Technical Note

Computer-Assisted and Hip Arthroscopy for Avascular Necrosis of the Femoral Head With Femoroacetabular Impingement

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Abstract: Avascular necrosis of the femoral head with femoroacetabular impingement is a disabling disease. Without early treatment and intervention, its further development will even lead to hip osteoarthritis and hip dysfunction. This technical note aims to introduce a computer-assisted precise core decompression of the femoral head, followed by injection of platelet-rich plasma and bone marrow aspirate concentrate. Then, the autologous ipsilateral iliac bone is transplanted to the core decompression area. Thereafter, under hip arthroscopy, the injured glenoid lip of the hip joint is repaired, and the cam deformity of the femoral head/neck junction is polished and formed. The advantages of this technique include accurately locating the core decompression area, combined with autologous cells and bone transplantation, being able to delay the process of avascular necrosis of the femoral head, and evaluating articular cartilage injury, subchondral collapse, and guidance during reaming and curettage.

Introduction

Femoroacetabular impingement (FAI) and avascular necrosis (AVN) of the femoral head are considered to be the main causes of hip pain, which usually occur in the young people. FAI, such as cam-type impingement or pincer-type FAI, is a kind of hip pain caused by premature contact between the femur and acetabulum due to femoral deformity.[1,2] In recent years, hip arthroscopy has been demonstrated to be an effective treatment for FAI patients.[3,4]

AVN is a debilitating disease involving multiple etiologic risk factors, which include, but are not limited to, corticosteroid use, alcohol abuse, trauma, etc.[5-7] Core decompression works well when the AVN lesion is small, and there is a sclerotic rim surrounding the necrotic bone. As an adjunctive therapy for core decompression, the use of platelet-rich plasma (PRP) and bone marrow aspirate concentrate (BMAC) has been recommended for improving the treatment of early-stage AVN patients.[8-10] In the core decompression technology, how to accurately locate the necrotic area is the key step that determines the curative effect after surgery.

Patient Evaluation and Indications for Surgery

In the early stage of nontraumatic AVN, there is often no obvious clinical manifestation. When the patients come to the hospital, they have usually developed obvious symptoms, such as pain in the middle of the groin or limited activity. For the early stage, the diagnosis of AVN is mainly confirmed through computed tomography and magnetic resonance image (MRI).[11,12] In general, MRI has high accuracy, and its specificity and sensitivity for early detection of osteonecrosis can be up to 99%, which guarantees a low chance of misdiagnosis.[13] The indications for patients undergoing hip surgery generally include a certain degree of hip joint pain, functional limitation, and ineffectiveness of

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conservative treatment for more than 3 months.[14,15] For late-stage AVN or elderly patients, total hip replacement is usually adopted, while young patients are recommended to seek hip preservation treatment.[16] The operations for preserving the femoral head include core decompression, bone grafting, and osteotomy, which are applicable to patients classified as Association Research Circulation Osseous (ARCO) stage I to stage III. In particular, core decompression (with implants, including bone marrow stromal cells) and bone grafting are preferred options for young adults with AVN.[9,14,15]

In AVN patients with FAI, the risk that AVN treatment will fail seems to be twice as high for $\alpha \geq 60°$ as for $\alpha < 60°$.[17] At present, the diagnosis of FAI relies heavily on the clinical context, examination findings, and plain radiographic imaging. The main purpose of the radiographs is to evaluate the bony structures for FAI or other mechanical deformities. MRI and MR arthrography are powerful imaging modalities for revealing morphologic abnormalities of the proximal femur and acetabulum, as well as the various changes happened in the hip secondary to FAI. MRI findings of changes secondary to FAI within the acetabulum involve the acetabular bone, labrum, and articular cartilage. One of the indicators for hip arthroscopic surgery is the occurrence of movement obstacle, such as impinging osteophytes, and another indicator is labral tears. After undergoing femoroplasty, acetabuloplasty, capsular release, and labral repair or reconstruction, many of these patients exhibited significant functional improvement (Fig 1).[18,19]

In this technical note, we aim to introduce the detailed technical steps (Table 1, Video 1) of computer-assisted core decompression and hip arthroscopy for AVN with FAI.

Table 1. Surgical Procedures

Technical type	Covering contents
Core Decompression	Computer-aided design of surgical approach
	Enlargement of the core decompression area
Cell biotherapy	Platelet-rich plasma
	Bone marrow aspirate concentrate
	Autogenous bone graft
Hip arthroscopy	Glenoplasty and chondroplasty

Surgical Technique

Computer Simulation Assessment

The TIANVI orthopaedic surgery robot is an orthopaedic surgery navigation and positioning system, mainly composed of a workstation, an optical tracking system, and a robotic arm. It can help surgeons to accurately locate the desired surgical approach through anteroposterior and lateral fluoroscopy (Fig 2). First, the patient is fixed on the traction bed in the supine position under general anesthesia, with the upper body secured by a strap. The left upper limb is fixed in front of the chest, and the right upper limb is abducted to allow the anesthesiologist to inject drugs. Then, the navigation device is installed at the surgical site, and the manipulator is assembled accordingly. The surgical area is routinely sterilized and covered with a sterile surgical towel to fully expose the surgical area on the affected side and the anterior superior iliac spine, and a tracer is placed on the affected side at the site of the anterior superior iliac spine. In the meantime, the patient's posture and the navigation device must be fixed securely; otherwise, it may lead to errors in the positioning of the navigation system. Further, through two times of fluoroscopy, the anteroposterior and lateral fluoroscopy images are transferred to the workstation,

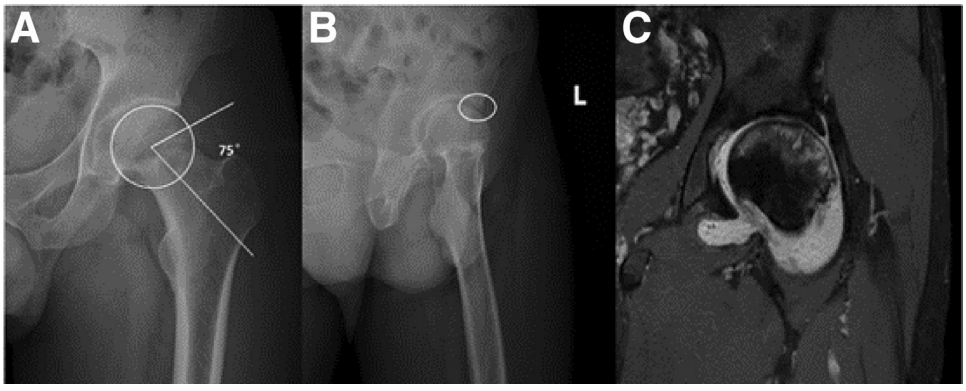

Fig 1. Preoperative anteroposterior (AP) (A) and lateral (B) radiograph and coronal magnetic resonance image (MRI) (C) of the left hip. (A) AP radiograph shows the subchondral fracture of the left femoral head, local osteoporosis, local cystic change, flattening of the articular surface of the femoral head, and the collapse of the femoral head less than 2 mm, which are Association Research Circulation Osseous stage III manifestations of femoral head necrosis, $\alpha = 75°$. (B) Lateral radiograph shows the cam-type impingement. (C) Coronal MRI of the left hip shows the intramedullary bone marrow edema, subchondral fracture, and crescent sign.

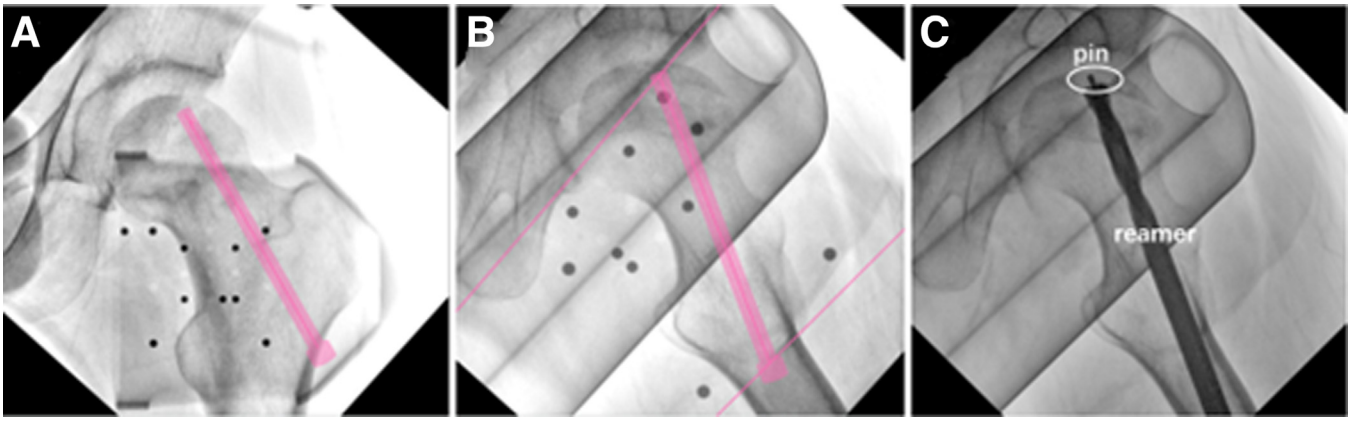

Fig 2. Intraoperative fluoroscopic images of the left hip, which are sent to the workstation for surgical planning in the direction of the guide pin in the anteroposterior (A) and lateral (B) positions. The mechanical arm with navigation sleeve moves under the greater trochanter, according to the design in the computer. The 2.4-mm guide pin is driven along the sleeve, and then it is expanded with the 8-mm drill pattern.

and the entry direction of the guide pin can be designed on the computer. The robotic arm with navigation sleeve will move under the greater trochanter, according to the design in the computer. Subsequently, the guide pin is driven with an electric drill, making sure that the drill reaches the AVN area and does not exceed the subchondral bone of the femoral head under perspective. Finally, an 8-mm reamer is used to drive along the pin to enlarge the femoral tunnel.

Adjunctive Therapy Procedures

An osteochondral transplantation instrument with a diameter of 8 mm is used to make four sections of biological autologous iliac rods with cortical bone (length 3 cm, diameter 8 mm) on the same side of the operation. Then, 25 mL of bone marrow fluid is extracted from the iliac bone. After centrifugation at 3,000 g for 5 min, 10 mL of BMAC is extracted from the lower layer. Further, 30 mL of upper limb arterial blood

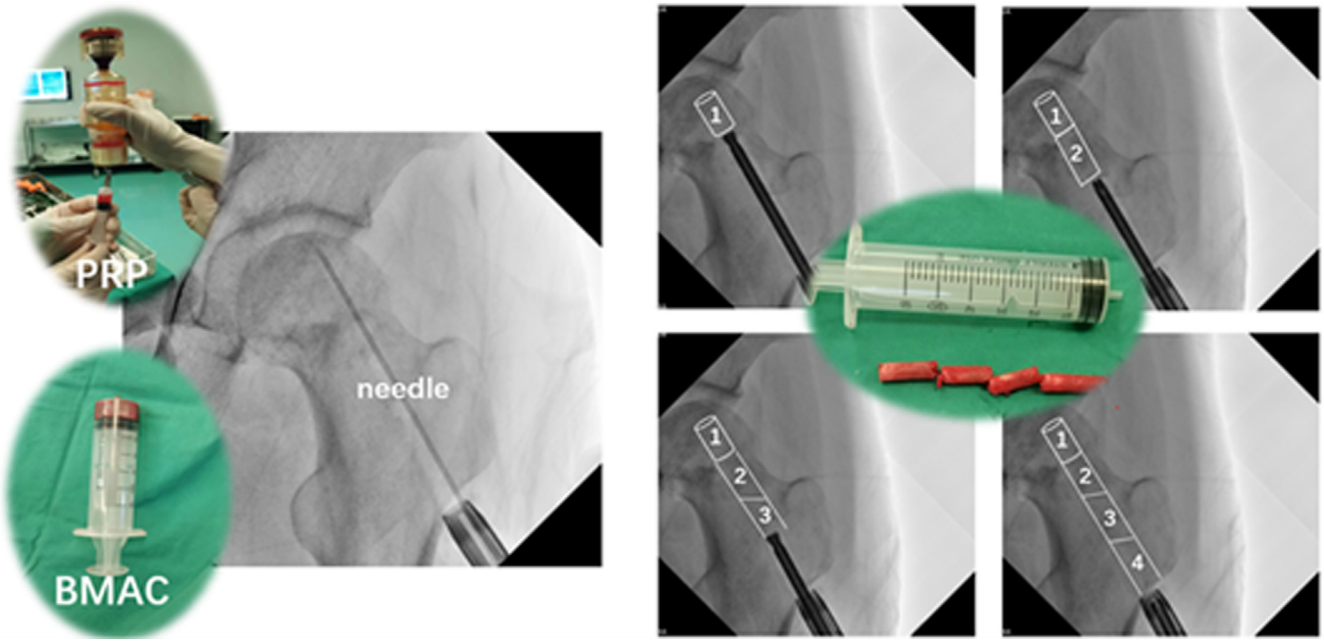

Fig 3. Platelet-rich plasma and bone marrow aspirate concentrate are prepared and injected into the previously established 8-mm femoral tunnel of the left femoral neck. Four bone plugs with a diameter of 8 mm and a length of 3 cm are taken from the ipsilateral iliac bone with the osteochondral grafting instrument, and are successively implanted into the 8-mm femoral tunnel.

mixed with 3 mL sodium citrate is extracted and injected into the platelet-rich plasma preparation device (TriCeLL PRP KIT, REV-MED Inc, Korea). PRP is prepared by single spinning at 3,000 g for 5 min at room temperature. After two rounds of centrifugation, 10 mL PRP is extracted.

In order to prevent leakage of injection, tilt the traction bed is titled for 20° to the right. PRP and BMAC are then injected after confirming that the needle has reached the necrotic area under fluoroscopy (Fig 3). Finally, the osteochondral transplanter instrument is used to implant 4 bone grafts to fill the femoral tunnel.

Hip Arthroscopy

The anterolateral portal and midanterior portal are used to explore the hip joint without traction, and the capsule is cut arthroscopically with a plasma knife to expose the joint cavity. Hip distraction is made under arthroscopic vision to enter the central compartment. Then, the conditions of the glenoid labrum, the femoral head-neck junction in the joint cavity and the synovium of the joint are evaluated (Fig 4). The injured glenoid labrum is shaped or repaired, and the articular surface of the femoral head is visualized. Then, the hip joint traction is loosened after treatment of glenoid labrum. Finally, femoral osteochondroplasty is performed for cam morphology, and a plasma electric knife is used to fully stop bleeding in the formed area.

Rehabilitation

The postoperative rehabilitation is similar to other hip salvage operations. In 0-2 weeks after operation, it is mainly to restore the muscle strength of lower limbs, and crutches are required for the patient to get out of bed in the first 6 weeks. After 3-6 weeks of operation, the degree of activity can be restored. After 7 weeks to 3 months, further muscle strength training and daily life are gradually restored.

Discussion

Because of an increasing prevalence of nontraumatic osteonecrosis of the femoral head, many hip-preserving treatments are being developed and improved. In this technical note, we combined core decompression, cell biotherapy, and hip arthroscopy to treat AVN and hip pain (Table 2).

Core decompression is recommended for symptomatic small-to-medium-sized precollapse lesions. It has been used in combination with platelet-rich plasma, cell-based forms, porous tantalum implant,

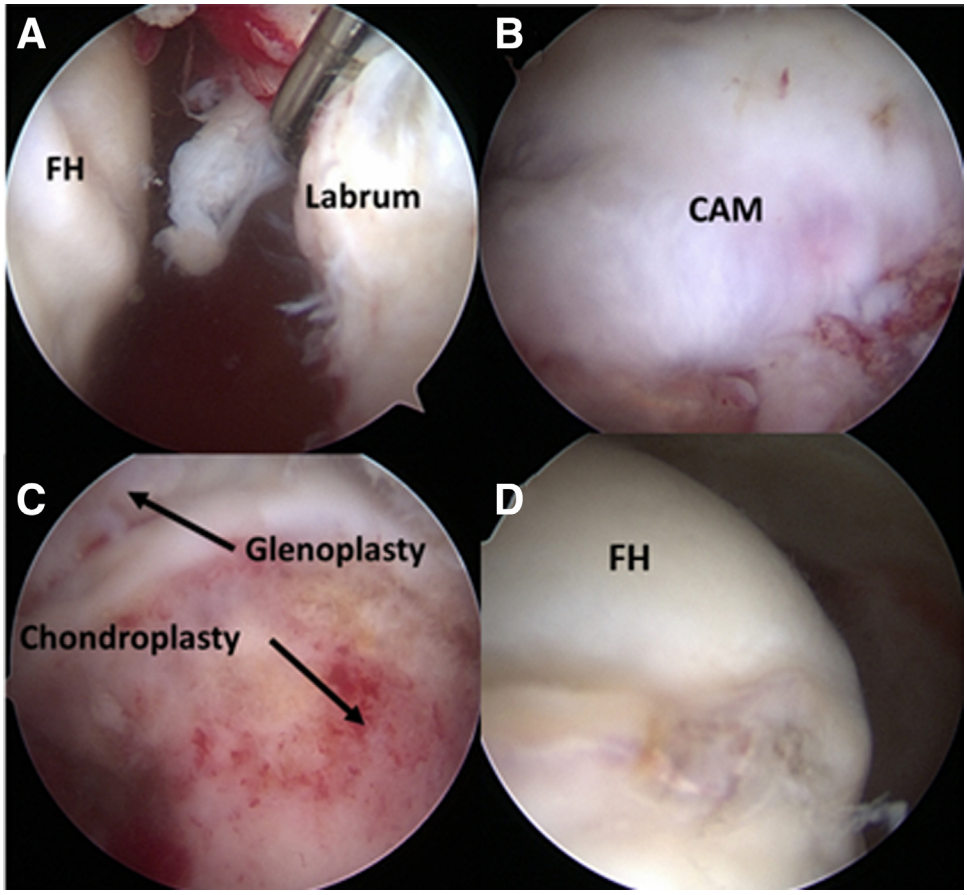

Fig 4. The hip arthroscopic surgery is performed through the anterolateral portal and midanterior portal of the left hip. Images show the inflammatory synovial hyperplasia, glenoid labrum injury (A) and the cam morphology (B) of the femoral head-neck junction. Then, the injured glenoid labrum is repaired and shaped, and excision of synovium and femoral chondroplasty is performed for cam morphology (C). In the traction state, it can be seen that the femoral head necrosis and collapse area are well supported under hip arthroscope (D).

Table 2. Advantages and Disadvantages

Advantages	Disadvantages
More accurate positioning of medullary core decompression	Longer operation time and higher cost
Patients and doctors receive less radiation from fluoroscopy.	Installing the positioning device will create an additional surgical incision.
Combined with a variety of biological therapies	

arthroscopy, and extracorporeal shockwave in the treatment, and has been proven to deliver ideal medium- and long-term results.[4,8,9,20,21] Computer assistance has been applied for treating several hip disorders, such as hip arthroscopy and peri-acetabular osteotomy. In core decompression, traditional fluoroscopy is still used to assist positioning, or in combination with arthroscopy.[22] This may require perspective to complete the positioning, and repeated penetration of the guide may lead to bone destruction or inaccurate positioning. In our technique, the TIANVI orthopaedic surgery robot is used for positioning, which only needs 2 times the perspective to complete the positioning and calculate the penetration depth of the guide needle. Houdek et al.[10] injected BMAC and PRP into AVN patients undergoing core decompression for enhanced treatment, and they demonstrated that it was effective in delaying arrival of total hip replacement. Serong et al.[17] verified that the prevalence of CAM-type deformity was greatly increased in patients with concomitant AVN, and recommended cotreatment of pathological head-neck offset for AVN patients with $\alpha \geq 60°$. When pain and dysfunction cannot be alleviated, total hip replacement is a reliable and effective final option.

In conclusion, accurate and effective hip preservation therapy has always been the focus of research and development. In this technical note, we applied a computer-assisted positioning system to perform hip preservation under hip arthroscopy, combined with various of biological therapies. A range of surgical methods are used for comprehensive hip preservation treatment.

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