CLINICAL ARTICLE

Clinical Outcome of Surgical Hip Dislocation Combined with Impacting Bone Grafts and Implanting Iliac Bone Flaps in the Treatment of Osteonecrosis of the Femoral Head: A Mid-term Retrospective Study

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Objective: To report the medium-term outcomes of surgical hip dislocation (SHD) combined with impacting bone grafts and implanting iliac bone flaps in the treatment of osteonecrosis of the femoral head (ONFH) and to define the indications for this treatment.

Methods: This was a single-center retrospective study. In total, 64 patients (70 hips) with ONFH treated from January 2014 to December 2017 were included in this study. There were 51 males and 13 females aged 18–55 years with an average age of 32 years. All patients underwent surgery for SHD combined with impacting bone grafts and implanting iliac bone flaps. Preoperative and postoperative clinical outcomes were assessed. The clinical outcome was assessed using the Harris hip score (HHS) and the conversion rate of total hip arthroplasty (THA). Univariate and multivariate logistic regression analyses were performed to identify risk factors affecting the clinical outcome. Kaplan–Meier (K-M) analysis was applied to calculate the survival rate of the femoral head.

Results: At the last follow-up (60 ± 15.08 months), the HHS was excellent for 41 hips, good for 17 hips, fair for three hips, and poor for nine hips. All nine hips with poor HHS underwent THA, including five in the first 2 years following the index surgery and four between three and 5 years. The conversion rate of total hip arthroplasty was 12.86%. Univariate and multivariate logistic regression analyses showed that the duration of hip pain and JIC classification type were significantly associated with clinical outcomes. Elderly age and advanced ONFH stage tended to lead to worse surgical outcomes. The overall survival rate of JIC classification type C1 and duration of pain ≤6 months was 98.1% and 97.8% at 72 months, respectively, as estimated by the Kaplan–Meier method.

Conclusion: Surgical hip dislocation combined with impacting bone grafts and implanting iliac bone flaps in the treatment of ONFH had a good mid-term clinical outcome, especially for patients with retention of the lateral column of the femoral head and hip pain less than 1 year.

Key words: Bone grafts; Hip preservation surgery; Iliac bone flaps; Osteonecrosis of the femoral head; Surgical hip dislocation

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Introduction

Osteonecrosis of the femoral head (ONFH) is a progressive hip joint disease caused by vascular injury. Subchondral fractures and collapse of the femoral head often occur, leading to severe hip pain, joint dysfunction, and even disability.[1,2] Total hip arthroplasty (THA) is the treatment of choice for symptomatic advanced femoral head collapse, especially when secondary acetabular changes are found.[2–4] Previous studies have confirmed that ONFH usually affects relatively young and active patients.[2,5] However, young patients with ONFH prefer to avoid THA to prevent multiple revision surgeries in the future.[6–8] Revision surgery is usually more difficult, more expensive, and less effective than primary surgery, even leading to severe complications and mortality.[6,7,9] Therefore, it is necessary to identify suitable and effective hip preservation surgeries to protect the joints of young patients with early-stage ONFH.[4,10,11]

In different stages of ONFH, the value of choosing different hip-preserving surgery options according to the patient's images and clinical symptoms has been widely recognized. Numerous types of hip preservation surgery have been applied to treat ONFH, such as core decompression, artificial biomaterial impaction, transplantation of a tantalum rod, vascularized or nonvascularized bone grafting, osteotomy, and bone grafting combined with bone morphogenetic protein administration.[1,12–16] All these procedures aim to provide mechanical support by preventing the collapse of the femoral head and to promote bone regeneration in the focal osteonecrosis area.[17–20] The application of bone grafts in ONFH has been well described; bone grafts not only provide mechanical support but also completely remove necrotic tissue to provide a good biological environment for bone regeneration.[21] Although these hip-preserving surgeries can treat ONFH to a certain extent, no hip preservation surgery is available that can completely satisfy everyone.[9] Improving the success rate of hip preservation treatment remains an important direction of ONFH clinical research.

In 2001, Ganz *et al.*[22] first proposed surgical hip dislocation (SHD) to treat various hip diseases and showed that this surgical approach would not damage the blood supply of the femoral head. None of the 213 hip joint disease patients followed in their study developed ONFH. Subsequent studies[23–25] confirmed that SHD protected the blood supply of the femoral head. Gautier *et al.*[26] suggested that the deep branch of the medial femoral circumflex artery (MFCA) is an important blood vessel that mainly supplies the femoral head. Protecting the deep branch of the MFCA can increase the success rate of hip preservation surgery and has become the operating principle of SHD. Currently, there is no study on the application of SHD with bone grafts. Thus, a retrospective study was conducted on SHD combined with impacting bone grafts and implanting iliac bone flaps for the treatment of ONFH in Association Research Circulation Osseuse (ARCO) stage II and III patients after a mid-term follow-up.

The purpose of this study was as follows: (i) to investigate the clinical improvement of SHD combined with impacting bone grafts and implanting iliac bone flaps for the treatment of ONFH; (ii) to explore the risk factors that affect the surgical outcome; and (iii) to preliminarily determine the optimal indications for this technique.

Materials and Methods

Patient source

Patients who underwent SHD combined with impacting bone grafts and iliac bone flap implantation for the treatment of ONFH at the First Affiliated Hospital of Guangzhou University of Chinese Medicine from January 2014 to December 2017 were retrospectively investigated. The diagnosis of ONFH was determined by senior doctors' judgment from X-rays and MRIs according to the Chinese Guideline for the Diagnosis and Treatment of Osteonecrosis of the Femoral Head in Adults.[27] In addition to the Association Research Circulation Osseous (ARCO) established in 2019, the Japanese Osteonecrosis Investigation Committee (JIC) was also used as an image classification standard for patients with ONFH. This study was approved by the institutional review board of the First Affiliated Hospital of Guangzhou University of Chinese Medicine (Approval number: NO. JY【2020】0620).

Inclusion and exclusion criteria

Inclusion criteria

Inclusion criteria were as follows: (i) patients who presented with ARCO stage II or III; (ii) aged between 18 and 55 years; (iii) actively cooperate with rehabilitation after operation; (iv) regular follow-up after operation; and (v) complete imaging data, i.e., X-rays of the hip must be taken at least once every 6 months.

Exclusion criteria

The exclusion criteria were as follows: (i) patients with a previous history of other hip preservation surgeries (such as core decompression and transplantation of a tantalum rod), tumors, hip joint infections, or bone metabolism diseases (such as osteoporosis); (ii) noncompliance with postoperative exercises; (iii) mental health deficit; and (iv) continued to take hormones and drink alcohol.

Surgical technique

Removal of autogenous iliac bone

The patients were placed in a lateral position after epidural anesthesia. An incision approximately 5 cm in length along the direction of the iliac wing was made approximately 1 cm distal and posterior to the anterior superior iliac spine to expose the iliac bone. The free iliac bone was approximately 4.0 cm × 1.5 cm, and part of the cancellous bone was excavated.

Exposure of the femoral head

The Ganz approach was chosen. First, the surgeon made a longitudinal incision approximately 15–20 cm long around the apex of the greater trochanter (Fig. 1). Soft tissues, such as the gluteus maximus and tensor fascia lata muscle, were cut layer by layer to expose the greater trochanter. Next, a greater trochanter osteotomy with a thickness of approximately 1.5 cm was performed, and the osteotomy block and the gluteus minor muscle were pulled forward and upwards to expose the upper joint capsule (Fig. 1B). The surgeon could see the anterior, upper and posterior upper parts of the joint capsule directly. Then, the surgeon cut the joint capsule along the long axis of the femoral neck to expose the femoral neck and cut the joint capsule along the edge of the acetabulum to avoid damage to the deep branch of the MFCA. The surgeon opened the joint capsule inward and downwards along the base of the femoral neck through a "Z"-shaped incision and could clearly see the front femoral head and neck, acetabulum, and labrum. Finally, the assistant dislocated the hip joint anteriorly and exposed the femoral head by flexing the hip, bending the knee, and adducting and externally rotating the hip joint (Fig. 1C).

Implanting iliac bone after opening the window

First, the surgeon opened a bone window along the axis of the femoral neck in front of the femoral head–neck junction for approximately 2.0 cm × 1.5 cm × 1.0 cm and thoroughly cleaned the necrotic bone and granulation tissue underneath the collapse (Fig. 1D,E). It is worth mentioning that the surgeon should care to protect the femoral head cartilage and subchondral cortex. Then, through the window at the junction of the femoral head and neck, autologous cancellous bone was used to impact the bone graft (Fig. 1F). At this time, the collapsed cartilage surface could be observed and lifted, and the collapse was corrected. Finally, the free iliac bone flap after proper trimming was implanted into the femoral head as a supporting bone graft.

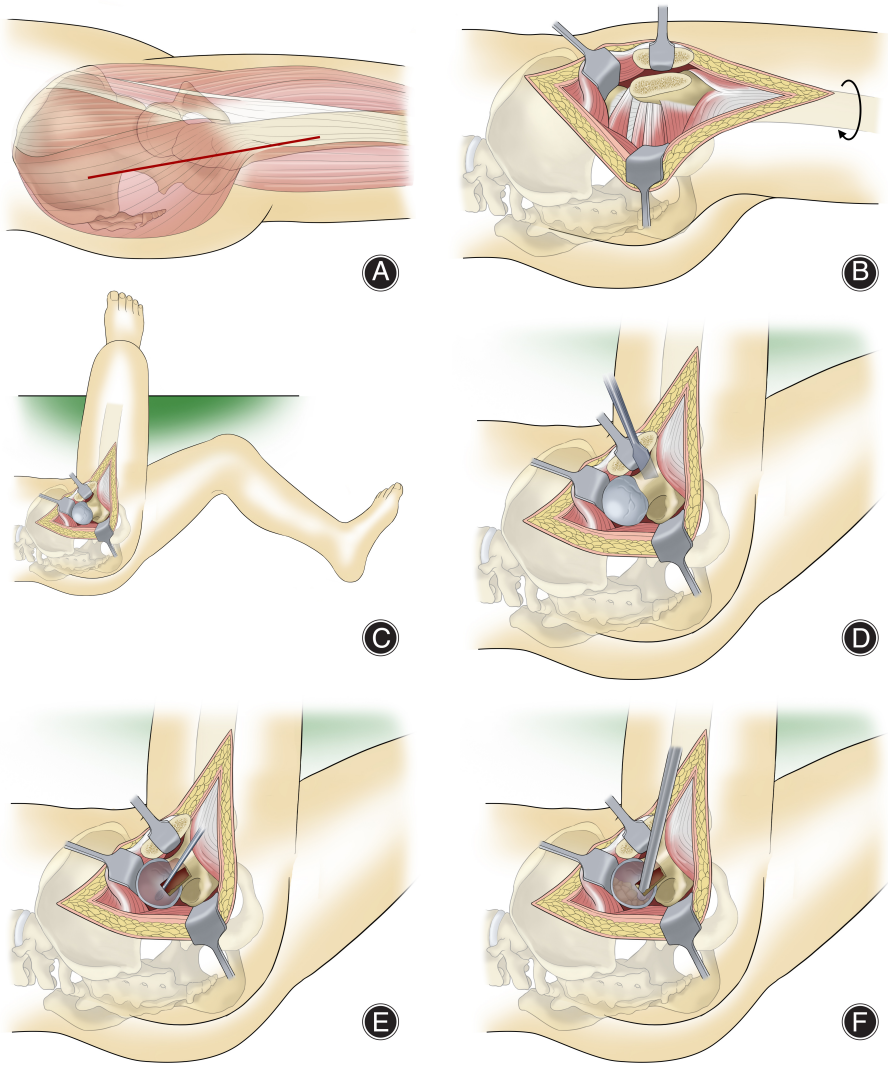

Fig. 1 (A) Ganz approach. (B) Osteotomy of the greater trochanter. (C) exposure of the femoral head. (D) Opening of the femoral head–neck junction window. (E) Clearance of necrotic bone. (F) Impaction and implantation of autologous cancellous bone

Reset of the greater trochanter and closing the wound
First, after washing, the surgeon reset the hip joint and sutured the front joint capsule. Next, two to three screws were inserted for internal fixation after anatomical reduction of the greater trochanter. Finally, the surgical port was conventionally sutured layer by layer.

Postoperative care and outcome evaluation
Postoperatively, the surgical hip was abducted in a neutral position with holster traction for 2 weeks. The patients were encouraged to actively exercise the limb and were instructed to undergo quadriceps femoris and gastrocnemius muscle isometric contraction training and ankle pump exercises. Unilateral ONFH patients could get out of bed early to practice walking with two crutches, whereas bilateral ONFH patients were told to walk with help for 6 months after the surgery.

Postoperative follow-up was performed at 3 days, 1 week, 3 months, and 12 months. At each appointment, anteroposterior and frog lateral X-rays of the bilateral hips were obtained for radiographic evaluation. Clinical outcomes were assessed by comparing the Harris hip score (HHS) before surgery and at the latest follow-up appointment. HHS <70 was defined as a symptomatic hip, and a greater score was considered to indicate a preserved hip.

Observation indicator
HHS was considered an evaluation index of the curative effect of SHD combined with impacting bone grafts and implanting iliac bone flaps. In clinical research, the HHS was used to evaluate postoperative recovery of hip function in an adult population. The HHS score system mainly included four aspects: pain, function, absence of deformity, and range of motion. The score standard had a maximum of 100 points, which were grouped into excellent (≥90), good (80–89), fair (70–79), and poor (<70) groups.

TABLE 1 The characteristics of 70 hips

Characteristic			
Hips (patients)	70 (64)	IIIb	17
Age[a] (year)	32(18–52)	JIC type	
Sex		C1	53
Females	13	C2	17
Males	51	Associated factor	
BMI (kg/m^2)	22.7	Corticosteroid	33
ARCO		Alcohol	19
II	8	Idiopathic	10
IIIa	45	Traumatic	8

[a] Note: The values are given as the mean and the range in parentheses.

Statistical analysis
All analyses of data were conducted with SPSS Software version 23.0 (International Business Machines, Armonk, New York, USA) and GraphPad Prism Software version 7.04 (GraphPad Software Inc.). Sex and JIC classification were evaluated using the independent-samples t test. The age group, BMI, associated factors, duration of pain, and ARCO classification, which included multiple groups, were assessed by one-way analysis of variance. The primary clinical outcome was HSS, which was classified into excellent (≥90), good (80–89), fair (70–79), and poor (<70) groups using the Kruskal–Wallis rank sum nonparametric test. When the nonparametric test result of a factor was $P < 0.2$, this factor was included in the logistic regression analysis. Univariate and multivariate logistic regression analyses were used to explore the risk factors affecting clinical outcomes. A poor HHS score was considered the clinical endpoint. A Kaplan–Meier (K-M) survival analysis was performed in GraphPad Prism with poor HSS score as the endpoint. $P < 0.05$ was considered statistically significant.

Results

General characteristics of participants
A total of 80 hips (73 patients) were included in the analysis. Ten hips (nine patients) were excluded due to age. The remaining 70 hips were not lost to follow-up. Thus, a total of 70 hips (64 patients) with a mean follow-up time of 60 months (41–80) were enrolled in this study. There were 13 female and 51 male patients with an average age of 32 years (18–52). Based on the ARCO classification, eight hips were classified as stage II, 45 hips were classified as stage IIIa, and 17 hips were classified as stage IIIb. According to the JIC classification, 53 hips were classified as JIC type C1, and 17 hips were classified as JIC type C2 at initial diagnosis. Other baseline data of patients with ONFH, including body mass index (BMI) and associated factors, are presented in Table 1.

Clinical outcomes
All patients in this study successfully underwent surgery without special circumstances or serious complications. Nine patients with poor HHS underwent THA: five in the first 2 years following the surgery and four between 3 and 5 years.

Radiographic outcomes
For all patients, the bone graft area was full, and the fractures in the greater trochanter healed well postoperatively. In patients who were found to have collapse in the necrotic area postoperatively, nine patients with poor HHS finally converted to THA. Others had acceptable hip function and did not turn to THA. Except for the patients noted above, the necrotic area was gradually repaired in the other patients. It should be noted that

TABLE 2 Comparison of preoperative and postoperative Harris Hip Scores in different factors

	Hips, n	Mean preoperative HHS (Mean ± SD)	Statistic value	*P* value	Mean postoperative HHS (Mean ± SD)	Statistic value	*P* value	Grading of postoperative HHS, n				Statistic value[c]	*p* value[c]
								Excellent	Good	Fair	Poor		
Age group (years)			0.440[a]	0.646[a]		4.475[a]	0.015[a]					7.596	0.022
18–30	34	56.62 ± 8.135			89.24 ± 10.003			20	10	1	3		
31–40	22	56.14 ± 8.073			89.55 ± 12.180			17	2	0	3		
>40	14	54.14 ± 9.363			79.57 ± 11.168			4	5	2	3		
Sex			0.439[a]	0.662[b]		0.809[a]	0.421[b]					0.495	0.482
Females	55	56.20 ± 8.521			88.05 ± 10.950			33	14	2	6		
Males	15	55.13 ± 7.652			85.27 ± 13.392			8	3	1	3		
BMI			1.518[a]	0.227[a]		0.104[a]	0.901[a]					0.704	0.703
<18.5	5	59.20 ± 7.463			88.60 ± 6.950			2	3	0	0		
18.5–23.9	41	54.56 ± 7.665			86.88 ± 11.843			23	10	2	6		
>23.9	24	57.71 ± 9.266			88.04 ± 11.944			16	4	1	3		
Associated factor			1.015[a]	0.392[a]		1.415[a]	0.246[a]					4.415	0.220
Corticosteroid	33	55.85 ± 8.570			87.18 ± 11.815			21	6	1	5		
Alcohol	19	53.79 ± 9.102			84.74 ± 13.932			9	6	0	4		
Idiopathic	10	58.10 ± 6.999			93.80 ± 4.492			8	2	0	0		
Traumatic	8	59.00 ± 6.118			86.63 ± 7.745			3	3	2	0		
Duration of pain (months)			4.872[a]	0.011[a]		26.483[a]	<0.001[a]					18.977	<0.001
≤6	46	55.17 ± 7.499			90.22 ± 6.950			28	14	3	1		
7–12	15	56.87 ± 8.323			90.60 ± 9.927			12	2	0	1		
>12	9	48.33 ± 9.014			67.67 ± 13.856			1	1	0	7		
ARCO			0.623[a]	0.540[a]		5.181[a]	0.008[a]					8.101	0.017
II	8	54.63 ± 6.022			92.00 ± 3.625			7	1	0	0		
IIIa	45	56.80 ± 8.204			89.31 ± 10.193			28	11	2	4		
IIIb	17	54.41 ± 9.527			80.18 ± 14.205			6	5	1	5		
JIC			3.284[b]	0.002[b]		3.648[b]	0.002[b]					10.620	0.001
C1	53	57.70 ± 7.475			90.94 ± 6.567			35	15	2	1		
C2	17	50.59 ± 8.653			76.35 ± 16.066			6	2	1	8		

[a] Notes: One-way analysis of variance; Statistic value is *F* value.; [b] Independent-samples *t*-tests; Statistic value is *t* value.; [c] Kruskal-Wallis rank sum test. Statistic value is *Z* value.

radiographic outcomes are occasionally not consistent with clinical symptoms, and it is difficult to evaluate the prognosis exclusively by radiography. Typical cases are shown in Figs 3–5.

Harris hip score

At the last follow-up, the HHS was excellent for 41 hips, good for 17 hips, fair for three hips, and poor for nine hips. The postoperative HHS was much higher in young patients (89.24 ± 10.003 and 89.55 ± 12.180) compared with those 40 years or older (79.57 ± 11.168) ($F = 4.475$, $P = 0.015$) and in those who had reported hip pain for less than 12 months (90.22 ± 6.950 and 90.60 ± 9.927) compared with those reporting a long duration of hip pain (67.67 ± 13.856) ($F = 26.483$, $P < 0.01$). ARCO II and IIIa had better outcomes (92.00 ± 3.625 and 89.31 ± 10.193, respectively) than ACRO IIIb (80.18 ± 14.205) ($F = 5.181$, $P = 0.008$), and JIC classification type C1 (90.94 ± 6.567) had better outcomes than JIC classification type C2 (76.35 ± 16.066) ($t = 3.648$, $P = 0.002$). Sex ($F = 0.809$, $p = 0.421$), BMI ($F = 0.104$, $P = 0.901$), and associated factors ($F = 1.415$, $P = 0.246$) did not significantly differ in the analysis (Table 2).

Logistic regression analysis

As shown in Table 3, univariate logistic regression analysis demonstrated a significant difference between the preserved group and symptomatic group in the duration of pain ($P < 0.01$) and JIC classification type ($P = 0.01$). The multivariate analysis revealed that JIC classification type C1 (OR 0.053; 95% CI 0.003–0.883; $P = 0.041$) was a protective factor for preserved hips. Moreover, a duration of pain ≤6 months (OR 0.020; 95% CI 0.001–0.298; $P = 0.005$) and duration of pain between 7 and 12 months (OR 0.143; 95%

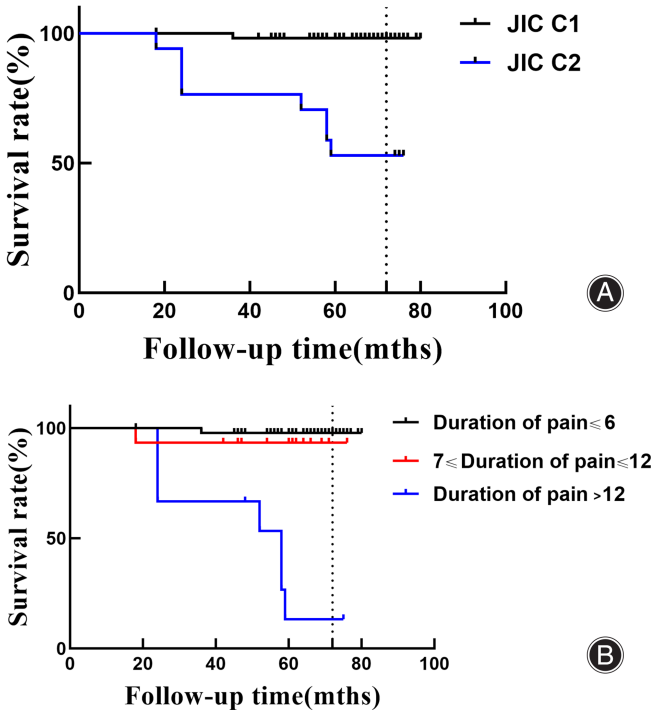

Fig. 2 Kaplan–Meier survival curve (A) Kaplan–Meier survival curve of JIC. (B) Kaplan–Meier survival curve of duration of pain

TABLE 3 Univariate and multivariate logistic regression analysis of 70 hips

	Preserved group ($n = 61$ hips)	Symptomatic group ($n = 9$ hips)	Univariate *P* value	Multivariate *P* value[a]	OR (95% CI)
Age group(years)			0.507	—	—
19–30	31	3			
31–40	19	3			
>40	11	3			
Duration of pain (months)			<0.001	0.018	
≤6	45	1		0.005	0.020 (0.001–0.298)
7–12	14	1		0.237	0.143 (0.006–3.596)
>12	2	7			
ARCO			0.151	—	
II	8	0			
IIIa	45	4			
IIIb	17	5			
JIC			0.001	0.041	0.053 (0.003–0.883)
C1	52	1			
C2	9	8			

[a] Notes: The statistical results of OR of Duration of pain ≤6 months and 7–12 months were compared with Duration of pain >12 months which was a dummy variable. The statistical results of OR of JIC is JIC-C1 relative to JIC-C2.

CI 0.006–3.596; $P = 0.237$) were independent protective factors for preserved hips.

Kaplan–Meier analysis

The overall survival rate of JIC classification type C1 and duration of pain ≤6 months was 98.1% and 97.8% at 72 months, respectively, as estimated by the Kaplan–Meier method (Fig. 2A,B). Similarly, a duration of pain of 7–12 months also has a high survival rate.

Discussion

Surgical advantages

An analysis of clinical and functional improvements after surgery of surgical hip dislocation combined with impacting bone grafts and implanting iliac bone flaps was performed. The results showed that this surgery could significantly improve the results of HHS. The rate of conversion to THA is low.

The basic principle of hip preservation surgeries is to provide sufficient and lasting support for necrotic subchondral bone and cartilage to prevent collapse and the need for osteoarthropathy.[28] At present, many types of hip preservation surgeries are available for ONFH to provide mechanical support. The choice of an appropriate hip preservation surgery depends on the clinical prognosis of patients and the success rate of hip preservation. Bone grafts are currently one of the most popular surgeries for preserving the femoral head and delaying THA. Iliac bone grafts have achieved good clinical effects as hip-preserving treatments for patients with ONFH.[5,13,29]

The main technical point of SHD is to reduce the damage to the MFCA, which is the main artery supplying the femoral head.[26] The characteristics of the blood supply of the femoral head indicate that both the anterior and posterior approaches will aggravate the blood supply damage, and SHD undoubtedly circumvents this problem. Furthermore, SHD can provide the best exposure of the femoral head. Thus, a new technique that combines SHD with impacting bone grafts and iliac bone grafts was created to treat patients

Fig. 3 Male, 18 years. (A) Radiographs at the anteroposterior and frog lateral views indicated left ONFH, graded as ARCO stage IIIb and JIC type C1. (B) Three months postoperatively: The bone graft area was full, and no further collapse was seen. (C) 12 months postoperatively: The necrotic area was partially repaired. (D) 24 months postoperatively: Consistent density uniformity of the necrotic area and no further collapse were seen. (E) 36 months postoperatively: The necrotic area was further repaired. (F) 42 months postoperatively: The necrotic area of the femoral head was basically repaired

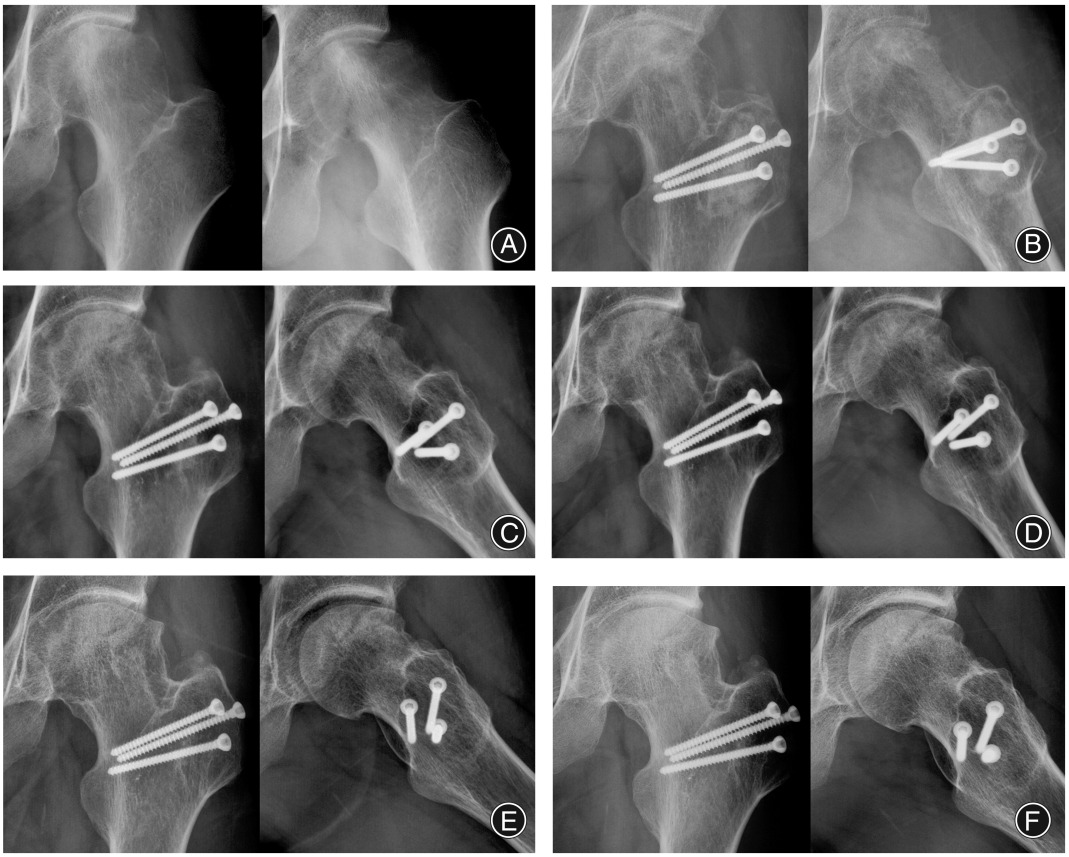

Fig. 4 Male, 20 years. (A) Radiographs at the anteroposterior and frog lateral views indicated left ONFH, graded as ARCO stage IIIb and JIC type C2. (B) Three months postoperatively: The necrotic area was partially repaired, and no further collapse was seen. (C) 12 months postoperatively: Consistent density uniformity of the necrotic area and fractures in the greater trochanter had healed well. (D) 24 months postoperatively: The necrotic area was further repaired. (E) 48 months postoperatively, no further collapse of the femoral head was found. (F) 72 months postoperatively: The necrotic area of the femoral head was basically repaired, and no further collapse was seen

with ARCO stage II to III ONFH. Compared with other hip preservation surgeries, this technique has the following advantages: (i) the femoral head is more completely exposed, which is convenient for precise removal of the necrotic bone, especially the subchondral dead bone, without worrying about damaging the femoral head cartilage; (2) it is convenient to fully impact the bone graft, correct the collapse of the femoral head, and repair the cartilage; and (iii) It is convenient to use autogenous bone for bone grafting. In addition to autogenous iliac bone, a large amount of cancellous bone in the greater trochanter area can also be easily obtained. However, it is challenging to promote the repair of the necrotic area of the femoral head in the event of collapse, and the results are unpredictable. In this retrospective study, although the patients with ONFH had good improvement outcomes in imaging (Figs 3 and 4) and patient-reported outcomes, as indicated by the HHS, a JIC classification type C2 (Fig. 5) and a duration of pain >12 months correlated with unsatisfactory HHS.

Relevant risk factors

A previous study showed that the JIC class is correlated with bone collapse in ONFH.[30] Ma *et al.*[31] reported similar results; that is, progressive necrosis and bone collapse were closely correlated with JIC classification type C2. Chen *et al.*[32] found poorer functional results in patients with JIC classification type C2 after bone grafting compared with patients with JIC classification type C1. In patients with JIC classification type C2, the absence of the lateral column of the femoral head as the main weight-bearing site makes ONFH more likely to progress.[33] In this study, patients with JIC classification type C2 had a poor clinical outcome.

Some studies have shown that pain and patient-reported outcomes are interrelated with the continuous progression of ONFH.[34,35] The results of this study are consistent with those: the success rate of hip preservation when there was more than 1 year of hip pain was lower than when there was less than 1 year of pain. The results of Chen *et al.*

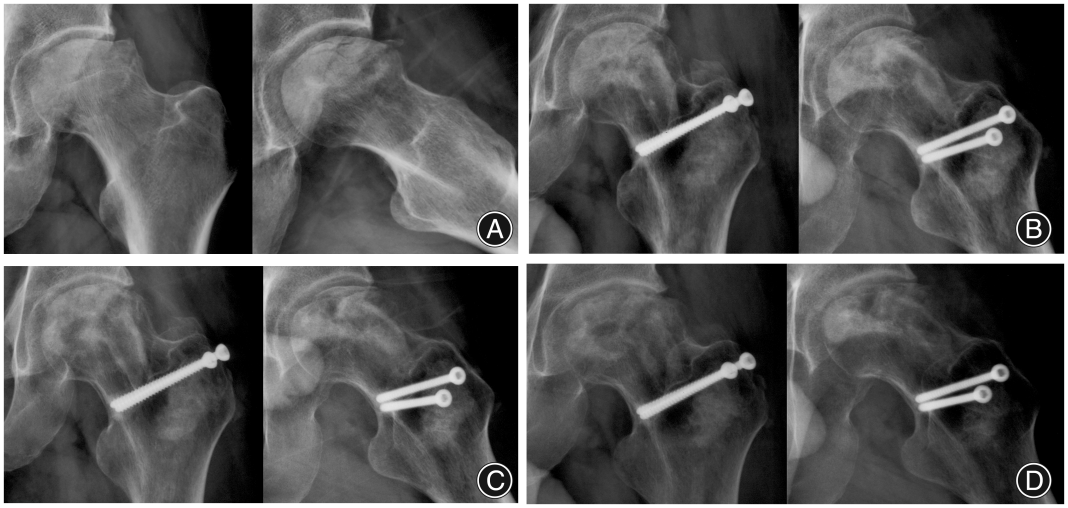

Fig. 5 Male, 31 years. (A) Radiograph imaging at an anteroposterior and frog lateral view indicated left ONFH, graded as ARCO stage IIIa and JIC classification type C2. (B) 3 months postoperative: The collapse of bone graft area was seen. (C) 6 months postoperative: Inconsistent density uniformity of necrotic area, and further collapse was seen. (D) 12 months postoperative: The necrotic area was further collapsed

confirm this finding.[32] A previous study showed that the occurrence of pain in the asymptomatic hip was a good predictor of collapse.[36] It could be hypothesized that hip preservation after less than 1 year of pain may prevent further collapse of the femoral head.

Several other risk factors were also analyzed here. Some studies have reported that hip preservation surgeries cannot achieve better clinical results compared with other approaches in the case of advanced ONFH.[1,37] However, this study obtained the opposite result, which may be because the patients included had less advanced ONFH. Although the logistic regression analyses showed that advanced ONFH was not considered a risk factor, the mean postoperative HHS in advanced ONFH was lower than that in early ONFH. Univariate and multivariate logistic regression analyses suggested that age did not affect the final clinical outcome, but significant differences in postoperative HHS were noted between different age groups mainly due to the reduction of bone matrix and reduced potential for bone recovery of old patients.

Preliminary indications and precautions

For surgery of free vascularized fibular grafting, Kawate *et al.*[38] reported that small osteonecrosis (less than 300 degrees of the femoral head) without preoperative collapse (Steinberg's stages I and II) is the major indication. Yoo *et al.*[39] also concentrated on the size and location of the lesion. Regarding the iliac bone flap grafting technique, Xie H *et al.*[28] showed that patients in the precollapse stages exhibit significant improvement. Lau *et al.*[40] reported the results of 50 hips following iliac bone flap grafting at 17 years. All patients with precollapse (Ficat Stage II) and early postcollapse (Ficat stage III) ONFH had excellent or good results. This study showed that patients with JIC classification type C1 are expected to have favorable outcomes, including repair of necrotic tissue, improved hip pain, and delay or avoidance of conversion to THA. These findings are consistent with the results of the study.

Pain in ONFH indicates trabecular interruption and structural instability of the femoral head. Our study considered the duration of pain and showed that patients with hip pain less than 1 year had better results, whereas the studies above did not analyze the influence of hip pain on ONFH. Surgery should be performed as soon as possible after the development of symptoms to obtain satisfactory outcomes. Furthermore, the studies above showed that young patients had better outcomes than older patients. It is indicated that young patients are more suitable for hip preservation surgeries.

In summary, patients with retention of the lateral column of the femoral head and hip pain less than 1 year are suitable for this technique, and it is necessary to consider carefully whether to apply this surgery when treating advanced ONFH and older patients.

Limitations

Several limitations of this study must be acknowledged. First, this single-center retrospective study had an insufficient level of evidence compared with prospective and multicenter studies. Second, long-term follow-up can better reflect the effectiveness of hip preservation surgeries, but this study only conducted mid-term follow-up (mean follow-up time of 5 years). Third, factors other than those described in the article that might affect the prognosis after surgery, such as bone marrow oedema, the size and location of the necrotic zone and cartilage characteristics, were not taken into consideration. Finally, the HHS was the only index used to evaluate clinical outcomes, and postoperative

images were not evaluated. According to previous experience with postoperative patients, although some patients may have poor imaging signs, they have good functional activity of the hips.

Conclusion

In this study, the results demonstrated that SHD combined with impacting bone grafts and implanting iliac bone flaps in the treatment of ONFH had a good mid-term clinical outcome, providing a new possibility for hip preservation. The preliminary exploration of indications demonstrated that retention of the lateral column of the femoral head and hip pain less than 1 year can lead to better clinical outcomes in the treatment of ONFH. Age and ACRO stage are factors that surgeons need to consider carefully before proceeding.

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