CLINICAL ARTICLE

Borderline Developmental Dysplasia of the Hip: A Risk Factor Predicting the Development and Poor Prognosis after Core Decompression for Idiopathic Osteonecrosis of the Femoral Head

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Objective: It is unclear whether idiopathic osteonecrosis of the femoral head (ONFH) is associated with borderline developmental dysplasia of the hip (BDDH). This study aimed to compare the incidence of BDDH between patients with idiopathic ONFH and matched control subjects and determine the influence of BDDH on poor prognosis after core decompression (CD).

Methods: We retrospectively examined 78 consecutive patients (111 hips) with idiopathic ONFH undergoing CD and 1:2 matched with 156 control subjects (222 hips). The anteroposterior pelvic radiographs were used to measure the acetabular anatomical parameters and divide included subjects into BDDH or non-BDDH group. The incidence of BDDH and acetabular anatomical parameters were compared between patients with idiopathic ONFH and matched controls. Clinical outcomes, such as Harris Hip Score (HHS), progression of collapse, and conversion to total hip arthroplasty (THA), were compared between patients with BDDH and without BDDH in the idiopathic ONFH group, with a mean follow-up of 72.1 ± 36.6 months.

Results: Patients with idiopathic ONFH had a significantly higher incidence of BDDH than matched controls (29.7% *vs* 12.2%, $p < 0.001$). Less acetabular coverage was also found in patients with idiopathic ONFH than in matched controls as demonstrated by lower CEA (28.5° ± 4.7° *vs* 33.1° ± 5.7°, $p < 0.001$), AHI (82.4 ± 5.0 *vs* 86.3 ± 5.4, $p < 0.001$), ADR (299.6 ± 28.4 *vs* 318.8 ± 31.3, $p < 0.001$), and a higher sharp angle (40.0° ± 3.4° *vs* 37.4° ± 3.7°, $p < 0.001$). In patients with idiopathic ONFH, the BDDH group had a significantly lower mean HHS at the last follow-up (83.5 ± 17.4 *vs* 91.6 ± 9.7, $p = 0.015$) with a different score distribution ($p = 0.004$), and a lower 5-year survival rate with both clinical failure (66.7%, 95% CI 52.4%–84.9% *vs* 83.7%, 95% CI 75.2%–93.1%; $p = 0.028$) and conversion to THA (74.6%, 95% CI 60.7%–91.6% *vs* 92.1%, 95% CI 85.6%–99.0%; $p = 0.008$) as the endpoints than the non-BDDH group.

Conclusion: The incidence of BDDH was significantly higher in patients with idiopathic ONFH than matched controls, and idiopathic ONFH patients who underwent CD with BDDH had lower mean HHS as well as 5-year survival rate than those without BDDH. Therefore, BDDH should be considered a risk factor predicting the development of idiopathic ONFH as well as poor prognosis after CD.

Key words: borderline al dysplasia of the hip; core decompression; development; idiopathic osteonecrosis of the femoral head; prognosis

Introduction

Osteonecrosis of the femoral head (ONFH) is a globally increasing and rapidly progressive hip disease that can lead to great deterioration in quality of life.[1,2] In China, the estimated number of nontraumatic ONFH patients is 8.12 million.[3] Once diagnosed with asymptomatic ONFH, progression to collapse the femoral head occurs in almost half of cases within 4 years if left untreated,[4] which often ends in total hip arthroplasty (THA).[5] It is well-acknowledged that high-dose corticosteroid use and alcohol abuse are the major risk factors for ONFH, while there are still 30% of patients without an underlying etiology who have idiopathic ONFH.[6] Therefore, identifying the potential predictors for the development of ONFH and prognosis after some hip-preservation treatments, such as core decompression (CD), is critical and urgent. Currently, several studies have illustrated that the decrease in acetabular coverage in certain scenarios, such as developmental dysplasia of the hip (DDH), dramatically increases intracapsular pressure and brings additional stress to the hip joint, which might contribute to the development of ONFH.[7] Furthermore, less acetabular coverage could also be a risk factor predicting ONFH failure of hip-preservation procedures,[8,9] which is worthy of attention.

Borderline developmental dysplasia of the hip (BDDH) was first described by Fredensorg in 1976 as a center-edge angle (CEA) of Wiberg between 20° and 25°,[10] where CEA is commonly measured for the quantification of acetabular coverage.[11] According to Wiberg's description, a hip with a CEA < 20° was considered pathological, and a CEA > 25° was normal; hence, BDDH illustrates a condition of relatively less acetabular coverage of the femoral head between acetabular dysplasia and normality. However, previous studies on BDDH have mainly focused on the challenging treatment dilemma involving either periacetabular osteotomy or arthroscopic surgery.[12,13] Although evidence has indicated the potential role of less acetabular coverage in ONFH, there is still no literature paying attention to the exact association between BDDH and ONFH.

Besides, we hypothesized that BDDH, which has relatively less acetabular coverage and increases weight bearing to hip joint, would be associated with the development of idiopathic ONFH as well as poor prognosis after CD. Therefore, the present study aimed to (i) compare the incidence of BDDH between patients with idiopathic ONFH and matched control subjects and (ii) determine the influence of BDDH on poor prognosis after CD.

Methods

Study Design and Patient Selection

This was a retrospective study approved by the Ethics Committee of West China Hospital (No. 2021[625]) and all patients provided written informed consent before participation. Between January 2010 and December 2020, we retrieved data of consecutive adult patients who were diagnosed with nontraumatic precollapse ONFH (Ficat stage I-II)[14] based on a comprehensive assessment of clinical history, physical examination, and findings on radiography and magnetic resonance imaging[15] from our institutional database. The inclusion criteria were patients who were diagnosed with idiopathic ONFH and underwent unilateral or bilateral CD. The exclusion criteria were as follows: (i) alcohol- or corticosteroid-induced ONFH; (ii) receiving nonoperative or any other surgical treatments; (iii) DDH; and (iv) loss to follow-up. Ultimately, a total of 78 patients (111 hips) met the selection criteria. In the 1:2 matched control cohort, subjects who visited our physical examination center without any articular or osseous diseases, and who underwent anteroposterior pelvic radiography that did not indicate any hip pathology, such as ONFH, DDH, hip osteoarthritis, fracture, bone tumor, and osteolytic or osteoblastic lesion, were reviewed. The matching criteria were sex, age, body mass index (BMI, $\pm$ 3 kg/m^2), hip side, and date of radiography (within 1 week). Finally, 156 subjects (222 hips) coming from 457 subjects who met matching criteria were included as the 1:2 matched control group after randomization using computer-generated random numbers. Figure 1 depicts the detailed filtration process.

Preoperative Radiographic Evaluation

For the radiographic evaluation, preoperative anteroposterior pelvic radiographs were obtained with patients in the supine position and the lower extremities internally rotated 15°, with a photon beam centered midway between the pubic symphysis and the top of the iliac crests and a tube-to-image distance of 120 cm.[16,17] Acetabular anatomical parameters, including CEA, sharp angle,[18] acetabular head index (AHI),[19] and acetabular depth ratio (ADR),[20] were evaluated by two blinded authors independently on Digimizer (version 5.7.2, MedCalc Software, Mariakerke, Belgium) (Figure 2). We then divided these included subjects into two groups based on CEA: the BDDH group with a CEA of 20° to 25° and the non-BDDH group with a CEA > 25°.[21,22]

Operative Method and Postoperative Care

All patients underwent CD in the standard procedure. Briefly, under general anesthesia, the patients were placed on the operating table in the supine position with the affected hips internally rotated 15°. A 3.0-mm Kirschner wire was driven through the lateral femoral cortex at the level of the lesser trochanter under fluoroscopic guidance. After penetrating through the femur, the wire was advanced to the femoral head via the femoral neck and gave access to the necrotic lesion. Anteroposterior and lateral fluoroscopic views were necessary to check on the appropriate position of the Kirschner wire. Finally, two passes were drilled through small-sized lesions, while three passes were drilled through larger lesions. All patients were protected from weight-bearing by crutches for 6 weeks postoperatively.
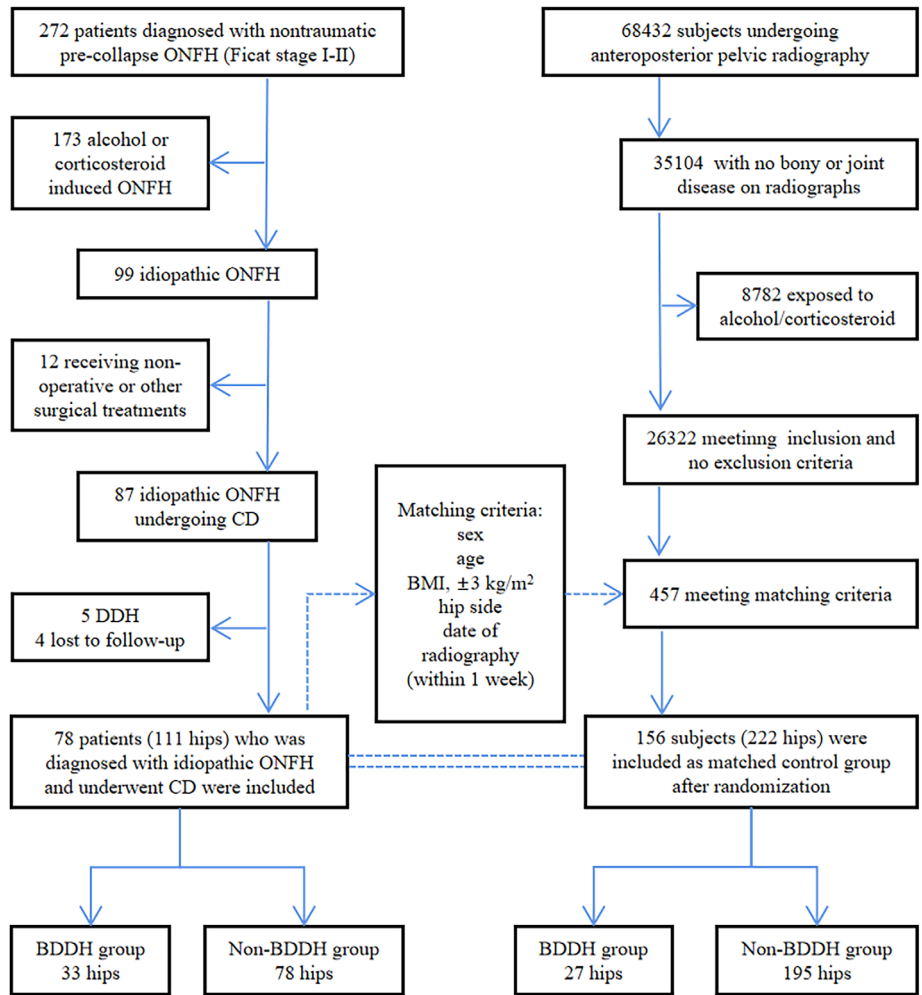
Fig. 1 Flowchart of the included patients with idiopathic ONFH and the matched controls
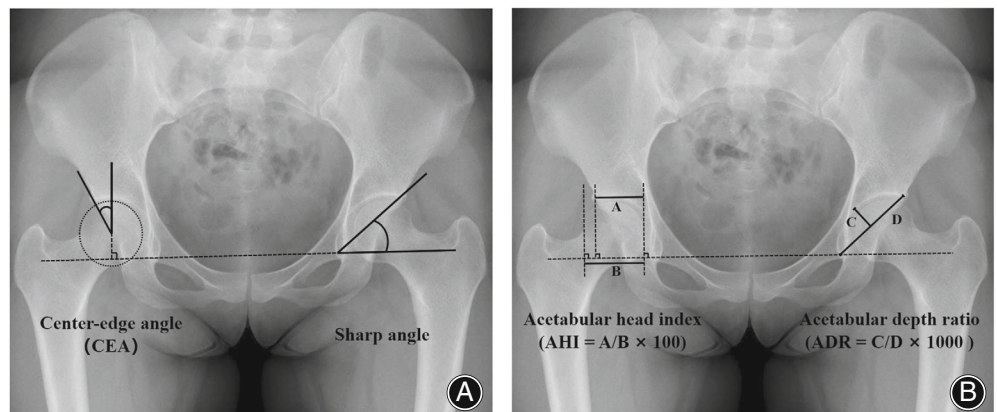

Fig. 2 Measurements of acetabular anatomical parameters on anteroposterior pelvic radiograph. (A) Measurements of CEA and sharp angle. (B) Measurements of AHI and ADR

Prognosis Evaluation

To further explore the influence of BDDH on the prognosis after CD, we followed idiopathic ONFH patients routinely at 1, 3, 6, and 12 months postoperatively and annually thereafter. Clinical symptom assessment was conducted using the Harris Hip Score (HHS) to evaluate the pain and functional level of the joint,[23] where a result was regarded as excellent if the total score was 90–100, good if 80–89, fair if 70–79, and poor if <70. The score at the last follow-up or the score before THA was considered the final HHS.

Survival analysis after CD was performed. In our study, clinical failure included progression of collapse and conversion

to THA, where progression of collapse, assessed by anteroposterior pelvic radiographs during follow-up, was considered as a subsidence of the articular surface more than 2 mm compared with the initial postoperative film.[24] The endpoints were defined as clinical failure and conversion to THA for survival analysis.

Statistical Analysis

All continuous variables are presented as the mean ± standard deviation (SD) and were analyzed using Student's t-test.

Unordered categorical variables were analyzed using the chi-squared test, whereas ordinal categorical variables were analyzed by Mann–Whitney U test and are presented as numbers (percentages). For survival analysis, the Kaplan–Meier method was employed using clinical failure or conversion to THA as the endpoint with the log-rank test to compare the discrepancy between the BDDH group and the non-BDDH group. All statistical analyses were performed using R software (version 4.0.3), and statistical significance was considered as a p value <0.05.

TABLE 1 The demographic characteristics of patients with idiopathic ONFH and matched control subjects

Variables	Idiopathic ONFH	Matched Controls	Statistic
Number of hips/subjects	111/78	222/156	
Age (y)[a]	36.6 ± 9.8	36.6 ± 9.8	t = 0, p = 1.000
Sex (male/female)[b]	79/32	158/64	$\chi^2 = 0$, p = 1.000
BMI[a]	24.0 ± 3.0	23.3 ± 4.7	t = 1.742, p = 0.083
Side (left/right)[b]	54/57	108/114	$\chi^2 = 0$, p = 1.000

Abbreviations: BMI, body mass index; ONFH, osteonecrosis of the femoral head.; [a] Data are presented as the mean ± standard deviation (SD) and analyzed by Student's t-test.; [b] Data are presented as the numbers and compared using chi-square test.

TABLE 2 Comparison of the BDDH incidence and acetabular anatomical parameters between idiopathic ONFH group and matched control group

Variables	Idiopathic ONFH (111 hips)	Matched Controls (222 hips)	Statistic
Number of BDDH (hips), n (%)[a]	33 (29.7)	27 (12.2)	$\chi^2 = 14.297$, p<0.001
CEA (°)[b]	28.5 ± 4.7	33.1 ± 5.7	t = 7.749, p<0.001
Sharp angle (°)[b]	40.0 ± 3.4	37.4 ± 3.7	t = 6.462, p<0.001
AHI[b]	82.4 ± 5.0	86.3 ± 5.4	t = 6.620, p<0.001
ADR[b]	299.6 ± 28.4	318.8 ± 31.3	t = 5.640, p<0.001

Abbreviations: AHI, acetabular head index; ADR, acetabular depth ratio; CEA, center-edge angle.; [a] Data are presented as the numbers (percentages) and compared using chi-square test.; [b] Data are presented as the mean ± standard deviation (SD) and analyzed by Student's t-test. ONFH, osteonecrosis of the femoral head; BDDH, borderline developmental dysplasia of the hip.

TABLE 3 The demographic characteristics of the BDDH and non-BDDH groups in patients with idiopathic ONFH

Variables	Idiopathic ONFH		Statistic
	BDDH group	Non-BDDH group	
Number of hips, n (%)	33 (29.7)	78 (70.3)	
Age (y)[a]	38.5 ± 8.9	35.8 ± 10.1	t = 1.357, p = 0.179
Sex (male/female)[b]	20/13	59/19	$\chi^2 = 1.845$, p = 0.171
BMI[a]	24.2 ± 2.7	23.9 ± 3.1	t = 0.479, p = 0.366
Side (left/right)[b]	13/20	41/37	$\chi^2 = 1.126$, p = 0.289
Preoperative HHS[a]	68.9 ± 14.0	73.9 ± 8.6	t = 1.900, p = 0.064

Abbreviations: BMI, body mass index; HHS, Harris Hip Score.; [a] Data are presented as the mean ± standard deviation (SD) and analyzed by Student's t-test. [b] Data are presented as the numbers (percentages) and compared using chi-square test. ONFH, osteonecrosis of the femoral head; BDDH, borderline developmental dysplasia of the hip.

Results

Preoperative Radiographic Outcomes

A total of 78 consecutive idiopathic ONFH patients (111 hips) met our criteria and were included. Meanwhile, 156 subjects (222 hips) were selected for the matched control group. The baseline demographic characteristics were similar, and no significant differences between the groups were detected (Table 1).

BDDH was found in 29.7% (33 hips) of the idiopathic ONFH group, which was significantly higher than the 12.2% (27 hips) of the matched control group ($\chi^2 = 14.297$, $p < 0.001$). In addition, acetabular anatomical parameters, including CEA, AHI, and ADR, in the idiopathic ONFH group were significantly lower than those in the matched control group ($28.5 \pm 4.7°$ vs $33.1 \pm 5.7°$, t = 7.749, $p < 0.001$; 82.4 ± 5.0 vs 86.3 ± 5.4, t = 6.620, $p < 0.001$; 299.6 ± 28.4 vs 318.8 ± 31.3, t = 5.640, $p < 0.001$,

TABLE 4 Comparison of clinical outcomes between hips with BDDH and without BDDH in the idiopathic ONFH group

Variables	Idiopathic ONFH		Statistic
	BDDH (33 hips)	Non-BDDH (78 hips)	
HHS at final follow-up[a]	83.5 ± 17.4	91.6 ± 9.7	t = 2.527, $p = 0.015$
Excellent, n (%)[b]	18 (54.5)	63 (80.8)	
Good, n (%)[b]	6 (18.2)	6 (7.7)	
Fair, n (%)[b]	1 (3.0)	4 (5.1)	
Poor, n (%)[b]	8 (24.2)	5 (6.4)	U = 936, $p = 0.004$
Clinical failure			
Number of hips, n (%)[c]	14 (42.4)	15 (19.2)	$\chi^2 = 5.317$, $p = 0.021$
5-year survival (mean% + 95% CI)[a]	66.7 (52.4–84.9)	83.7 (75.2–93.1)	$\chi^2 = 4.841$, $p = 0.028$
Conversion to THA			
Number of hips, n (%)[d]	8 (24.2)	6 (7.7)	$p = 0.026$
5-year survival (mean% + 95% CI)[a]	74.6 (60.7–91.6)	92.1 (85.6–99.0)	$\chi^2 = 7.014$, $p = 0.008$

Abbreviations: BDDH, borderline developmental dysplasia of the hip; CI, confidence interval; HHS, Harris Hip Score; ONFH, osteonecrosis of the femoral head; THA, total hip arthroplasty.; [a] Data are presented as the mean ± standard deviation (SD) and analyzed by Student's t-test.; [b] Data are presented as the numbers (percentages) and analyzed by Mann–Whitney U test.; [c] Data are presented as the numbers (percentages) and compared using chi-square test.; [d] Data are presented as the numbers (percentages) and analyzed by Fisher's exact tests.
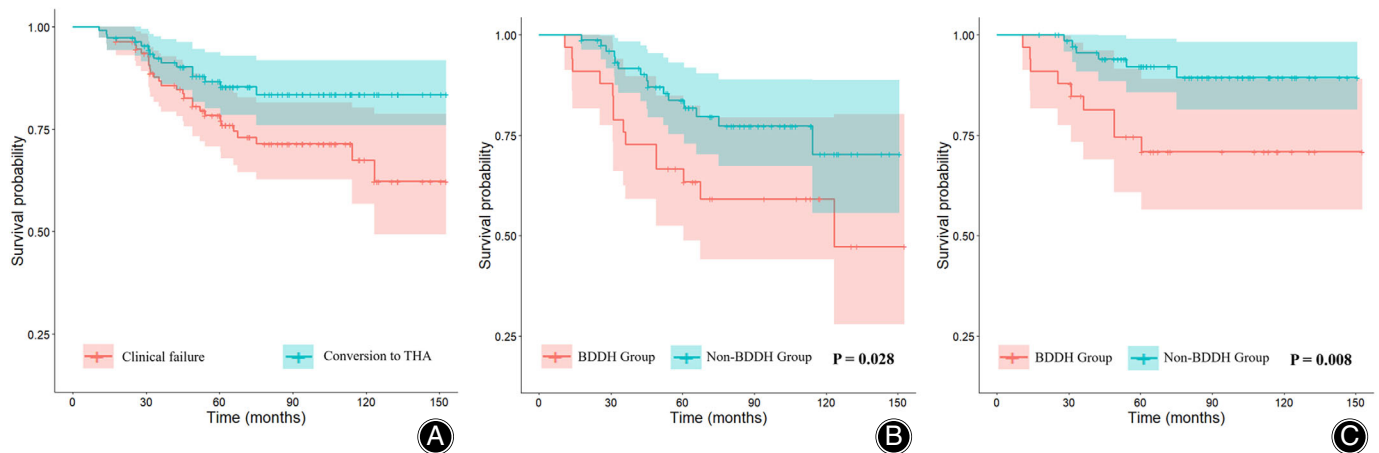

Fig. 3 The Kaplan–Meier survival curves for idiopathic ONFH patients undergoing CD. (A) The overall survival curves with clinical failure and conversion to THA as the endpoints. (B) The survival curves compared the BDDH group with the non-BDDH group with clinical failure as the endpoint (log-rank test, $p = 0.028$). (C) The survival curves compared the BDDH group with the non-BDDH group with conversion to THA as the endpoint (log-rank test, $p = 0.008$)
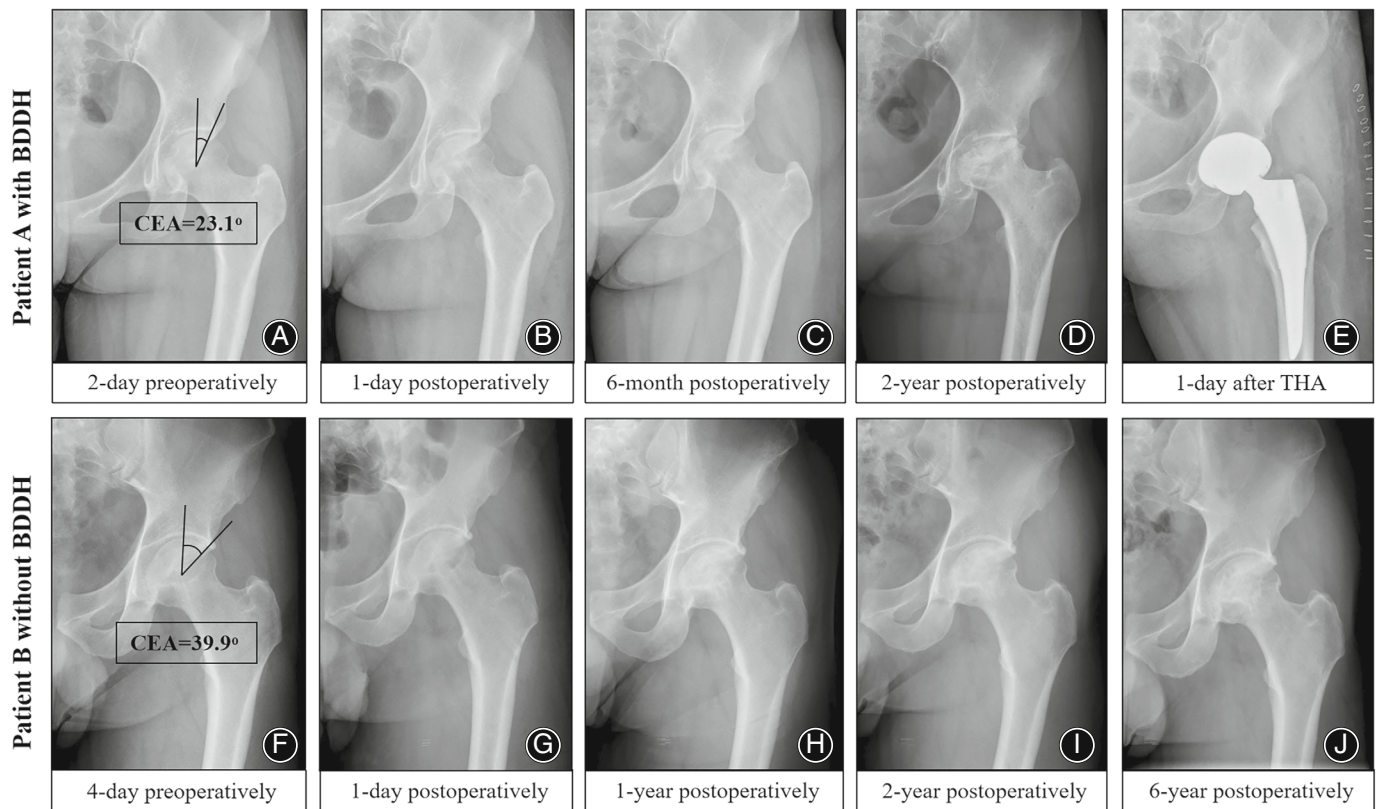
Fig. 4 Two typical idiopathic ONFH patients undergoing CD. Patient A was a 32-year-old woman with BDDH who initially underwent CD but finally was converted to THA in 2 years. Patient B was a 36-year-old man without BDDH whose necrotic lesion of femoral head became stable and was reconstructed gradually after CD

respectively), whereas the mean sharp angle in the idiopathic ONFH group was dramatically higher than that in the matched control group ($40.0 \pm 3.4°$ *vs* $37.4 \pm 3.7°$, t = 6.462, $p < 0.001$) (Table 2).

Prognosis Outcomes
In the idiopathic ONFH group, 33 hips were diagnosed with BDDH, and the other 78 hips were non-BDDH. There were no significant differences in terms of age, sex, BMI, hip side, or preoperative HHS (Table 3).

The mean HHS was significantly improved from 72.4 ± 10.7 preoperatively to 89.2 ± 13.0 at the last follow-up (t = 10.532, $p < 0.001$), with a mean follow-up of 72.1 ± 36.6 months. The final scores of 81 hips (73.0%) were considered excellent, 12 hips (10.8%) were good, five hips (4.5%) were fair, and 13 hips (11.7%) were poor. Furthermore, the mean HHS at the last follow-up was significantly lower in the BDDH group than in the non-BDDH group (83.5 ± 17.4 *vs* 91.6 ± 9.7, t = 2.527, $p = 0.015$), with a different score distribution (U = 936, $p = 0.004$), where the BDDH group had a lower incidence of hips with excellent HHS (54.5% *vs* 80.8%) and a higher incidence of hips with

poor HHS (24.2% *vs* 6.4%) than the non-BDDH group (Table 4).

The overall 5-year survival rate was 78.4% (95% CI 70.7%–86.8%) with clinical failure as the endpoint, and 86.7% (95% CI 80.1%–93.7%) with conversion to THA as the endpoint (Figure 3A). Clinical failure occurred in 14 hips (42.4%) in the BDDH group and 15 hips (19.2%) in the non-BDDH group ($\chi^2 = 5.317$, $p = 0.021$), and conversion to THA occurred in eight hips (24.2%) in the BDDH group and six hips (7.7%) in the non-BDDH group ($p = 0.026$) at the last follow-up (Figure 4). The log-rank tests showed that the 5-year survival rate was significantly lower in the BDDH group than in the non-BDDH group both with clinical failure as the endpoint (66.7%, 95% CI 52.4%–84.9% *vs* 83.7%, 95% CI 75.2%–93.1%; $\chi^2 = 4.841$, $p = 0.028$; Figure 3B) and with conversion to THA as the endpoint (74.6%, 95% CI 60.7%–91.6% *vs* 92.1%, 95% CI 85.6%–99.0%; $\chi^2 = 7.014$, $p = 0.008$; Figure 3C) (Table 4).

Discussion

In the present study, we compared the incidence of BDDH between patients with idiopathic ONFH and matched control subjects and determined the influence of BDDH on poor

prognosis after CD. When compared with the matched control group, we found that patients with idiopathic ONFH had a significantly higher incidence of BDDH and less acetabular coverage, suggesting that BDDH should be considered a potential risk factor for the development of idiopathic ONFH. In addition, BDDH indicated poor prognosis after CD, as demonstrated by the HHS at the last follow-up and log-rank tests with both clinical failure and conversion to THA as the endpoints.

BDDH Was Not Rare in Patients with Idiopathic ONFH

BDDH was typically defined as a CEA of 20° to 25°,[21,22] whereas some authors considered it to have a CEA as low as 18°.[25,26] Previous studies demonstrated that patients diagnosed with BDDH might have capsular laxity, which probably leads to poor outcomes following arthroscopic surgery.[21] It was also reported that DDH might be a predictor of the progression of collapse and conversion to THA in ONFH patients undergoing free vascularized fibular grafting.[8] However, the association between BDDH and ONFH has never been investigated. To the best of our knowledge, the present study represents the first study to systematically investigate the role of BDDH in the development of idiopathic ONFH and prognosis after CD. In addition, in our study, we found that there were seven hips (five patients) with DDH in the excluded idiopathic ONFH group, and the incidence of BDDH $(33/[111 + 7] = 28.0\%)$ was significantly higher than that of DDH $(7/[111 + 7] = 5.9\%)$ in idiopathic ONFH patients. As a consequent, it is necessary for us to attach importance to such a large population of BDDH patients who have the potential to suffer from ONFH with a poor prognosis.

BDDH Contributed to the Development of ONFH

It is not a novel concept that less acetabular coverage could increase intracapsular pressure and further add to excessive weight-bearing to the hip joint,[27,28] which might contribute to the development of ONFH. Ollivier et al.[29] retrospectively analyzed 90 idiopathic ONFH patients compared with 180 matched control patients, and noted that idiopathic ONFH patients had lower CEA than the control group (25.7° vs 35.0°, $p = 0.006$). Similarly, in Zeng's work, less acetabular coverage was found in the idiopathic ONFH group than in control subjects.[30] Moreover, an experimental study of rats revealed that standing, which applies excessive mechanical stress to the hip joints, could lead to ischemia and ONFH.[31] BDDH represents a hip with relatively less acetabular coverage than a normal hip, and a higher incidence of BDDH was found in the idiopathic ONFH group than in the matched control cohort in our study. Meanwhile, when compared to the control subjects, we demonstrated that patients with idiopathic ONFH had less acetabular coverage as demonstrated by lower CEA, AHI, ADR, and a higher sharp angle, which indirectly indicated the potential association between BDDH and the morbidity of ONFH. Therefore, all these results suggested that BDDH with undercoverage of the femoral head might increase intracapsular pressure and weight bearing of the hip joint, which further contributed to blood occlusion and avascular necrosis.

BDDH Predicted Poor Prognosis of ONFH after CD

Moreover, other studies reported that less acetabular coverage might be closely related to poor prognosis in ONFH patients who underwent hip-preservation procedures, which was consistent with our study. Roush et al.[8] demonstrated that hips with clinical failures had significantly lower CEA than hips without collapse or additional surgery in ONFH patients undergoing free vascularized fibular grafting ($p < 0.001$), where hips with CEA ≤ 25° were 11 times more likely to progress to collapse and seven times more likely to convert to THA than hips with CEA > 25°. Meanwhile, in another independent study, CEA < 25° was also regarded as an independent factor predicting radiographic failure and conversion to THA in ONFH patients who underwent curved intertrochanteric varus osteotomy.[9] Consequently, we speculated that a femoral head with osteonecrosis, in the setting of excessive weight bearing secondary to less acetabular coverage such as BDDH, is more likely to suffer from collapse or THA after the hip-preservation procedure.

Treatment Strategies of ONFH with or without BDDH

CD is one of the most common hip-preservation procedure options for precollapse ONFH. In hips with ONFH, intraosseous pressure increases rapidly due to cellular swelling and inflammation in the necrotic area, and CD is carried out through percutaneous drilling to effectively reduce such intraosseous hypertension and delay the process of ONFH.[32] However, the long-term clinical prognosis of CD varies in the literature.[33] To determine the indications of CD, Lieberman et al.[34] conducted a review and found that the failure rates of CD were 14% to 25% in small lesions and 42% to 84% in larger lesions. Likewise, Mont et al.[35] suggested that CD was more appropriate for symptomatic hips with precollapse, small-, or medium-sized lesions. In our study, CD showed a satisfactory overall 5-year survival rate, and ONFH patients with BDDH were more vulnerable to poor prognosis after CD than those without BDDH. Therefore, it is highly recommended that CD be chosen as the first hip-preservation procedure option in symptomatic, small-sized precollapse lesions without BDDH.

For ONFH patients with BDDH, the 5-year survival rate was 74.6% with conversion to THA as the endpoint and 66.7% with clinical failure as the endpoint, which might still be a favorable result referring to previous studies.[36,37] What's more, because of the minimal invasion and low complication of CD, we thought that if the procedure fails to relieve the pain or avoid progression of the femoral head, it does not preclude the use of other procedures, so CD could still be the first procedure option for ONFH patients with BDDH. Nevertheless, given that BDDH was tightly related to the development of idiopathic ONFH and prognosis after CD, orthopaedic surgeons should pay more attention to the

existence of BDDH, and early prevention as well as prompt diagnosis of ONFH were necessary for those patients. Once diagnosed with ONFH, receiving CD as soon as possible is recommended. Furthermore, combining with limited weight-bearing and relevant pharmacological treatment, regular follow-up is also warranted to observe the dynamic progression of ONFH in time and improve the survival rate of the femoral head.

Limitations

This study had several limitations. First, we retrospectively reviewed idiopathic ONFH patients undergoing CD and matched them with control subjects, which could not assess the potential advantages of CD compared with other treatments, such as femoral osteotomy. Second, we merely discussed the influence of BDDH on the clinical results after CD, although the size of the lesion or clinical stage might also play an important role in the final prognosis. Third, we ruled out idiopathic ONFH patients with DDH in the analysis, so the overall survivorship of ONFH after CD might be overestimated. Fourth, BDDH represents a borderline condition between DDH and normal hip, so the use of CEA as the only diagnostic criterion may be not enough and other measures about acetabulum and femoral morphology should be further considered to define BDDH more comprehensively. Finally, this was a single-center retrospective study that might not be applicable to all patients. Further larger, multicenter, prospective studies are warranted to confirm our findings.

Conclusion

The present study demonstrated that idiopathic ONFH patients had a significantly higher incidence of BDDH and less acetabular coverage than matched control subjects. Furthermore, the mean HHS at the last follow-up and the 5-year survival rate in the BDDH group were also significantly lower than those in the non-BDDH group among patients with idiopathic ONFH who underwent CD. Consequently, BDDH should be considered a risk factor predicting the development of idiopathic ONFH as well as poor prognosis after CD. Although patients with idiopathic ONFH have good outcomes from CD, more cautious treatment with regular follow-up is suggested for those with BDDH.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Kai Huang, Qing-Yi Zhang, Hui-Yu He, and Chen-Xiang Gao. The first draft of the manuscript was written by Kai Huang and Qing-Yi Zhang. All authors commented on previous versions of the manuscript. All authors were in agreement with the final manuscript.

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