels were flushed using a combination of irrigation and suction. Finally, the lesion area and the surgical operation created bone defect were backfilled with graft. We take appropriate amount of cancellous bone and bone marrow aspirate (20ml) from the patient’s ipsilateral ilium thru 1.5cm incision by percutaneous
technique, using a 6mm hollow mill. First a 2mm k wire introduced to depth of 1 cm. Tap the hollow mill over k wire to prevent slipping from iliac crest. Hollow mill was drilled slowly till 3cm. Toggle it and reverse drill it out. Follow similar technique till optimum graft is obtained. We mix both autologous bone and tricalcium phosphate and bone marrow aspirate. After adding the BMA, the mixture was introduced into the lesion area and drill channels through a drill sleeve used for proximal lag screw locking of PFN. The mixture was tapped by a pestle. The incision was closed by the standard steps. After operation they were put on non-weight-bearing for 6 wk. and oral bisphosphonate, alendronate 70 mg weekly for 3 years to be continued.

Fig 2: The tools for the surgery (stryker), usa). A: 2.5 mm flexible guide wire; B: ACL femoral guide C: guide with guide wire D: rigid reamers E: flexible reamers; F:6.5mm hollowmill; G: PFN drill sleeve.

Fig 3: The main steps of the percutaneous core decompression and mixed bone graft technique under C-arm fluoroscopy. [A] 2.5 mmguide wire into the lesion area under image guidance [B] straight reamer 4mm; [C] The versitomic femoral acl guide in superolateral part; [D] flexible guide wire [E] 4mm flexible reamer [F] femoral guide in inferomedial aspect of lesion [G] residual lesion removal with curette.[H] Autologous bone from the ipsilateral ilium with hollow mill; [I]: Introduce the bone graft into the sleeve and punch with blunt end of steinmann pin.[ J] wounds closed.

Results
Total of 23 patients and 23 hips were included in the study during the study period of 3 years (2017-2021). Average age of the study population was 43 years ranging between 32-53 years. The study included 17 males (73.9%) and six females (26%). Regarding the risk factors of AVN, 13 were idiopathic and five were steroid induced, four alcoholic and one rheumatoid arthritis.

Mean surgical time was 50 min, and mean intraoperative bleeding was 70 ml. At 2 years follow up mean Harris hip score and VAS preoperatively were 37 and 8. After surgery mean HHS was 91 and VAS was 1. Post-operative x ray at latest follow up showed that the grafted bone was basically healed.

Since 2017, we have used this new modified technique in multiple patients, and gratifying results have been obtained from the comparison of HHS, VAS, and imaging examination before and after operation.

Discussion
ANFH leads to significant articular disability in young and middle aged people. It is due to osteocyte ischemia and necrosis, trabecular fracture, and femoral head collapse induced by a local blood circulation disorder of the femoral head due to various etiologies [3]. Without early diagnosis and effective intervention and treatment, most of the patients need a THA after 2 years due to femoral head collapse [17,24]. Current consensus is that THA is used just for advanced-stage ANFH in older patients or those who have failed joint-preserving treatment [25]. Therefore, a definite and effective joint-preserving surgical treatment is urgently needed for young and middle-aged patients with early stage ANFH.

Core decompression combined with bone grafting (with or without adjuvants) as a joint-preserving surgical treatment has been widely recognized before [3, 16, 26, 27, 28]. In recent years, studies also showed that patients with ARCO classification system stage II treated by Core decompression combined with autologous bone and BMA had good outcomes [29]. The usefulness of eliminating the necrotic bone and structural support by the adjuvant substances in the treatment of early ANFH has already been shown by other studies [3, 22, 30].

Core decompression was first introduced by Arlet and Ficat in 1964 and they reported “good to very good results” in 90% of these hips on clinical evaluation and in 79% on radiographic
evaluation [31]. Marker et al. in his meta-analysis documented that upto 30% of hips required THR at 3 years follow-up after core decompression [32]. Rajagopal et al. also reported the similar rate of conversion to THR and they pointed out that the results were better with stage 1 disease compared to other stages [33]. Core decompression was done by removing single 8-10 mm core removal to decompress the femoral head but it has been documented to be associated with complications like iatrogenic subtrochanteric fracture, inadequate decompression as well as risk of chondral injury [34, 35, 36, 37, 38]. Later multiple drill hole decompressions has been documented in the literature by different authors. Kim et al. compared multiple drilling with single core decompression and reported that statistically significant longer time for progression to collapse with multiple drilling techniques [35]. Other authors also obtained similar results with multiple drilling [36, 38].

Over the period of time, different methods have been documented in the literature to augment the results associated with core decompression. This includes use of mesenchymal stem cells (MSC), BMPs, bone grafting, nonvascularized cortical grafts, iliac artery pedicled graft, vascularised fibular graft etc [12, 13]. MSC from adult bone marrow are multipotent and have been documented to influence the bone repair in AVNF. Early functional and radiological results associated with use of MSC with core decompression has been reported to be encouraging even though the results of long term follow up is yet to be available [39, 40, 41]. Limitation associated with routine use of MSC is its isolation, purification and culture needs special machineries which may be available only at selected centres.

Core decompression with bone grafting has most favourable outcomes in many studies and in some could stop progression or could delay the necessity of THA in young patients. Many people used straight reamers and superolateral part is difficult to debride with straight reamers. If multiple entry points are made to target the lesion we will compromise on the lateral cortical bone and also we will remove the healthy bone adjacent to lesion if we use reamers more than 8mm, the healthy bone scaffolding effect may reduce. More healthy bone can be retained with flexible reamers with our technique we are precisely targeting the lesion and maximum lesion can be excised and preserving as much as healthy bone in the femoral neck and head. With our technique we can address more kerboul angle.

Our new method is to use flexible Acl reamers (stryker USA) so that the lesion can be removed more precisely and thoroughly. Residual necrotic lesions are removed by cleaning with a curved curettes. We use autologous bone from the ipsilateral ilium mixed with autologous bone marrow aspirate (BMA) and backfill the bone defects in the femoral head. Sometimes we harvest graft percutaneously with help of hollow mill from ipsilateral distal femoral condyle if more graft is needed. Ashraf. M et al. [42] described Micro-core decompression combined with intrallesional zoledronic acid as a treatment of osteonecrosis of femoral head. They reported mean postoperative modified Harris hip score at two years in stage I, stage IIa, stage IIb and stage III which were 97.3, 91.1, 88.4 and 82.5 respectively. They found that the use of multiple micro core-decompressions with intra-lesional bisphosphonate will provide higher chances towards hip preservation especially in late cases or cases with larger lesions where percutaneous core decompression may not be successful. The author has hypothesized that a higher concentration of bisphosphonate at the pathological site can bring better results compared to systemic administration. The author did safe surgical dislocation of femoral head for micro drilling and injecting zoledronic acid.

Landgraeb et al. [23, 29, 80] described advanced core decompression with expandable reamer and adjuvant substances. Wei kuan Gu et al. [43] used percutaneous expanded core decompression and mixed bone graft technique with grattifying results. Autologous bone graft has better biomechanical and biological properties than artificial bone graft and has all the requirements for good bone remodeling in terms of osteoconduction, osteoinduction, osteogenesis as well as osteointegration [49].

However, our new technique needs to be confirmed in more cases along with more detailed data comparison and further research. In the future, the research will also include age factors, Kerboul angle [45], and the size and location of lesions on the outcomes.

**Conclusion**

Technique of percutaneous core decompression with flexible reamers and percutaneous autologous iliac bone harvesting mixed with bone marrow aspirate and tricalcium phosphates is minimally invasive, simple, safe, and reliable and advantageous in terms of precise targeting lesion and bone preserving. More kerboul angle can be addressed. No serious perioperative complications were observed in our cases. The percutaneous technique of iliac bone graft harvesting is easy to obtain and less traumatic to patient. Thus, this technique is an effective joint-preserving surgical treatment for patients with early stage ANFH. It has less learning curve and inexpensive as well. We present it here in the hope that our other colleagues could perform and further demonstrate and verify its effectiveness.

**Pitfalls and future research perspectives**

1. Short follow up period. 2. Did not include bilateral AVN.3.We did not do MRI and CT post operatively and during follow up due to financial constrains.

Future research should demonstrate effect of age, gender, risk factors, Modified Kerboul angle [45], the size and location of lesions on the outcomes of this technique.

Mixing with allogenic bone graft and use of fibular strut in femoral neck and lateral cortex was not studied and may improve clinical outcomes much better than cancellous bone graft alone.

Core decompression combined with bone grafting mixed with BMA and zoledronic acid may be considered for future research.

**Conflict-of-interest statement**: The authors declare that they have no conflicts of interest.

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