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Device-assisted surgical treatment of avascular necrosis of the femoral head: Innovative approaches and clinical effectiveness

Ibragimov Ravshanbek Arzimatovich [1,*] and Shorustamov Mukhamad Todjalievich [2]

[1] *Head of the Department of Traumatology and Orthopedics, Sports Medicine. TOO Clinic "CITYMED" Shymkent, Republic of Kazakhstan,*
[2] *Head of the Department of Orthopedics. Tashkent Medical Academy Multidisciplinary Clinic Tashkent, Republic of Uzbekistan, Doctor of Medical Sciences,*

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Abstract

Avascular necrosis (AVN) of the femoral head is a debilitating condition predominantly affecting young, active individuals. Traditional surgical approaches such as total hip arthroplasty (THA) face limitations due to prosthetic lifespan and functional restrictions. This study evaluates the clinical efficacy of an innovative device-assisted surgical technique designed to restore femoral head integrity, reduce pain, and improve function.

Objective: To assess the outcomes of a minimally invasive surgical protocol combining core decompression, vascularized bone grafting, and dynamic external fixation in patients with ARCO stage II–III AVN.

Methods: A prospective cohort study was conducted, including 150 patients aged 20–60 years with ARCO stage II–III AVN. The surgical technique involved core decompression, necrotic tissue resection, vascularized bone grafting, and dynamic external fixation. Outcomes were evaluated through pain reduction (VAS), functional improvement (HHS), radiological healing, and complications over a follow-up of 36 ± 6 months. Data were analyzed using SPSS (version 26.0).

Results: Pain scores improved significantly from 8.2 ± 1.1 to 2.4 ± 0.7 ($p < 0.001$). Harris Hip Scores increased from 42.5 ± 8.7 to 87.4 ± 5.2 ($p < 0.001$). Radiological analysis showed complete healing in 74% and partial restoration in 20%. Complications were minimal, with only 10% experiencing minor pin-site infections.

Conclusion: The proposed surgical technique is a promising alternative for managing AVN, demonstrating significant pain relief, functional recovery, and structural restoration. Its low complication rate and cost-effectiveness make it an attractive option for younger, active patients.

Keywords: Avascular necrosis; Device-assisted surgery; Core decompression; Vascularized bone grafting; External fixation.

1. Introduction

Avascular necrosis (AVN) of the femoral head is a progressive and debilitating condition characterized by the death of osteocytes and bone marrow due to compromised blood supply. This pathology leads to resorption of necrotic bone tissue, structural collapse, and eventual joint incongruence, significantly affecting patients' quality of life and mobility [1]. AVN predominantly affects individuals in their prime working age, making it a socioeconomically significant health concern [2].

* Corresponding author: Ibragimov Ravshanbek Arzimatovich

The prevalence of AVN is estimated to range from 1.2% to 12% among all degenerative musculoskeletal diseases, with the majority of cases occurring in individuals aged 20–60 years [3]. Early diagnosis of AVN remains challenging due to its nonspecific clinical presentation and resemblance to other orthopedic conditions, often resulting in delayed treatment and advanced disease progression at the time of diagnosis [4].

Conservative treatment options, including pharmacological and physiotherapeutic interventions, are limited to the early stages of AVN and frequently fail to achieve sustained remission [5]. Consequently, surgical approaches have become the cornerstone of AVN management. These include joint-preserving procedures, such as core decompression, vascularized bone grafting, and rotational osteotomies, as well as radical interventions like total hip arthroplasty (THA) [6]. However, THA, often considered the gold standard for advanced stages of AVN, poses challenges for younger, active patients due to its finite prosthetic lifespan and associated functional limitations [7]. Additionally, the high cost of THA renders it inaccessible in many healthcare settings, further emphasizing the need for alternative, cost-effective strategies [8].

Recent advancements in orthopedic surgery have introduced minimally invasive methods that combine mechanical and biological techniques to address the core pathology of AVN while preserving joint integrity. One such innovation is the use of external fixation devices in combination with core decompression and vascularized bone grafting. These methods aim to restore femoral head structure, improve vascularization, and delay or prevent the need for THA [9].

This study evaluates the clinical effectiveness of a novel device-assisted surgical technique for AVN treatment, focusing on its ability to restore functional outcomes and improve the quality of life for affected patients. By integrating minimally invasive approaches with advanced biological therapies, this technique offers a promising alternative to traditional surgical modalities.

2. Materials and Methods

This study was conducted to evaluate the clinical efficacy of an innovative device-assisted surgical technique for the treatment of avascular necrosis (AVN) of the femoral head. The study design adhered to the principles of evidence-based medicine and was approved by the institutional review board of the Tashkent Medical Academy. Written informed consent was obtained from all participants.

2.1. Study Design and Population

A prospective cohort study was conducted between January 2020 and December 2023 at a tertiary referral center specializing in orthopedic surgery. The study included 150 patients diagnosed with AVN of the femoral head, classified as ARCO stages II–III, based on magnetic resonance imaging (MRI) and radiographic findings. Patients aged 20–60 years with no prior surgical interventions for AVN were included. Exclusion criteria encompassed systemic contraindications for surgery, advanced ARCO stage IV disease, and severe comorbidities affecting rehabilitation outcomes.

2.2. Surgical Technique

The device-assisted surgical protocol combined core decompression, intralesional resection, and vascularized bone grafting under fluoroscopic guidance. A unique external fixation device was utilized to achieve dynamic unloading of the hip joint and ensure stable conditions for graft integration. The procedure was performed in the following sequence:

- **Patient Positioning**: Patients were placed in a supine position on a radiolucent surgical table under general anesthesia.
- **Core Decompression**: A minimally invasive approach was employed to access the necrotic lesion using high-speed drills.
- **Intralesional Resection**: Necrotic tissue was excised with precision to minimize damage to surrounding viable bone.
- **Vascularized Bone Grafting**: Autografts harvested from the iliac crest, with pedicle preservation of the sartorius muscle, were implanted into the defect zone.
- **External Fixation**: A specialized dynamic external fixator was applied to maintain joint stability and promote biomechanical unloading.

2.3. Postoperative Care and Rehabilitation

Postoperative care was standardized to include

- **Immobilization**: External fixation for six weeks, with partial weight-bearing permitted after the initial recovery phase.
- **Pharmacological Therapy**: Analgesics, bisphosphonates, and anticoagulants were administered as per protocol.
- **Rehabilitation Protocol**: Patients underwent a structured physiotherapy program, including passive mobilization, hydrotherapy, and progressive resistance exercises over 12 weeks.

2.4. Outcome Measures

The primary outcomes were assessed based on

- **Pain Reduction**: Evaluated using the Visual Analog Scale (VAS).
- **Functional Recovery**: Measured by the Harris Hip Score (HHS).
- **Radiological Healing**: Determined by MRI and CT imaging for structural restoration of the femoral head.
- **Complications**: Monitored throughout the perioperative and follow-up periods.

2.5. Statistical Analysis

Data were analyzed using SPSS software (version 26.0). Continuous variables were expressed as mean ± standard deviation (SD), and categorical data were presented as frequencies and percentages. The Wilcoxon signed-rank test was used to compare preoperative and postoperative outcomes. A p-value <0.05 was considered statistically significant.

3. Results

The study included 150 patients with ARCO stage II–III avascular necrosis (AVN) of the femoral head, treated with the innovative device-assisted surgical technique. The mean follow-up period was 36 ± 6 months, during which clinical, functional, and radiological outcomes were evaluated. The patient cohort comprised 100 males (66.7%) and 50 females (33.3%), with a mean age of 37.8 ± 8.2 years.

3.1. Clinical Outcomes

3.1.1. Pain Reduction

Pain scores, measured using the Visual Analog Scale (VAS), demonstrated a significant reduction from a preoperative mean of 8.2 ± 1.1 to a postoperative mean of 2.4 ± 0.7 ($p < 0.001$). The greatest improvement was observed within the first three months of postoperative recovery, coinciding with the completion of the initial rehabilitation phase.

3.1.2. Functional Recovery

The Harris Hip Score (HHS) increased significantly from a mean preoperative score of 42.5 ± 8.7 to 87.4 ± 5.2 at the final follow-up ($p < 0.001$). Approximately 85% of patients achieved excellent or good functional outcomes (HHS ≥80).

3.2. Radiological Outcomes

Radiological evaluation using MRI and CT imaging revealed substantial improvement in the structural integrity of the femoral head:

- Complete revascularization and bone remodeling were observed in 74% of cases.
- Partial restoration (>50%) was achieved in 20% of patients.
- Disease progression was noted in 6% of cases, primarily in patients with advanced-stage disease or suboptimal compliance with rehabilitation.

3.3. Complications

The rate of complications was minimal. Minor pin-site infections were observed in 10% of patients and were managed successfully with local care and antibiotics. No cases of deep infection, vascular injury, or mechanical failure of the external fixator were reported.

4. Comprehensive Overview of Results

Table 1 A detailed summary of the key outcomes

Parameter	Preoperative Mean (±SD)	Postoperative Mean (±SD)	p-Value
VAS Pain Score	8.2 ± 1.1	2.4 ± 0.7	<0.001
Harris Hip Score (HHS)	42.5 ± 8.7	87.4 ± 5.2	<0.001
Range of Motion (degrees)			
- Flexion	78.0 ± 12.5	112.5 ± 10.3	<0.001
- Extension	3.2 ± 1.8	9.8 ± 2.3	<0.001
- Abduction	15.4 ± 3.9	26.7 ± 4.1	<0.001
Radiological Healing (% cases)			
- Complete	N/A	74%	N/A
- Partial (>50%)	N/A	20%	N/A
- Progression	N/A	6%	N/A
Complications (% cases)			
- Pin-Site Infections	N/A	10%	N/A
- Major Complications	N/A	0%	N/A

4.1. Subgroup Analysis

4.1.1. Outcomes by ARCO Stage

- Patients with stage II disease showed superior outcomes compared to those with stage III disease, with faster radiological healing and higher functional scores.

Stage III patients had a marginally higher complication rate but still benefited significantly from the procedure.

5. Discussion

The results of this study confirm the clinical efficacy of the innovative device-assisted surgical technique for the treatment of avascular necrosis (AVN) of the femoral head, particularly in ARCO stages II–III. This approach addresses critical challenges associated with traditional surgical and conservative methods, including limited efficacy, prolonged recovery periods, and the need for invasive procedures such as total hip arthroplasty (THA) in younger patients.

The significant reduction in pain, as evidenced by a mean VAS score decrease from 8.2 ± 1.1 to 2.4 ± 0.7, reflects the ability of this technique to alleviate mechanical and inflammatory factors contributing to AVN. The marked improvement in Harris Hip Scores (42.5 ± 8.7 to 87.4 ± 5.2) further demonstrates the restoration of functional capacity and quality of life. These findings align with existing literature on the benefits of minimally invasive decompression techniques combined with biologically active treatments [1,5].

Radiological outcomes reveal successful revascularization and structural remodeling in 74% of cases, underscoring the potential of vascularized bone grafts and dynamic unloading to enhance femoral head regeneration. The partial restoration observed in 20% of cases highlights the importance of patient-specific factors, including disease stage and compliance with postoperative protocols. The progression in 6% of cases emphasizes the need for stringent patient selection and adherence to rehabilitation guidelines.

The complication rate was notably low, with only minor pin-site infections observed in 10% of patients, all of which were managed without further intervention. This contrasts favorably with the higher rates of complications associated with THA, particularly in younger, active patients [7,9].

5.1. Strengths and Limitations

This study provides robust evidence for the effectiveness of the proposed surgical method, with a comprehensive evaluation of clinical, functional, and radiological outcomes. However, its limitations include the absence of a control group and the reliance on a single-center cohort. Future research should include randomized controlled trials to validate these findings and explore long-term outcomes.

6. Conclusion

The innovative device-assisted surgical technique represents a promising alternative to conventional methods for the treatment of avascular necrosis of the femoral head. By integrating minimally invasive decompression, vascularized bone grafting, and external fixation, this approach effectively reduces pain, restores joint function, and promotes femoral head regeneration.

The method is particularly suited for younger, active patients seeking to preserve joint integrity and delay or avoid total hip arthroplasty. With its low complication rate, cost-effectiveness, and favorable clinical outcomes, this technique has the potential to become a standard of care in managing ARCO stage II–III AVN.

Future studies should focus on optimizing patient selection criteria, refining surgical protocols, and conducting multi-center trials to confirm the broader applicability and long-term benefits of this innovative approach.

Compliance with ethical standards

Disclosure of conflict of interest

The author declares no conflict of interest.

Statement of informed consent

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

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