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Long-term results of Birmingham hip resurfacing arthroplasty in Asian patients

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Abstract Several reports have shown good long-term results with the Birmingham hip resurfacing (BHR) arthroplasty, but little is known about the results in Asian countries where there is a high prevalence of osteonecrosis and developmental dysplasia of the hip, and many females with small femoral head sizes. Therefore, we retrospectively evaluated the long-term clinical results of the BHR in 112 Japanese patients (53 males and 59 females—130 hips) with an average age of 52 years. Implant survivorship was analyzed using the Kaplan–Meier method with the endpoint being revision for any reason. Factors such as sex, femoral component size, and type of hip disease were analyzed as predictors of implant survivorship. With a median follow-up of 12 years, six cases were revised (two for femoral component aseptic loosening, two for infection, one for cup aseptic loosening, and one for femoral neck fracture), and the overall survival rate was 96.5% (95% CI 90.9–98.7) at 10 years and 93.6% (95% CI 83.4–97.7) at 15 years. When septic revisions were excluded, the implant survival rate was 98.2% (95% CI 92.9–99.6) at 10 years and 95.3% (95% CI 83.9–98.7) at 15 years. Sex, femoral component size, and type of hip disease were not predictors of implant survivorship. In conclusion, good clinical results were obtained with the BHR at 10- and 15-year follow-up in Japanese patients who have different stature and types of hip diseases as compared with patients in Western countries.

Keywords Birmingham hip resurfacing · Long-term results · Japanese · Asian · Implant survivorship

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Introduction

Hip resurfacing arthroplasty has several advantages over conventional stemmed total hip arthroplasty (THA), as the risk of dislocation is small [1] and stress shielding is minimal [2, 3]. Hip resurfacing arthroplasty can precisely restore normal hip biomechanics, which results in a higher speed of walking and stair climbing than conventional THA [4]. It also allows a high activity level, including participation in various sports [5]. One of the keys for long-term success in hip resurfacing is the acetabular cup material, which provides sufficient strength and wear resistance despite being relatively thin. For these reasons, metal-on-metal resurfacing hips gained popularity in the early 2000s. However, the number of hip resurfacing cases decreased significantly following reported adverse reactions to metal debris (ARMD) and poor short-term results of a particular resurfacing implant [Articular Surface Replacement (ASR); Depuy, Warsaw, IN, USA], which resulted in recalls [6, 7]. Conversely, several mid- to long-term clinical reports have described positive results with the Birmingham hip resurfacing system (BHR; Smith and Nephew, Warwick, United Kingdom) in Europe, Australia, and the United States [8–17], and good 10-year survivorship has been reported in national joint registries [18, 19]. In these reports, several patient-related factors including female sex, small femoral component sizes, and hip diseases such as developmental dysplasia of the hip (DDH) and osteonecrosis have also been shown to be risk factors that affect implant survivorship [8–10, 12–14, 16, 18, 19]. However, little [20] is known about the long-term results of BHR in Asian countries where there is a high prevalence of osteonecrosis, DDH, and females with small femoral head sizes [21]. Therefore, the goals of this study were to evaluate long-term clinical results of the BHR in Japanese patients and to analyze the factors that influence outcomes.

Patients and methods

This retrospective study was approved by the institutional review board at our institute. During the period of February 1998–September 2007, BHR was performed by two experienced hip surgeons (NS and KO) who have mastered the resurfacing techniques of Dr. Derek McMinn. BHR was indicated when patients would be returning to highly demanding postoperative activities. The exclusion criteria [20] were as follows: Dorr type C femoral bone [22], more than two-third collapse of the femoral head due to osteonecrosis, short femoral neck due to DDH or Perthes disease, and excessive femoral anteversion of more than 50°.

Surgical technique

All the surgeries were performed through a posterolateral approach with the patients in the lateral position under general anesthesia. The target of the acetabular component was 40° of abduction and 15° of anteversion by radiography [23]. The acetabular component was impacted after 1-mm underreaming of the acetabulum. Bone grafting with morselized reamed bone was performed when the coverage of the acetabular component was insufficient. For the femoral component, a femoral guide wire was inserted while being aimed neutral to slightly valgus to the original femoral neck. After the guide wire was inserted, the femoral head was reamed and all the cysts, granulation tissue, and necrotic lesions were carefully curetted. When the femoral head was prepared, multiple anchoring holes were made and the femoral component was implanted with the use of cement.

Patient follow-up and study materials

One hundred and thirty-six patients were treated with BHR during the study period. Postoperatively, the patients were followed annually until death or loss to follow-up. Out of these 136 cases, three non-Asian patients were excluded, and three cases that had less than 2 years of follow-up were excluded. In the end, 130 hips from 112 patients were evaluated in this study. There were 53 males and 59 females with a median age of 53 (range 19–85). The disease processes of the patients undergoing hip resurfacing included osteoarthritis (96 hips) and osteonecrosis (31 hips) (Table 1). Of the 96 cases with osteoarthritis, 67 cases (70%) were secondary to DDH, which reflects the main etiology for osteoarthritis of the hip in Japanese patients [21].

Imaging evaluation and clinical assessment

On immediate postoperative radiographs, the abduction angle of the acetabular component, the femoral neck–shaft angle (NSA), and the femoral stem–shaft angle (SSA) were measured using imaging analysis software (ImageJ version 1.48; National Institutes of Health, Bethesda, MD). The position of the femoral component was defined as valgus when SSA was ≥5° greater than NSA, varus when SSA was ≥5° less than NSA, and neutral when the difference between the SSA and NSA was within 5°. During the final examination, radiolucency and osteolysis were evaluated around the acetabular cup using the zone classification of DeLee and Charnley [24] and around the femoral

Table 1 Patient characteristics

Parameters	Value
Number of patients (M/F)	53 (47%)/59 (53%)
Age at surgery (years)	53 (19–85)*
Height (cm)	
Male patients	169 (165–172)**
Female patients	154 (150–157)**
Body weight (kg)	
Male patients	65 (58–74)**
Female patients	54 (50–60)**
Diagnosis	
Osteoarthritis due to DDH	67 (52%)
Osteonecrosis	31 (24%)
Osteoarthritis without DDH	29 (22%)
Rheumatoid arthritis	3 (2%)

M male, *F* female, *DDH* developmental dysplasia of the hip

* Value expressed as mean (range)

** Value expressed as median (interquartile range) component using the zone classification of Amstutz [25]. Migration of the acetabular and femoral component center was evaluated, and component loosening was diagnosed if this value was more than 2 mm.

To screen for lesions possibly representing ARMD, ultrasound imaging was recommended to patients when more than 10 years had passed since surgery. Ultrasound screening was performed only if the patient agreed. Patients with suspicion for ARMD on ultrasound were further evaluated by MRI. Additionally, ultrasound or MRI was also performed for patients who had unexplained hip pain, an uncomfortable feeling around the hip, dislocation events, or infection during the follow-up period. When ARMD was detected on MRI, the maximum diameter of the lesion in the axial plane, shape, contents, and thickness of the wall were measured and classified according to the system proposed by Hart [26].

Statistical analysis

All statistical analyses were performed using statistical software (SPSS version 23; IBM Japan, Tokyo, Japan). Normality of the data was evaluated with the Kolmogorov–Smirnov test, and the survival curve of the implants was analyzed with the Kaplan–Meier method, with revision or radiologic loosening of the component being the endpoints. Sex, type of hip disease (osteoarthritis due to DDH [DDH–OA] vs osteonecrosis vs others), femoral component size (≧50 vs 46 mm or smaller), and femoral component position (neutral vs valgus vs varus) were analyzed as predictors of implant survivorship with the use of a log-rank test. Values of $p < 0.05$ were considered statistically significant.

Results

During the average follow-up period of 12 years (range 2–18 years), six revisions were performed. Two revisions were for femoral component aseptic loosening, two for infection, one for cup aseptic loosening, and one for femoral neck fracture (Table 2). All of the revision cases were converted to a stemmed-type THA, but ARMD was not observed in these cases during the procedures. In the histological findings of the revised femoral component, new necrotic lesions were not found. However, fibrous tissue was observed between the femoral component and the cement layer, which represented aseptic loosening. Dislocation occurred in two hips, but no revision was required. Implant loosening was not seen in the cases that did not require a revision, but a partial radiolucent line was observed in two acetabular components in zone 2, and in three femoral components (two in zone 2, and one in zones 1–3). Six patients died due to causes unrelated to their hip surgery, but none of these had signs of osteolysis or loosening during their final follow-up visit. The overall survival rate, with revision for any reason set as the endpoint, was 96.5% [95% confidence interval (CI) 90.9–98.7] at 10 years and 93.6% (95% CI 83.4–97.7) at 15 years. When septic revisions were excluded, the implant survival rate was 98.2% (95% CI 92.9–99.6) at 10 years and 95.3% (95% CI 83.9–98.7) at 15 years (Fig. 1).

The femoral component size ranged from 38 to 54 mm, with 46 mm being the most commonly used size (Table 3). The size of the femoral component was ≧50 mm in 50 cases (38%) and 46 mm or smaller in 80 cases (62%). All of the femoral component sizes in females were 46 mm or smaller (Table 3). In the radiological assessment of component position, the average cup abduction angle was 42.9° ± 5.0°, and the angle was less than 50° in 119 cases (92%). The average SSA was 141.0° ± 8.5°, and the average NSA was 137.9° ± 6.1°. Eighty-two femoral components were in neutral NSA, 42 components were in valgus NSA, and 6 components were in varus NSA. After exclusion of the septic revision cases, an analysis of the predictors showed that there were no significant differences in implant survivorship between a femoral component size of ≧50 mm and 46 mm or smaller ($p = 0.79$), between males and females ($p = 0.84$), or between the three femoral component positions ($p = 0.47$). There was also no significant difference in implant survivorship between the hip diseases ($p = 0.97$). The survival rates in hips with DDH–OA were 98.5% (95% CI 87.8–99.7) at both 10 and 15 years, while the survival rates in hips with

Table 2 Characteristics of the revision cases

Case	Sex	Age at initial surgery (years)	Hip disease	Cup/head size (mm)	Cup abduction angle (°)	Femoral component position	Revision period (years)	Reason for revision
1	Male	54	DDH–OA	60/54	38.8	Valgus	9.2	FCL
2	Male	24	ON	52/46	45.2	Valgus	14.5	FCL
3	Female	56	DDH–OA	48/42	42.1	Valgus	2.6	Infection
4	Female	62	Primary OA	50/42	40.5	Neutral	0.1	Neck fracture
5	Female	44	DDH–OA	52/46	47.0	Neutral	15.5	Cup loosening
6	Female	63	ON	56/50	40.0	Neutral	9	Infection

DDH–OA Osteoarthritis derived from developmental dysplasia of the hip, *ON* osteonecrosis, *FCL* femoral component loosening

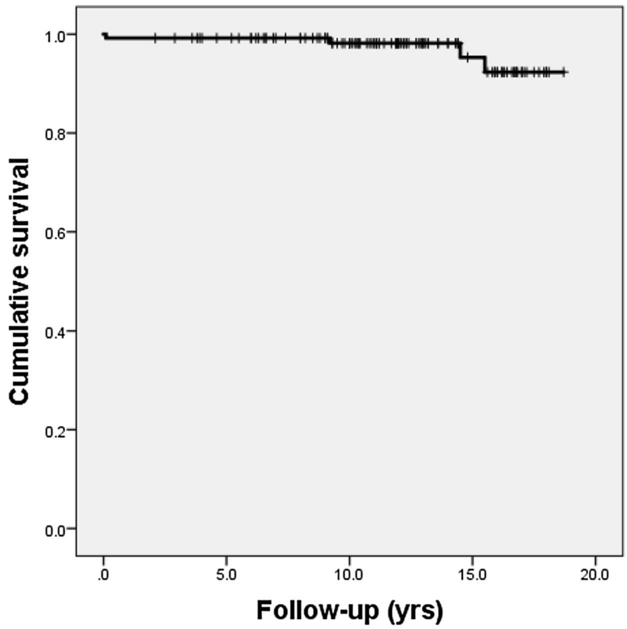

Fig. 1 Kaplan–Meier survival curve for BHR (excluding septic revisions). Six hips were revised in total. The 10-year implant survival rate was 98.2% (95% CI 92.9–99.6) and the 15-year survival rate was 95.3% (95% CI 83.9–98.7)

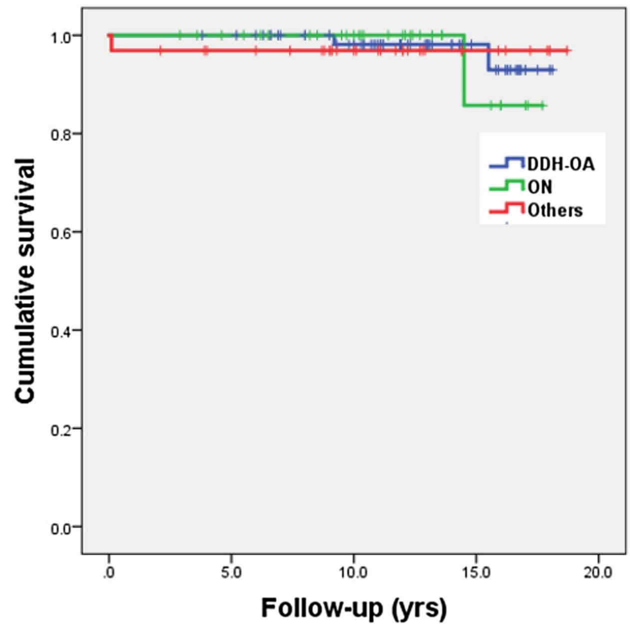

Fig. 2 Comparison of the survival curve among hip diseases. The *blue*, *red*, and *green* survival curves indicate DDH-derived osteoarthritis, ON, and others, respectively. No significant difference was seen among hip diseases

Table 3 Implant details

Parameter	Number of components
Femoral component size (male/female)	38 mm: 4 (0/4) 42 mm: 28 (0/28) 46 mm: 48 (16/32) 50 mm: 34 (34/0) 54 mm: 16 (16/0)

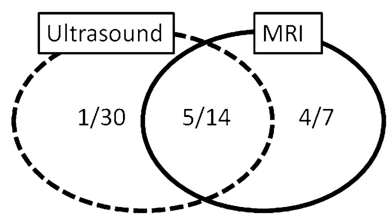

Fig. 3 Venn diagram of the imaging analysis to detect ARMD. Total number in the *dotted circle* indicates the cases examined in ultrasound, and the total number in the *solid circle* indicates the cases examined in MRI. The denominator indicates the number examined, and the numerator indicates the number detected

osteonecrosis were 100% at 10 years and 85.7% (95% CI 41.9–98.0) at 15 years (Fig. 2).

Ultrasound screening for ARMD was done in 44 hips (37 patients) with a mean duration of 11 years from surgery (range 7–15 years) while MRI was done in 21 hips (17 patients) with a mean duration of 11 years from surgery (range 8–15 years). There were 14 hips (11 patients) that were examined using both ultrasound and MRI, and in total, ARMD was identified by ultrasound or MRI in 51 hips (Fig. 3). When considering MRI as the gold standard, small amounts of fluid collection were detected in 9 hips (Figs. 3, 4). One patient with a small lateral fluid lesion on ultrasound refused to be examined by MRI since he had no symptoms. The lesions found on MRI were all smaller than 35 mm in diameter, fluid-filled, and had a wall thickness of less than 2 mm, which would be classified as type 1 according to the Hart system [26]. For the six hips that had been revised and converted to a stemmed THA, both the acetabular and femoral components were revised. No additional revisions were required for these patients at an average follow-up of 7 years (range 0–16 years).

Discussion

It has been reported that metal-on-metal hip resurfacing has several advantages over conventional THA [1–5], but the frequency of hip resurfacing procedures decreased significantly due to the concerns related to metal debris and an initially higher failure rate [6, 7, 18, 19]. However, hip resurfacing with BHR still seems to be a good option in young, active patients since several studies have shown good long-term (over 10 years) results in Europe and Australia [8–16, 18, 19]. The superior results of BHR to other

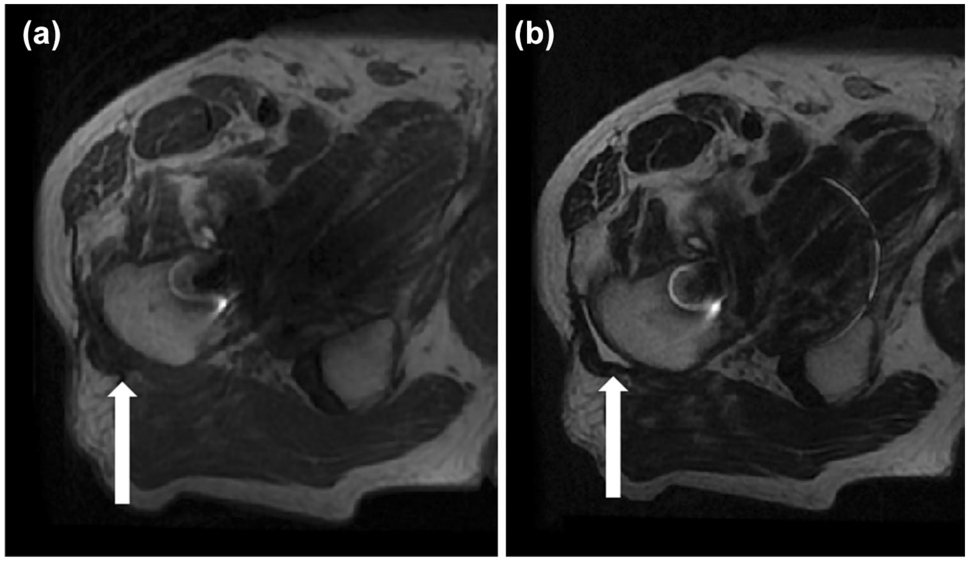

Fig. 4 MRI of the right hip at 10 years following BHR with no symptoms. T1 weighted image (**a**) and T2 weighted image (**b**). A lesion which is hypointense on T1 weighted image, and hyperintense on T2 weighted image (*white arrow*) is found laterally to the greater trochanter. The largest diameter is 30 mm with a flat shape and a thin wall. The lesion is classified as type 1 according to the Hart system [27]

resurfacing implants are thought to be due to the design and manufacturing process of the implant, which has a larger arc of coverage, higher clearance, and a high carbide volume fraction without heat treatment [28]. However, there are not many indications for the use of BHR at the present time since the manufacturing company contraindicated the use of BHR for female patients and announced the withdrawal of femoral head components sized 46 mm and smaller in June 2015. This is because many studies have reported that female sex and a small femoral component size are risk factors for implant failure [8–10, 12–14, 16, 18, 19]. It is difficult for Japanese people, who generally have a smaller stature, to be treated with BHR when these contraindications are in place. Moreover, one large series of cases performed by a single surgeon revealed that DDH, which is the main cause of hip osteoarthritis in Japan [20], is an independent risk factor for the survival of BHR, and some studies also reported that osteonecrosis is an independent risk factor for hip resurfacing [17]. Therefore, it was important to evaluate the long-term results of BHR in Japanese patients since the results thus far have been unexpectedly poor.

In this study, the risk factors indicated above were commonly observed. The femoral component size was less than 50 mm in 62% of cases, the hip disease leading to surgery was DDH–OA or osteonecrosis 75% of the time, and 53% of the patients were females, indicating a cumulative higher risk of failure than the previous studies reporting long-term results following BHR (Table 4). However, the overall BHR survivorship rate in our study was 96.5% for 10 years and 93.6% for 15 years, which is comparable to results from the other studies listed in Table 4. Additionally, female sex, femoral component size 46 mm or smaller, and hip diseases such as DDH and osteonecrosis were not risk factors for implant failure. A number of reasons could explain our favorable results. First, the location of the acetabular component may have affected the results. We attempted to achieve an acetabular component inclination of 40°, and our results showed a mean inclination of 42.9°. An inclination of over 50°, which has been reported to increase wear due to edge loading [28], was only seen in 8% of the cases, and this factor may have helped prevent ARMD even with the use of smaller components. Second, the surgical techniques performed in this study may be one of the reasons for favorable results. It has been reported that notching of the femoral neck [29], insufficient cup fixation by inadequate coverage [30], and insufficient curettage of the necrotic lesion of the femoral head [31] are risk factors for implant survival. In our study, operations were performed by two expert hip surgeons who have done many THAs on hips with DDH–OA and osteonecrosis and who have mastered the resurfacing techniques of Dr. Derek McMinn. Special attention was focused on initial fixation of the acetabular component using bone graft in cases with a low center-edge angle [32] and the position of the femoral guide wire was carefully examined to avoid notching. Furthermore, careful preparation of the femoral head was done by removing all cysts, granulation tissue, and necrotic lesions to fix the femoral component. We believe that these surgical techniques led to the positive results. But we also acknowledge that further analysis with a larger number of subjects is required to clarify all possible reasons for our positive results.

Hip resurfacing may have better results in revision than conventional stemmed THA since it preserves the proximal anatomy of the femur, but some studies have reported that the results of converting hip resurfacing to conventional THA are not favorable. Matharu and colleagues [33] reported a 37% rate of requiring additional revisions in revised metal-on-metal hip resurfacing cases. In contrast,

Table 4 Comparison of studies reporting survival rate of BHR over 10 years

Author	Number of hips	Type of hip disease	Female ratio	Femoral component size <46	10 years survival rate	Risk factors
Treacy et al. [8]	144	OA: 87% ON: 7% DDH: 2%	26%	28%	93.5%	Female, femoral component size
Coulter et al. [9]	230	N/A	34%	N/A	94.5%	Female, femoral component size
Holland et al. [10]	100	OA:79% DDH: 4%	26%	29%	92%	Femoral component size
Van Der Straeten et al. [12]	250	OA: 81% ON: 9% DDH: 4%	30%	N/A	13y:92.4%	N/A
Matharu et al. [13]	447	Primary OA: 68% DDH: 10% ON: 9%	40%	39%	96.3%	Female, femoral component size
Daniel et al. [14]	1000	OA: 76% ON: 4% DDH: 10%	33%	N/A	97.4%	Female, DDH, ON
Reito et al. [15]	261	OA: 77% DDH: 13% ON: 7%	32%	17%	91%	Female
Mehra et al. [16]	120	Primary OA: 57% ON: 14% DDH: 12%	48%	47%	94.2%	Nothing specific
Azam et al. [17]	244	OA: 100% (DDH excluded)	31%	N/A	12y:93.7%	Femoral component size
Current study	130	DDH: 52% ON: 24% OA: 22%	53%	62%	96.5%	Nothing specific

N/A Not applicable, *DDH* Developmental dysplasia of the hip, *ON* Osteonecrosis, *OA* Osteoarthritis

our six revision cases did not require an additional revision in an average follow-up of 7 years. Revision for reasons other than ARMD may be one of the reasons for our good long-term outcomes, and with these excellent results, we think that BHR can be recommended to young patients who may require an additional revision in their lifetime.

Limitations

We acknowledge the limitations of our study. First, because of the small rate of implant failure, the number of subjects may not have been large enough to identify a significant difference between the groups. However, despite the relatively few number of subjects, the survival rate for each group (DDH–OA, females, small femoral components) was still favorable. Second, the anteversion of the cup and femoral component was not measured. These factors may influence the longevity of the implants, and analysis using CT images may be required for further analysis. Third, screening for ARMD was not performed in all patients, and thus, the occurrence of ARMD may be underestimated. However, we believe that this factor does not have a large impact on implant survival since patients who have pain or any kind of symptoms were examined.

Conclusions

The overall implant survival rate of BHR in our Japanese cohort was 96.5% at 10 years and 93.6% at 15 years. Good clinical results were obtained with the use of BHR at 10- and 15-year follow-up in Japanese patients who have different stature and types of hip diseases as compared with patients in Western countries.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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