Original Article Clinics in Orthopedic Surgery 2024;16:390-396 • https://doi.org/10.4055/cios23189

Outcomes of Hybrid Total Hip Arthroplasty for Subchondral Insufficiency Fracture of the Femoral Head

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Background: The purpose of this study was to evaluate functional outcomes, radiologic results, and complications after hybrid total hip arthroplasty (THA) in patients with subchondral insufficiency fractures (SIFs) of the femoral head.

Methods: From June 2009 to December 2020, among 985 patients who underwent hybrid THA at our hospital, 19 patients diagnosed with SIF through a retrospective chart review were included. Those under 50 years of age, with radiographic findings of osteonecrosis on the contralateral side of surgery, a history of organ transplantation, and alcohol abuse, were excluded. Functional evaluation was performed using a modified Harris Hip Score (HHS). After surgery, inclination and anteversion of the acetabular cup and version of the femoral system were measured using postoperative x-ray. The outpatient follow-up was performed at 6 weeks, 3 months, 9 months, and 12 months after surgery and every year thereafter. Complications including dislocation, implant loosening, stem subsidence, and periprosthetic infection were observed on follow-up radiographs.

Results: The average follow-up time was 29.3 ± 9.1 months (range, 24–64 months) with no loss to follow-up. The mean modified HHS was 83.4 ± 9.6 (range, 65–100) at the last outpatient clinic follow-up. The average inclination of the acetabular cup was 41.9° ± 3.4° (range, 37°–48°), and the anteversion was 27.5° ± 6.7° (range, 18°–39°). The version of the femoral stem was 19° ± 5.7° (range, 12°–29°). There was no case of intraoperative fracture. There were no cases of dislocation, loosening of the cup, subsidence of the femoral stem, intraoperative or periprosthetic fracture, or periprosthetic infection on the follow-up radiographs.

Conclusions: In our study, hybrid THA showed favorable outcomes in patients diagnosed with SIF, and there were no further special considerations as for THA performed due to other diseases or fractures.

Keywords: *Subchondral insufficiency fracture, Hybrid Total hip arthroplasty*

Subchondral insufficiency fracture (SIF) of the femoral head without any evidence of predisposing osteonecrosis (ON) has been proposed as an etiology of femoral head collapse.[1,2] Although the precise prevalence of SIFs is unknown, a recent histopathological evaluation has revealed that SIFs were observed in 6.3% of patients with a preoperative diagnosis of osteoarthritis and in 11.1% of patients with ON.[3] SIF also results in femoral head collapse on radiographs; however, its pathophysiology is different from that of ON.[3] It is necessary to differentiate SIF from ON of the femoral head because these two conditions have several overlapping characteristics in both imaging and clinical appearances.[1,4]

Considering that the risk factors for SIF are osteoporosis and deficiency of acetabulum coverage, arthroplasty should be performed with caution. Intraoperative fracture and dislocation due to stem malposition may occur because of poor bone quality and patient's pelvic tilt, and lumbar kyphosis. The implant placement angle is associ-

Received June 13, 2023; Revised January 18, 2024;
Accepted January 18, 2024
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ated with postoperative complications, such as dislocation and wear of the articular surface.[5] In the setting of loss of lumbar lordosis and reduction in the sacral slope, the pelvis tilts posteriorly and increases functional acetabular anteversion, increasing the risk of posterior impingement and thus anterior dislocation.[6] If the size is small and no apparent femoral head collapse is observed, the SIF might heal without surgical intervention. However, large SIFs frequently progress to secondary arthritis of the hip and when a collapse progresses or pain increases, total hip arthroplasty (THA) may be necessary.[7]

In addition to these factors, the surgical method and cement or cementless fixation are factors that influence prognosis. Traditionally, the revision rate of cementless arthroplasty has been higher than that of cemented arthroplasty.[8] The risk of revision, including periprosthetic fractures, dislocations, and infections, is higher in cementless arthroplasty.[9] In addition, a cementless stem had a higher revision risk due to aseptic loosening than a cemented stem after 5 years.[10] However, due to the technical difficulties of ceasing to reduce bone cement implantation syndrome and cost aspects, cementless hip arthroplasty is being implemented. Hybrid THA is a variation of low-friction arthroplasty that employs cemented fixation of the femoral component, with cementless fixation of the acetabular component.[11] Since no studies have been reported on hybrid THA in SIFs, we analyzed functional outcomes, radiologic results, and complications in patients who underwent hybrid THA at our hospital.

METHODS

This study was approved by the Institutional Review Board of Wonkwang University Hospital (IRB No. WKUHIRB 2023-01-021-006). The need for informed consent was waived due to the retrospective design of the study.

From June 2009 to December 2020, among the 985 patients who underwent hybrid THA at our hospital, 19 patients diagnosed with SIF were included upon retrospective review of their char (Table 1). Those under 50 years of age, with radiographic findings of ON on the contralateral side of surgery, a history of organ transplantation, and a history of alcohol abuse were excluded (Table 2).

SIF was diagnosed based on characteristic findings of magnetic resonance imaging (MRI). A characteristic MRI finding of SIF is a diffuse bone marrow edema pattern, as well as a band-like lesion with a low signal intensity lesion in the bone marrow edema pattern on T1-weighted imaging[1,2,12] (Fig. 1). This band-like lesion is the most distinctive finding and is essential for the diagnosis of SIF.[12] In addition, the shape of this low-intensity band, which is usually irregular, serpiginous, parallel to the articular surface, and often discontinuous, is useful for diagnosis.[12] SIF was diagnosed when the opinions of both radiologists (SKJ) and two orthopedic surgeons (JSP and SHK) were concordant.

THA was performed using a lateral approach combined with a tight transosseous suture of the joint capsule. Cementless acetabular cups and cemented femoral stems were used in all hybrid THAs. The acetabular cup was placed within a safe range, with a cup inclination between 30° and 50°, and cup anteversion between 5° and 25°.[13] This was confirmed during surgery through a C-arm. Fourteen THAs were performed using a Continuum Acetabular System (Zimmer Biomet) with collarless polished taper stems (Zimmer), and 5 THAs were performed using an Exeter Trident cup (Stryker Orthopaedics) with Exeter V 40 (Stryker) stems.

Functional evaluation was performed using a modified Harris Hip Score (HHS). The number of intraoperative fractures was evaluated during surgery. After surgery, inclination and anteversion of the acetabular cup and version of the femoral system were measured using radiographs. Cup inclination was measured on the anteroposterior (AP) radiographs using the method described by

Table 1. Demographics of Patients with Subchondral Insufficiency Fracture of Femoral Head

Variable	Value
Sex (male : female)	11 : 8
Age (yr)	70.9 (62 to 86)
BMI (kg/m^2)	24.1 (17.1 to 30.0)
BMD (T-score)	–2.5 (–4.4 to –0.1)
ASA score	2.5 (1 to 3)
LCEA	22.9 (14 to 45)
Acetabular inclination	36.1 (33 to 44)
Acetabular anteversion	18.9 (10 to 27)
Pelvic incidence	53.9 (40 to 68)
Lumbar lordosis angle*	22.8 (8 to 40)
Posterior pelvic tilt	16.1 (8 to 29)

Values are presented as mean (range).
BMI: body mass index, BMD: bone mineral density, ASA: American Society of Anesthesiologists, LCEA: lateral center-edge angle.
*Lumbar lordosis angle was measured by Cobb's method (L1–5, recumbent position).

Table 2. SIF Patients List

No.	Sex	Age (yr)	BMI (kg/m^2)	BMD	LCEA	AI	AA	PI	LLA	PPT
1	M	71	25.0	–2.1	23	36	14	47	15	15
2	M	72	27.4	–4.4	14	34	21	60	28	12
3	F	66	22.0	–2.8	35	35	19	52	17	16
4	F	62	26.1	–2.7	19	36	13	55	19	13
5	M	62	21.5	–1.4	29	43	18	57	32	10
6	M	70	30.0	–1.8	30	34	22	55	18	25
7	M	69	19.8	–2.0	21	33	15	49	20	11
8	M	75	18.5	–2.9	14	37	12	52	35	15
9	M	71	28.2	–2.5	45	35	25	65	3	16
10	F	70	24.0	–3.1	22	35	17	50	25	12
11	M	76	29.3	–2.0	15	37	16	51	30	9
12	F	73	17.1	–3.0	27	33	20	63	8	13
13	F	63	26.1	–2.0	20	44	18	48	10	17
14	F	65	27.0	–1.5	24	33	24	40	40	8
15	F	86	26.5	–3.3	21	42	23	66	22	26
16	M	81	22.8	–3.9	15	35	27	59	14	14
17	M	74	30.0	–2.2	16	35	26	68	37	29
18	F	74	19.5	–3.8	17	35	10	43	31	22
19	F	67	17.1	–0.1	28	34	19	44	29	23

SIF: subchondral insufficiency fracture, BMI: body mass index, BMD: bone mineral density, LCEA: lateral center-edge angle, AI: acetabular inclination, AA: acetabular anteversion, PI: pelvic incidence, LLA: lumbar lordosis angle, PPT: posterior pelvic tilt.

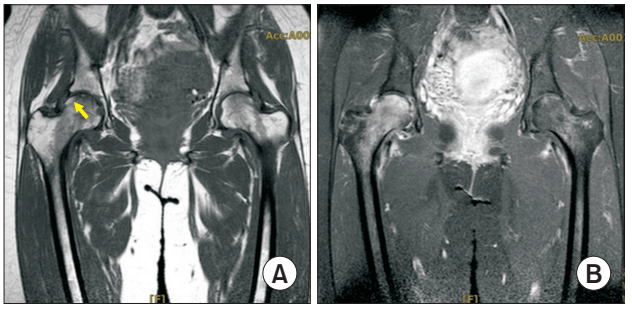

Fig. 1. On magnetic resonance imaging, a diffuse bone marrow edema pattern was seen with low signal intensity on the T1-weighted image (A) and with high signal intensity on the T2-weighted image (B). A very low signal intensity band (arrow) parallel to the articular surface was also seen.

Engh et al.[14] (Fig. 2). The anteversion of the cup was evaluated using the method described by Woo and Morrey[15] on cross-table lateral radiographs (Fig. 3). The version of a femoral stem was calculated using the method described by Weber et al.[16] (Fig. 4).

The outpatient follow-up was performed at 6 weeks, 3 months, 9 months, and 12 months after surgery and every year thereafter. Functional outcomes and radiographs were performed during follow-up. Complications, including dislocation, implant loosening, stem subsidence, intraoperative or periprosthetic fracture, and periprosthetic infection, were evaluated using follow-up radiographs. Loosening of the cup was considered when migration of 2 mm or more was observed, and femoral stem loosening was considered when subsidence of 3 mm or more or radiolucent findings were observed in both AP and lateral radiographs.[17] Stem subsidence was defined as a decrease in the distance between the shoulder of the stem and the most medial portion of the lesser trochanter.[18] The survivorship was defined as reoperation of the hip for complications.

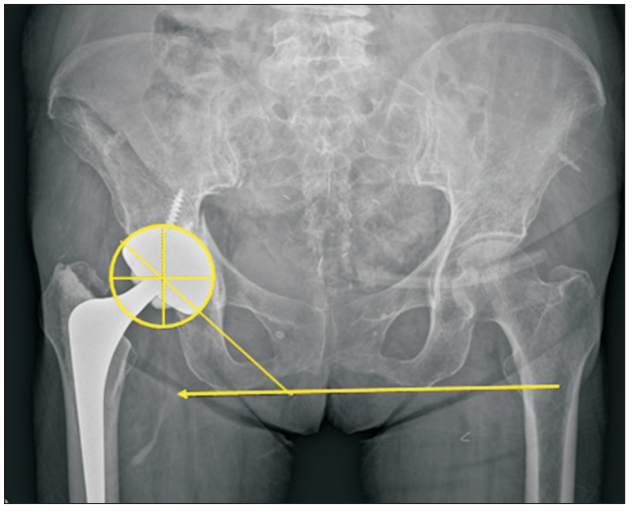

Fig. 2. Cup inclination was measured as the angle of a line drawn through its opening to a transverse line drawn through the bottom edge of the acetabular teardrops.

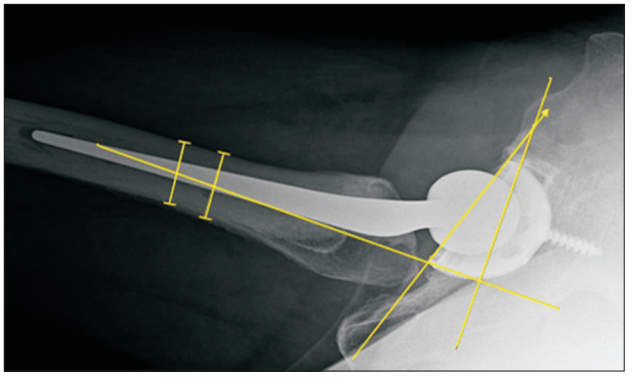

Fig. 3. Cup anteversion was measured as the angle between a line drawn across the face of the acetabulum and a line perpendicular to the horizontal plane.

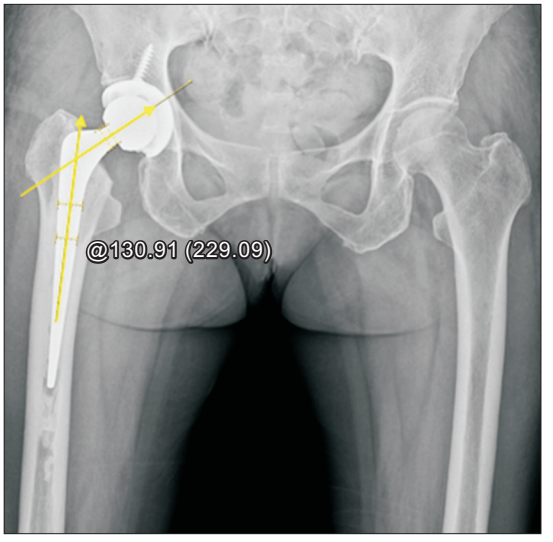

Fig. 4. Femoral stem version: arcos (tan [NSA] / tan [TNSA]). It is calculated from an anteroposterior hip radiograph using rotation-based change in the projected prosthetic NSA. NSA: neck shaft angle, TNSA: true neck shaft angle.

Table 3. Results of Functional Outcome and Radiologic Findings in SIF Patients

Variable	Value
Follow-up period (mo)	29.3 (24–64)
Modified HHS	83.4 (65–100)
Acetabular inclination (°)	41.9 (37–48)
Acetabular anteversion (°)	27.5 (18–39)
Femoral stem version (°)	19 (12–29)

Values are presented as mean (range).
SIF: subchondral insufficiency fracture, HHS: Harris Hip Score.

The chi-square test or Fisher's exact test was used for categorical variables, and the Student *t*-test or analysis of variance was used for continuous variables. A p-value < 0.05 was used to determine statistical significance. Kaplan-Meier time analysis was used to estimate survival after surgery. Statistical analyses were performed using IBM SPSS ver. 25.0 (IBM Corp.).

RESULTS

All 19 patients were followed up for an average of 29.3 ± 9.1 months (range, 24–64 months). The mean modified HHS was 83.4 ± 9.6 (range, 65–100) at the last outpatient clinic follow-up. The average inclination of the acetabular cup was 41.9° ± 3.4° (range, 37°–48°), and the anteversion was 27.5° ± 6.7° (range, 18°–39°). The version of the femoral stem was 19° ± 5.7° (range, 12°–29°) (Table 3). There were no cases of dislocation, implant loosening, stem subsidence, intraoperative or periprosthetic fracture, and periprosthetic infection on the follow-up radiographs (Table 4). The survivorship was 100%.

DISCUSSION

The results of our study suggest that hybrid THA performed in patients with SIFs can lead to favorable outcomes, and there is no particular difference compared to the results of THA performed in patients with osteoarthritis or ON. Lee et al.[7] reported that cementless THA is a favorable treatment option for SIF patients.

Table 4. List of Functional Outcomes and Radiologic Findings in SIF Patients

No.	Follow-up period (mo)	Modified HHS	Acetabular inclination	Acetabular anteversion	Femoral stem version
1	24	90	40	22	18
2	30	95	47	26	15
3	26	79	39	30	14
4	31	78	38	33	17
5	26	86	42	28	29
6	25	92	45	18	19
7	32	75	41	25	22
8	33	98	46	38	12
9	29	65	48	34	16
10	28	100	44	39	26
11	24	80	43	20	28
12	24	89	37	25	27
13	25	90	40	19	25
14	36	88	43	27	19
15	64	83	38	31	14
16	25	75	42	20	13
17	24	76	40	36	14
18	25	76	37	32	21
19	26	70	46	20	12

SIF: subchondral insufficiency fracture, HHS: Harris Hip Score.

Since both SIF and ON show similar findings in early and advanced stages, x-rays cannot be used to differentiate between the 2 diseases. The shape of the low-intensity band in T1 on MRI is useful for differentiation.[12,19,20] In SIF, the low-intensity band has been reported to have an irregular serpentine shape, often parallel to the articular surface because it corresponds to a fracture line.[1,2,12,19] Its shape is the convexity of the articular surface, which is irregular, serpiginous, and discontinuous.[20] On the other hand, the low-intensity band in ON often appears as a smooth mirror image of the articular surface, representing the band of repair tissue formed around the wedge-shaped osteonecrotic area.[21,22] Its shape is a concavity of the articular surface, which is smooth and circumscribed.[21] Another specific finding is the presence of homogenous high signal intensity in the proximal segment divided by the fracture line on T2 or gadolinium-contrast MRI.[3] SIF shows high signal intensity, which corresponds to a proximal segment that is generally alive and consists of repaired tissue.[3] The subchondral bone segment proximal to the low-intensity band in ON does not show a high signal intensity, as the proximal segment is totally necrotic.[12] The clinical aspects of SIF and ON also differ. SIF is usually observed in elderly women with osteoporosis and obesity, and bilateral involvement is rare.[23] ON is usually seen in middle-aged patients with a history of steroid or alcohol abuse, and 50%–70% of them have bilateral involvement.[3]

Excessive contact pressure at the femoral head due to anterior and lateral coverage deficiencies may be the pathophysiology of SIF.[24] Lateral coverage deficiency is mostly caused by hip dysplasia, and anterior coverage deficiency can be caused by pelvic posterior tilt.[25] Loss of lumbar lordosis with aging can induce pelvic posterior tilt.[3,25,26] Lumbar kyphotic changes can lead to anterior dislocations. Pelvic tilt and acetabular anteversion appear to have a definite relationship.[27] Implanted cups remain static within the acetabulum, while the pelvis is a mobile segment that adapts its position during movements to maintain sagittal balance and provide hip joint stability by avoiding bony impingement.[28] To locate the acetabular cup in the safe zone claimed by Lewinnek et al.,[13] we made efforts to secure the true acetabulum by removing osteophytes and soft tissue around the acetabulum. Osteoporosis can also increase the risk of periprosthetic fracture.

To reduce these risk factors, the choice of surgical approaches or the presence of cementation during THA may vary; however, no study has analyzed the results of hybrid THA. Currently, cementless THA is predominantly performed because of the advantages of the rapid progression of cementless design, shorter operating time, and technical difficulties associated with cementing.[29] However, the survival rate of hybrid THA is comparable with that of cementless THA.[30] Cementing techniques have a lower risk of complications that are associated with cementless THA such as periprosthetic fracture and thigh pain.[31] In addition, the greatest benefit of using bone cement in hip arthroplasty is firm initial stability, which allows for rapid rehabilitation and a good prognosis after surgery.[30]

In our study, THA performed for the diagnosis of SIF showed favorable results. It is considered safe to perform without any special considerations compared with general THA in terms of surgical technique, as well as cup and femoral stem type. A limitation of this study is that only 19 patients were included. Considering the rare diagnosis and prevalence of SIF, multicenter studies with long-term follow-up are needed. Second, the diagnosis of SIF

was only made using MRI; therefore, a pathological diagnosis was not performed. Referring to a report that 6.3% of preoperative OA-diagnosed patients and 11.1% of ON-diagnosed patients were pathologically diagnosed with SIF,[2] a study with pathological diagnosis seems necessary. In our study, hybrid THA showed favorable outcomes in patients diagnosed with SIF, and there were no further special considerations as for THA performed due to other diseases or fractures.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to Seon Kwan Jeong from Wonkwang University Hospital for the assistance in this study.

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