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RESEARCH

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10-year follow-up results of the initial application of 3D-printed percutaneous guides in drilled decompression of femoral head necrosis

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Abstract

Objective To explore the feasibility and clinical significance of computer-aided design 3D-printed percutaneous guides in femoral head necrosis drilling and decompression surgery, and compare it with traditional surgery under fluoroscopy. The study also reports the results of follow-up after 10 years.

Methods A retrospective study was conducted on patients with femoral head necrosis who had undergone drilling decompression surgery from November 2011 to November 2015. There were 15 patients in the guide group and 15 patients in the control group, and all of them were followed up for 5 to 10 years after the surgery. All patients were staged according to ARCO staging based on imaging manifestations. The guide group used 3D-printed percutaneous guides designed with computer-aided design and printed using 3D printing technology, while the control group used traditional fluoroscopy for guidance. The study compared operative time, number of fluoroscopies, and guide needle adjustments.

Results The baseline data did not differ statistically significantly. The guide group had significantly shorter operative times, fewer fluoroscopies, and fewer guide needle adjustments compared to the control group. The average operative time in the guide group was 27.8 min, with 11.2 fluoroscopies and 1.2 guide needle adjustments, while the control group had an average operative time of 44.4 min, with 34.4 fluoroscopies and 3.4 needle adjustments. There was no significant difference in preoperative Harris scores between the two groups, but both groups showed significant improvement in postoperative Harris scores. After 10 years, the guide group had fewer cases of femoral head necrosis progressing to advanced ARCO stages III or IV, and fewer cases requiring total hip arthroplasty compared to the control group.

Conclusion The use of computer-aided design 3D-printed percutaneous guides in femoral head necrosis drilling and decompression surgery is feasible and clinically significant. It reduces operative time, fluoroscopy, and guide

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needle adjustments, and is more effective in preventing the progression of femoral head necrosis to advanced stages compared to traditional surgery under fluoroscopy.

Keywords 3D printing, Computer-assisted surgery, Osteonecrosis, Femoral head necrosis, Drilling decompression, Total hip arthroplasty

Introduction

The phenomenon of Osteonecrosis of the Femoral Head (ONFH), also recognized as aseptic or ischemic necrosis of the femoral head arises from a disruption in blood flow to this critical area, stemming from diverse etiologies [1, 2]. These causative factors can be broadly classified into traumatic and non-traumatic categories [3, 4]. Therapeutic strategies for ONFH encompass both conservative and surgical approaches [5]. Surgical intervention becomes necessary for many patients, encompassing both head-preserving and non-head-preserving treatments. Head-preserving treatments, notably drilling decompression, bone grafting, and osteotomy [6–10], aim to preserve the femoral head, while non-head-preserving treatments, primarily total hip arthroplasty (THA), replace the damaged joint. Despite its advantages, THA poses challenges related to prosthesis longevity, treatment costs, and a high incidence of complications, particularly in younger and middle-aged patients, rendering long-term outcomes unpredictable [11, 12]. Thus, early intervention in ONFH holds paramount importance, this study to explore the feasibility and clinical significance of computer-aided design 3D-printed percutaneous guides in femoral head necrosis drilling and decompression surgery, and compare it with traditional surgery under fluoroscopy to evaluate its long-term effects through a 10-year follow-up study.

The accuracy of drilling is of great significance to the surgical outcome. On the one hand, the sclerotic bone is penetrated through the drilling hole to reach the necrotic area, allowing for adequate decompression of the lesion. On the other hand, it is crucial to avoid damaging the cartilage of the femoral head and to prevent its deformation and collapse [10, 13]. However, traditional surgery under fluoroscopy relies heavily on the operator's experience and has limitations in accuracy and safety. 3D printing navigation technology offers a precise and innovative approach to surgical procedures, potentially improving the outcomes of ONFH surgeries.

The primary aim of this study is to assess the effectiveness of using computer-aided design in conjunction with 3D-printed percutaneous guides for drilling and decompression surgery in ONFH patients. Additionally, the study aims to compare this approach with conventional fluoroscopy-guided surgery and report the long-term outcomes after a 10-year follow-up period.

Materials and methods

General information

All the instances originated from the orthopedic inpatient, affiliated with Capital Medical University. Between November 2011 and November 2015, retrospective incorporation 30 patients (comprising 37 hips) with ONFH underwent percutaneous guide plate navigation drilling decompression surgery. In the guide plate group, there were 15 cases involving 18 hips, with a gender distribution of 10 males and 5 females. The mean age of these patients was 43.4 ± 11.4 years, ranging from 34 to 64 years old. According to the ARCO staging system, there was 1 hip at stage I, 7 hips at stage IIa, 9 hips at stage IIb, and 1 hip at an early stage III. The necrosis range varied, with 2 hips < 15%, 9 hips between 15 and 30%, and 7 hips > 30%. The etiologies contributing to ONFH in this group included HIV-related in 6 patients, hormone-induced in 3, alcohol-induced in 2, and idiopathic in 4 cases.The control group also consisted of 15 cases with 19 hips, comprising 11 males and 4 females. The mean age was 40.1 ± 10.9 years, spanning from 26 to 55 years old. In terms of ARCO staging, this group had 2 hips at stage I, 6 hips at stage IIa, 9 hips at stage IIb, and 2 hips at an early stage III. Similarly, the necrosis range varied, with 3 hips < 15%, 9 hips between 15 and 30%, and 7 hips > 30%. The etiological factors in this group were HIV-associated in 5 cases, hormone-induced in 4, alcohol-induced in 3, and idiopathic in 3 cases (Table 1).The clinical presentations among all patients were characterized by varying degrees of pain in the affected hip. Typical symptoms included deep pressure pain in the groin of the affected side, which could radiate to the knee or hip. Additionally, patients experienced varying degrees of claudication, with some severe cases requiring the use of crutches for walking or even being unable to stand and walk unaided.

Case selection criteria

Inclusion criteria: patients diagnosed with ONFH by a combination of clinical symptoms and imaging examinations, ARCO stage I, II, and early stage III patients < 60 years old, who agreed to undergo ONFH drilling and decompression surgery and signed an informed consent form. Exclusion criteria: patients with ARCO stage IV and late stage III patients aged > 60 years; patients whose heart, respiration, function of various organs, and general condition could not tolerate the surgery; patients with trauma-induced ONFH; patients who did not agree

Table 1 Basic patient characteristics

	guide plate group	comparison group	*P*
No. of patients	15	15	
Age (years)*	43.4 ± 11.4 (34~64)	40.1 ± 10.9 (26~55)	
Male/female	10∶5	11∶4	
BMI	24.0 ± 4.6	23.4 ± 4.4	
hips	18	19	
ARCO staging (hip number)			
I	1(5.5%)	2(10.5%)	0.929
IIa	7(39%)	6(31.6%)	
IIb	9(50%)	9(47.4%)	
early Stage III	1(5.5%)	2(10.5%)	
Range of necrosis			
< 15%	2(11.1%)	3(15.8%)	
15%~30%	9(50%)	9(47.4%)	0.909
> 30%	7(38.9%)	7(36.8%)	
Etiology (number)			
HIV	6(40%)	5(33.3%)	
hormones	3(20%)	4(26.7%)	1.000
ethanol	2(13.3%)	3(20%)	
idiopathic	4(26.7%)	3(20%)	

*Age is expressed as mean ± standard deviation, with age ranges in parentheses

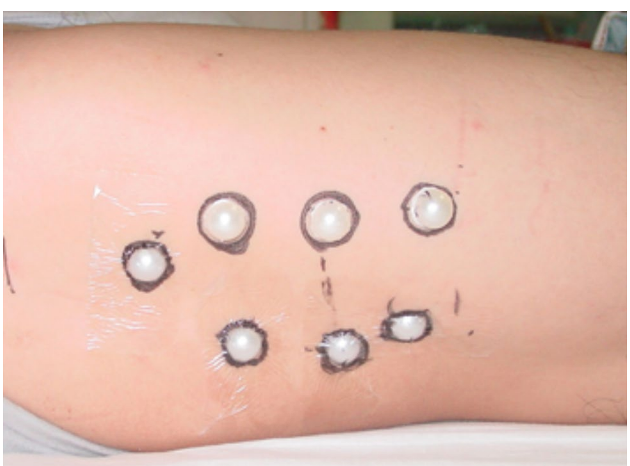

Fig. 1 Marker points are selected on the skin, skin markers are placed on the skin of the affected hip, supine on the body cushion, the body cushion is plasticized, and localization marks are made on the body cushion and the patient's skin, respectively, for CT scanning

to undergo drilling decompression surgery; and patients who did not sign the informed consent.

Experimental methods

Selection of skin marking points

For the guide plate group, 15 patients were selected. Before CT scanning, marking points were selected on the skin of the affected hip, choosing locations where the bones are more superficial, especially skeletal anatomical markers that can be palpated (such as the greater trochanter of the femur and the proximal end of the femoral shaft). Three points were used to determine a plane, and at least four points not in the same plane were selected to establish spatial dimensions. Based on our experience, using 6 to 8 points is appropriate, ensuring that no two points are too close together. The skin was marked with 1-cm-diameter hemispheres made of medical ABS (Acrylonitrile Butadiene Styrene) material. A circle was drawn around each marker with a marker pen and applied to the skin with a surgical patch. The marker can be visualized on a CT scan.

CT scanning

To facilitate CT tomography scanning of the hip joint, all patients were positioned in a lying stance. Given the concave nature of the CT scanning bed, a flat plate was meticulously placed atop it, ensuring the body position pad mirrored its surgical counterpart in shape (refer to Fig. 1). The Klarity vacuum position pad, crafted in China, was then smoothly laid out on this flat surface. With the patient comfortably supine on the pad, the vacuum pump was activated, drawing air to create a secure fit. As the vacuum intensified, the patient's waist, hips, and both lower extremities were gently molded into the grooves, while ensuring ample operating space remained at the affected hip's surgical site. Following approximately three minutes of vacuuming, once the pad had fully adapted to the patient's contours, the vacuum pump was gracefully deactivated.To maintain precision, a delicate line was traced on the patient's skin, marking the seamless junction between the affected limb and the body pad. Furthermore, corresponding landmarks at the waist, hip, knee, ankle, and on the body pad were meticulously identified and marked. Subsequently, a CT scan was executed with a precise layer thickness of 0.625 mm, ensuring exceptional clarity. Following the scan, the position pad was carefully preserved for intraoperative utilization.

Reconstruction of the three-dimensional model

First, meticulously gather the original CT image data and ensure they're imported into your computer system in the standardized DICOM format. Then, utilize the powerful computer-aided design (CAD) software, Mimics 21.0, from Materialise's Interactive Medical Image Control System (Materialise, Belgium), to perform the digital 3D reconstruction right on your computer. This step is crucial, and Fig. 2 showcases the result of this reconstruction.

Different tissues have varying density ranges, so accurately setting the threshold is key to extracting tissues correctly. Take caution: if you set the minimum threshold value too low, you'll end up with a lot of noise—meaning, you'll capture many tissues with similar densities simultaneously, making segmentation more difficult. On the other hand, if you set the minimum threshold too high, you risk losing part of the tissues you need. So, carefully calibrate the threshold to ensure optimal tissue extraction and segmentation outcomes.

Designing the puncture channel

Precisely outline the virtual guide pins on the 3D model, simulating their insertion to identify the optimal puncture site. Accurately set the virtual needles' advancement path, adjusting until all three pins traverse the femoral neck, targeting distinct sections of the necrotic area without intersecting (see Fig. 3).

Ensure each pin aligns with the upper, middle, and lower parts of the necrotic zone. Measure the skin-to-pin length precisely from a fixed point. Subsequently, print crisp front and side views of the guide pins in their femoral head placements, providing essential intraoperative guidance.

Design guide

Input the Mimics-designed image into Geomagic Studio 9.0 (Geomagic Inc., USA) in STL format. Select a precise area around the skin entry point, incorporating the marking point, and seamlessly integrate it with the virtual guide design. Following this, meticulously eliminate all 3D image noise to produce a navigation template that perfectly contours to the skin, featuring precisely positioned guide channels (see Fig. 4). This optimized template guarantees accuracy and efficiency during navigation.

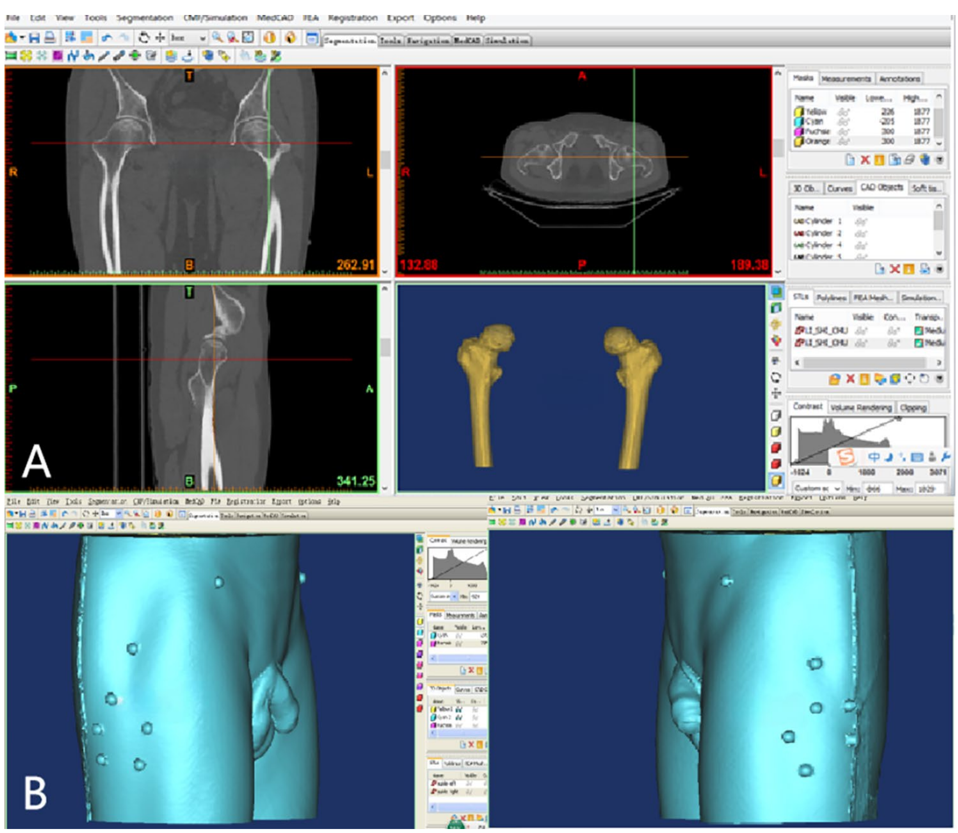

Fig. 2 CT data in DICOM format is imported into Mimics software for 3D reconstruction. a reconstruction of bone; b reconstruction of skin with markers on the skin

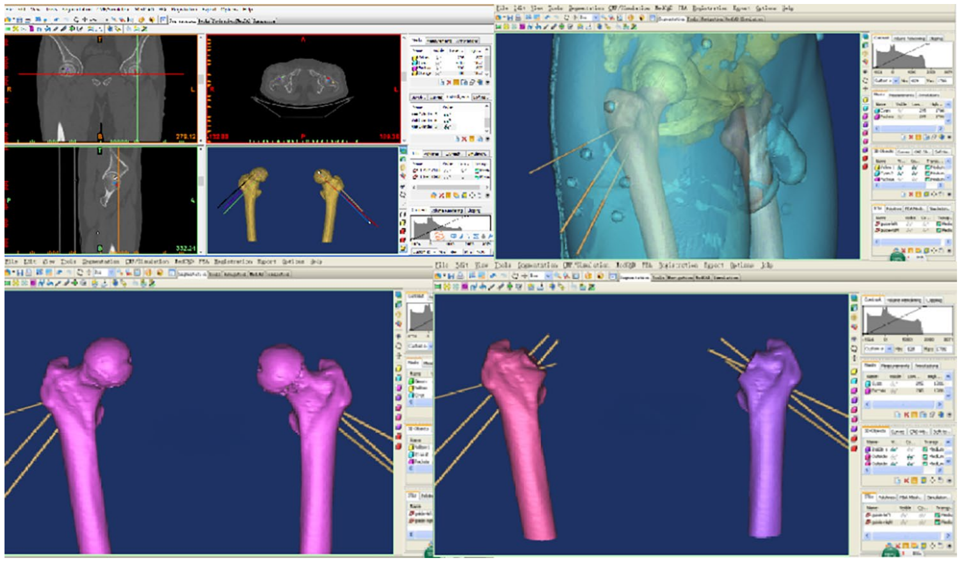

Fig. 3 Insert the guide needle and adjust the position of the guide needle so that it pierces the upper, middle and lower parts of the necrotic area, respectively

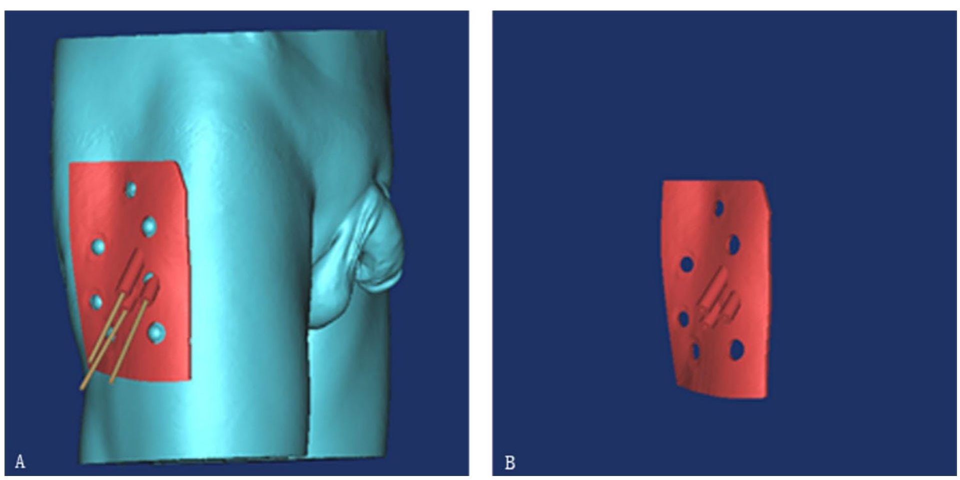

Fig. 4 Inputting data in STL format into Geomagic studio 9.0 software to design the guide plate. a Guide plate fits perfectly to the skin and skin markers; b Designed guide plate

3D printed navigation template

The designed guides were input into a 3D printer (SLA600) in STL format, and a 1:1 sized navigation template was created using Stereo Lithography Appearance (SLA) technology with medical photosensitive resin material (Watershed11122, Somos, USA) (Fig. 5).

Intraoperative application

Before the surgical procedure, the 3D-printed guides and skin markers underwent rigorous sterilization using cryo-plasma to ensure sterility. Epidural anesthesia was administered to all patients, ensuring a comfortable and safe surgical environment. The surgical plate, derived from the CT scan, was meticulously positioned on the surgical bed, upon which the body position pad was carefully placed. Once the patient was safely anesthetized, they were gently lifted onto the pad, ensuring that the junction lines and markers at critical points such as the waist, hip, knee, and ankle precisely aligned, mirroring the preoperative CT scan positioning (see Fig. 6a). To maintain the sterility and accuracy, surgical sterile patches were used to affix the body surface markers to the patient's skin marking points. The guide plate was then positioned precisely based on these skin locating points, ensuring a seamless fit of the navigation template to both the skin and markers. Utilizing an electric drill, the guide needle was precisely drilled through the guide channel on the plate, with the length of the guide needle calculated to include the measured distance from the skin to the needle's apex plus an additional 3 cm for

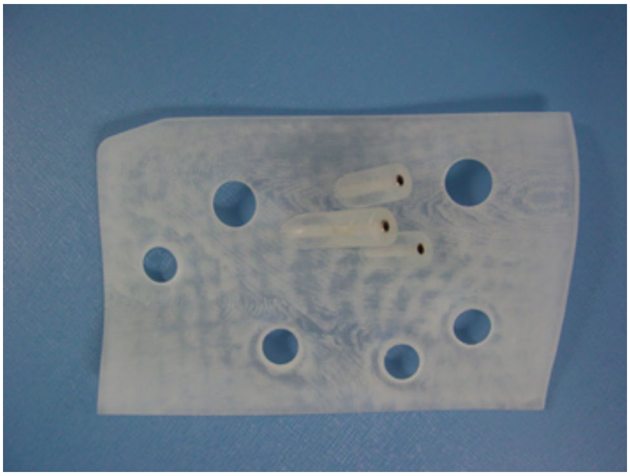

Fig. 5 Input the designed guide plate in STL format into the 3D printer to print the actual guide plate

the channel length (refer to Fig. 6b).Intraoperative fluoroscopy was employed to validate and adjust the position of the guide needle as necessary, ensuring it reached the preoperatively designated position. During lateral needle position verification, the affected limb was gently flexed and externally rotated to facilitate accurate assessment (see Fig. 7).In contrast, the control group underwent surgery under conventional C-arm fluoroscopy, relying solely on the operator's expertise, spatial imagination, and experience. Similar to the study group, three guide pins were drilled to reach the upper, middle, and lower segments of the necrotic area. Notably, both groups were operated by the same skilled surgeon, ensuring a fair comparison between methods.

Postoperative treatment

Both groups of patients were partially weight-bearing with crutches for 6 weeks after surgery, and according to the individual situation, the patients gradually became fully weight-bearing after 6 weeks and were completely removed from crutches in 3 months.

Observation index

The investigators recorded the operation time, the number of fluoroscopies, and the number of adjustments of each guide pin in both groups. The surgery was minimally invasive and intraoperative bleeding was negligible. Harris scores of hip joints were performed on patients before

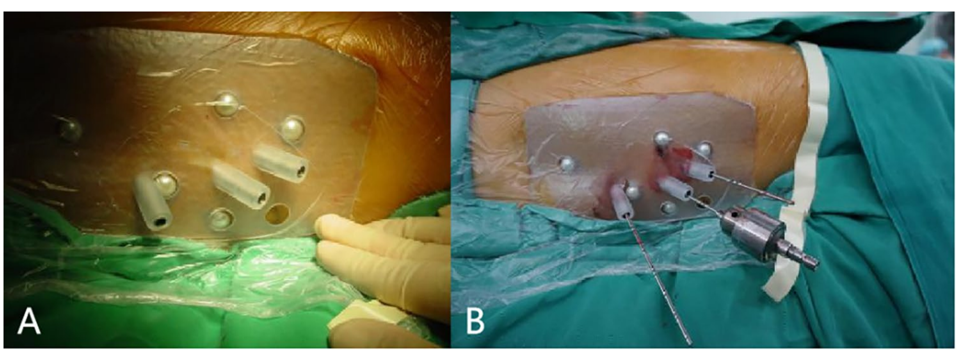

Fig. 6 Intraoperative application.A Patient supine on a positional cushion in the same position as during CT scanning.B Drilling the guide needle along the guiding channel

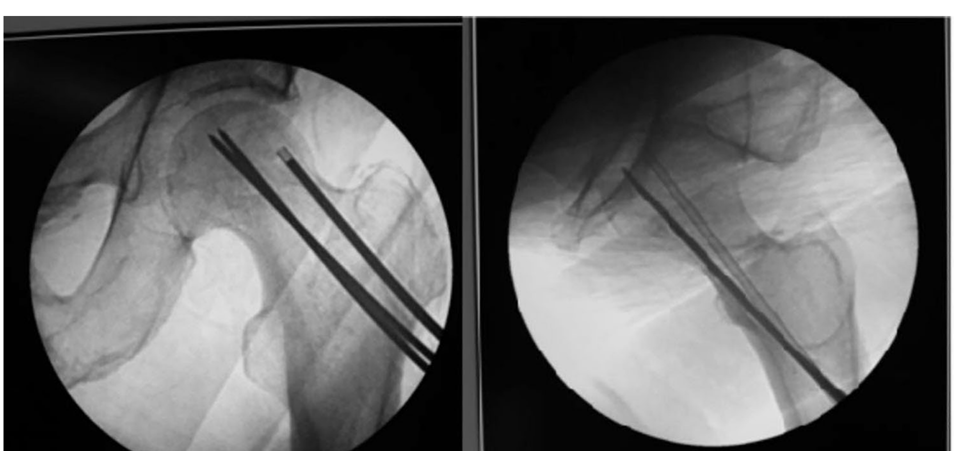

Fig. 7 Intraoperative fluoroscopy to verify the position of the needle guide

Table 2 Postoperative duration of surgery, number of fluoroscopies and number of guide adjustments in both groups

groups	operating time (min)	No. of fluoroscopies (times)	No. of guide pin adjustments (times)
guide plate set (18 hips)	27.8 ± 8.9	11.2 ± 4.8	1.2 ± 1.6
comparison group(19 hips)	43.7 ± 8.8	34.4 ± 8.7	3.4 ± 2.3
P	*P* < 0.001	*P* < 0.001	0.008

surgery and 5-year postoperative follow-up respectively, and the occurrence of complications in the two groups at the last follow-up after 10 years was recorded.

Statistical processing

SPSS26.0 (Statistical Product and Service Solutions, IBM Corp., USA) was used to statistically analyze the data, and the measurement data were expressed as standard deviation, and analyzed by independent samples t-test between the two groups, and paired samples t-test was used to compare the postoperative and preoperative periods within the groups. $p < 0.05$ was taken as the difference was statistically significant.

Results

Basic information

There was no statistical difference ($P > 0.05$) in the basic characteristics (age, gender, BMI, stage, necrosis extent and etiology, etc.) of the patients in the guide plate group and the control group (**see** Table 1).

Intraoperative and surgical complications

Both groups of patients completed the surgery as planned, and the surgical process was smooth. In the control group, one guide pin penetrated the cartilage of the femoral head. In the guide plate group, there were no complications such as femoral neck and intertrochanteric fracture, penetration of femoral head cartilage, infection and hematoma. The intraoperative fluoroscopic guide pin position was accurate in the guide plate group.

Postoperative evaluation

In the guide plate group, the average operation time for each hip was 27.8 min, the average number of fluoroscopies was 11.2, and the average number of guide pin adjustments was 1.2. In the control group, the average operation time for each hip was 44.4 min, the average number of X-ray fluoroscopies was 34.4, and the average number of guide pin adjustments was 3.4. P is less than 0.05, and the two groups are statistically different from each other (**see** Table 2). The preoperative Harris hip score of the guide group was 71.1 and the control group was 71.7, $P > 0.05$, with no statistical difference between the two groups; the score of the guide group was higher than that of the control group at 5 years after surgery (85.2), but the $P > 0.05$, no statistical difference between the two groups. However, the postoperative Harris scores of both groups were higher than the preoperative ones, with $P < 0.05$, which was statistically different (Table 3). The follow-up ONFH progression and the THA treatment performed in both groups at 10 years after surgery were significantly less in the guide group than in the control group, $P < 0.05$, with a statistical difference (Table 4). The postoperative follow-up imaging performance is shown in Fig. 8.

Table 3 Preoperative and 5-year postoperative follow-up in both groups

groups	Harris rating		*P*
	pre-operative	post-operative	
guide plate set (18 hips)	71.1 ± 3.8	85.2 ± 5.4	*P* < 0.001
comparison group(19 hips)	71.7 ± 3.4	82.4 ± 1.5	*P* < 0.001
P	0.649	0.281	

Table 4 Complications in both groups at 10 years postoperative follow-up

groups	progression of necrosis to advanced stage III or stage IV	treatment with THA
guide plate set (18 hips)	6	1
comparison group(19 hips)	6	9
T	2.116	
P	0.047	

Discussion

Drilling decompression surgery for femoral head necrosis

When the collapse of the femoral head leads to severe disability of the hip joint, treating it becomes highly challenging. Once the lesion advances to the intermediate and advanced stages, over 80% of patients will require THA within two years. However, this treatment option presents several drawbacks, such as the limited lifespan of the artificial joint prosthesis, high costs, and an increased risk of complications. Particularly for middle-aged and young patients, predicting the long-term outcomes of THA is difficult, and they may need revision surgeries down the line. Therefore, early intervention in ONFH is crucial. It can enhance the blood flow to the femoral head, facilitating the repair and reconstruction of necrotic bone, thus preventing deformation and collapse of the femoral head and slowing the progression of the disease.

The drilling and decompression techniques aim to lower the internal pressure of the femoral head, stimulate the growth of vascular tissues, improve the circulation in the femoral head, relieve hip pain, and avert further necrosis. For mild to moderate ONFH in stages I and II, the effectiveness of these procedures has been well-established [14–16]. In recent years, small-aperture drilling

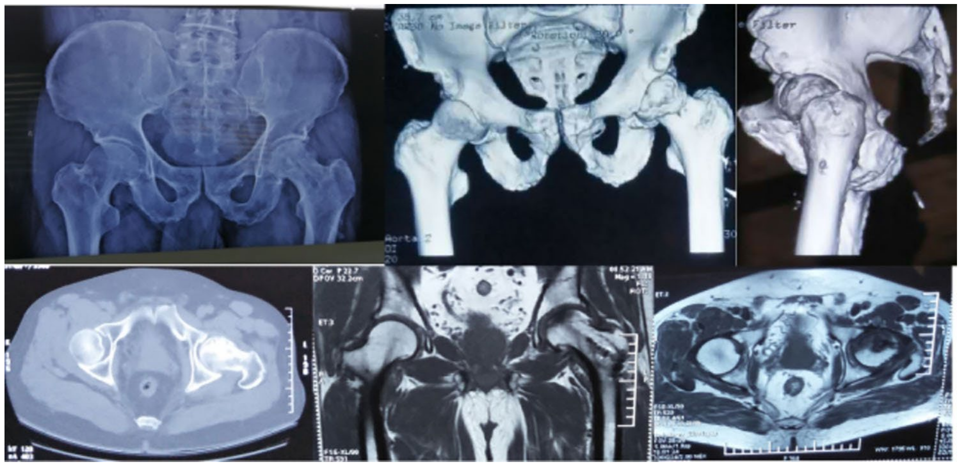

Fig. 8 Postoperative follow-up imaging.(Image quoted from Li S, Wang J, Ma R, Zhao C, Gao Z, Quan X, Zhang Q. Analysis of the efficacy of drilling decompression autologous bone marrow and allogeneic bone grafting in the treatment of HIV-positive patients with early osteonecrosis of the femoral head. BMC Musculoskelet Disord. Nov 21;24(1):902. doi: https://doi.org/10.1186/s12891-023-07039-9. PMID: 37990216; PMCID: PMC10661564.)

decompression has gained more popularity among scholars. It successfully mitigates the disadvantages of large-aperture medullary decompression, allowing for a broader decompression range while inflicting less trauma on the femoral head. From both mechanical and histological perspectives, it is conducive to reestablishing the blood supply and achieving better overall results [17–19].

Before the surgery, we carried out ARCO staging for all patients following the protocol in [20]. For patients in stage III with obvious femoral head deformation, the conventional approach would be non-head-preserving hip arthroplasty. But considering that the prosthesis typically lasts only 10–20 years, this option is not ideal for younger patients (under 60 years old) as it might lead to premature replacement. Instead, drilling and decompression surgery focused on preserving the femoral head can alleviate symptoms and decelerate the disease progression. After thorough discussions with patients who favored head-preserving treatment, we opted for drilled decompression surgery. We utilized the Harris score to evaluate hip function [21]. After the operation, both groups demonstrated statistically significant improvements in Harris scores compared to their preoperative baselines ($P < 0.05$). Notably, ten years after the procedure, significantly fewer patients in the guide plate group progressed to ONFH exacerbation or required total hip replacement (THA) compared to the control group, showing a remarkable statistical difference.

Innovation background of 3d-printed percutaneous guides

The precision of drilling and decompression procedures is of utmost importance when it comes to achieving favorable surgical outcomes in the treatment of femoral head necrosis. It demands effective decompression of the lesion while meticulously avoiding any damage to the femoral head cartilage during the operation. By accurately targeting and drilling through the sclerotic bone, the blood circulation and flow to the ischemic necrotic area can be restored, promoting bone remodeling, pain relief, and symptom improvement [22–25].

The current practice of performing femoral head drilling and decompression under intraoperative C-arm X-ray fluoroscopy has its limitations. It solely relies on 2D images during the procedure to position the guide pin, making it impossible to precisely target the necrotic sclerotic area. Moreover, this method suffers from issues like prolonged surgical durations, excessive intraoperative fluoroscopy, and a steep learning curve for the operators. Repeated adjustments to the guide pin's direction can cause severe harm to the femoral head's osteohematopoiesis, potentially worsening the necrosis, leading to femoral head collapse, and even triggering complications such as femoral neck and intertrochanteric fractures. Hence, enhancing the precision of drilling and decompression, reducing intraoperative fluoroscopy, and minimizing the risk of surgical complications are of great significance.Given that the guide is affixed to the skin, the thickness of all soft tissues bears an impact on the guidance accuracy. Generally, the thinner the patient and the weaker the soft tissues, the more prominent the skeletal anatomical landmarks will be, and the less mobile the soft tissues are, leading to more precise guidance by the guide plate. Consequently, we documented the BMI indices of both groups of patients prior to surgery to gauge their levels of fatness or thinness. It turned out that there was no statistically significant disparity in the BMI indices between the two groups. Owing to the mobility of soft tissues, intraoperative fluoroscopy remains necessary to confirm the position of the guide needle. Nevertheless, the number of fluoroscopies in the guide plate group was

27.8, which was markedly lower than that in the control group (43.7).Preoperatively, the patient's position has been firmly immobilized externally with the aid of the surgical bed and immobilization apparatus. During the intraoperative application of the percutaneous 3D guide plate, the patient's position remains unchanged.

The Computer Assisted Navigation System (CANS) combines X-ray, CT, MRI, and other image data with spatial stereo positioning, computer image processing, visualization technology, and clinical surgical procedures. It is capable of displaying human anatomy and dynamically tracking the relative positions of surgical instruments and anatomical structures during surgery, enabling frameless stereotactic positioning, avoiding vital anatomical structures, ensuring surgical safety, and allowing instruments to accurately reach the desired anatomical locations. Nevertheless, several obstacles impede its clinical application and widespread adoption: ① The complex technical equipment demands a long learning curve and cumbersome operation. ② The high cost of the equipment restricts its availability to only a few hospitals, preventing the broad implementation of this technology. ③ The current indications for CANS surgery are narrow, necessitating further exploration and research for its application in other areas. ④ The intraoperative imaging quality is suboptimal, with sensors lacking sensitivity and tracking signals prone to obstruction, affecting the smoothness of the surgery and requiring equipment improvement.

Meanwhile, 3D printing technology, a novel digital rapid prototyping technology developed in the mid-1980s, has opened up new avenues for precision surgery. In the 21st century, clinicians are faced with both significant challenges and excellent opportunities. They should not merely rely on patients' medical records, images, and other information to conceive surgical plans in their minds but also skillfully employ surgical planning software to construct a three-dimensional anatomical model of the target area. This software empowers them to simulate the surgical procedure on a computer and refine the design until the optimal surgical plan is achieved.

Application prospect of percutaneous guides

As medical technology progresses, patients are increasingly seeking minimally invasive procedures. And with the growing number of infected individuals, especially those with specific health conditions, there is an urgent need to develop novel surgical methods that are straightforward, safe, effective, and can minimize occupational hazards for healthcare workers.

Limitations and future prospects of 3d-printed percutaneous guides

It should be noted that the reported surgical duration for the guide plate group does not encompass crucial preparatory steps like patient positioning, application of the three-dimensional guide plate, and installation of the vacuum pad. Additionally, this innovative technique will unavoidably introduce extra costs to the overall care and logistics framework, including preoperative CT scans at designated facilities and the intricate process of guide plate design.When applied to overweight patients, percutaneous 3D guides tend to exhibit reduced accuracy. In patients with a lower BMI, the bony landmarks in the hips are more conspicuous, and our inclusion criteria are designed to minimize the impact of skin mobility factors. Our decade-long clinical follow-up study corroborates that, for the appropriate population with osteonecrosis of the femoral head, the utilization of 3D percutaneous guides is both safe and efficacious. To date, our study boasts the longest follow-up period globally and can offer valuable guidance to clinical practitioners.

The research and application scope of percutaneous guide plate navigation technology demands further expansion, particularly in areas other than ONFH. For example, in trauma cases such as non-displaced internal fixation of femoral neck fractures using hollow nails and vertebral compression fracture shaping. In trauma surgery, this personalized percutaneous guidance system can guarantee surgical precision, minimize damage to surrounding tissues, and expedite patient recovery. In hip and other joint surgeries, 3D-printed percutaneous guides afford surgeons excellent control over surgical angles and depths, ensuring accurate prosthesis placement, which can enhance patient outcomes by improving joint function and overall quality of life.

With the continuous advancement of science and technology, 3D CT scanners and printers are becoming standard equipment in operating rooms. This technological leap enables intraoperative 3D CT scanning, rapid design iterations, and the speedy production of percutaneous navigation templates, which can substantially reduce preparation time and errors caused by body position changes.In recent years, robotic technology has witnessed extensive application in orthopedics. Although robotic-assisted drilling decompression might achieve greater precision, not all hospitals in economically underdeveloped regions can afford to popularize robots. In contrast to both conventional unarmed nailing and robot-assisted nailing, the application of percutaneous 3D guides not only enhances the nailing accuracy but also curtails medical expenses.

Conclusion

In a revolutionary move, we have integrated a 3D-printed percutaneous guide plate into the femoral head drilling and decompression procedure. Through elaborate preoperative planning, the guide needle can accurately reach the sclerotic necrotic area of the femoral head. This innovative method shifts the function of intraoperative fluoroscopy from merely guiding the operation to verifying its accuracy, thus converting the traditional "blind" 2D decompression into a targeted and meticulously planned precise decompression of the necrotic region. This remarkable progress substantially shortens the operation time, reduces the frequency of intraoperative fluoroscopies and needle adjustments, simplifies the surgical process while enhancing its precision. Moreover, it augments the operational safety, fitting impeccably with the current standards of minimally invasive surgical techniques for HIV-positive patients. What's more, it diminishes the risk of occupational exposure for healthcare workers, highlighting its indispensable role in clinical practice.

Abbreviations

HIV	Human Immunodeficiency Virus
HAART	highly active anti-retroviral therapy
ONFH	osteonecrosis of the femoral head
THA	total hip arthroplasty

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Author contributions

Shengtao Li and Jie Wang wrote the main text of the manuscript, Jie Wang prepared Figs. 1, 2, 3, 4, 5, 6, 7 and 8. Qiang Zhang reviewed the manuscript.

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Data availability

The datasets generated and/or analysed during the current study are not publicly available but available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This was a retrospective study of patients who had previously received treatment in the Department of Orthopedics of our hospital, and informed consent was obtained from all subjects and/or their legal guardians. The study was approved by the Ethics Committee of Beijing Ditan Hospital of Capital Medical University (No. DTEC-KY2023-022-02).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

Human and animal rights

No animals were used in this research. All human research procedures were in accordance with the standards set forth in the Declaration of Helsinki principles of 1975, as revised in 2013 (http://www.wma.net/en/20activities/10ethics/10helsinki/).

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