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The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Minimum Five-Year Outcomes of Birmingham Hip Resurfacing: Propensity-Score Matched Against Total Hip Arthroplasty Control Groups

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ARTICLE INFO

Article history:

Received 11 August 2020

Received in revised form

11 January 2021

Accepted 15 January 2021

Available online xxx

Keywords:

Birmingham hip resurfacing

5-year outcomes

total hip arthroplasty

clinical outcomes

forgotten joint score

ABSTRACT

Background: The aim of this study is to evaluate clinical outcomes of patients undergoing Birmingham hip resurfacing (BHR) with a minimum 5-year follow-up and compare these outcomes to 2 matched control groups of patients undergoing either direct anterior approach (DAA) or posterior approach (PA) total hip arthroplasty (THA).

Methods: Data between September 2008 and April 2015 were retrospectively reviewed. Male patients were included if they underwent a THA or BHR with minimum 5-year patient-reported outcomes. BHR patients were propensity-score matched in a 1:1 ratio to 2 control groups of patients: one group who underwent DAA THA and one group who underwent PA THA.

Results: Fifty BHR patients were propensity-score matched to 2 control groups: 50 cases of PA THA and 50 cases of DAA THA. Both control groups were well matched with respect to demographics. The BHR 5-year patient-reported outcomes were comparable to both control groups. The BHR cohort compared favorably to the PA THA group with no significant differences in their average Forgotten Joint Score (77.9, 79.4, $P = .84$ respectively) and the number of patients reporting a score greater than or equal to 50 were also comparable, 41 (82%), 42 (84%), $P = .79$ respectively.

Conclusion: BHR yielded good functional status and outcomes, which compared favorably with control groups of DAA THA and PA THA. Decision-making should be based upon other factors such as potential risk factors, the surgeon's and patient's preferences, and the patient's physical demand.

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This study was performed in accordance with the ethical standards in the 1964 Declaration of Helsinki. This study was carried out in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act. Details that might disclose the identity of the subjects under study have been omitted. This study was approved by the Institutional Review Board (Institutional Review Board ID: 5276).

Investigation was performed at the American Hip Institute, Chicago, IL.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to <https://doi.org/10.1016/j.arth.2021.01.042>.

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<https://doi.org/10.1016/j.arth.2021.01.042>

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Total hip arthroplasty (THA) was initially indicated for debilitated patients with osteoarthritis to provide basic locomotor requirements [1]. As this field progressed, prostheses were able to withstand higher impacts and provide better longevity with lower failure rates [1]. In recent years, there has been an increased interest in the direct anterior approach (DAA) for THA due to the belief that this non-muscle-splitting approach is associated with better recovery and lower risk of dislocations compared to the more commonly utilized posterior approach (PA). As a result of these advancements in technology and practice, a THA is now indicated for younger, more active patients who wish to maintain their high level of activity [1]. However, despite the improvements in prostheses, younger patients are more prone to undergoing a revision THA due to their higher activity level and longer life expectancy [2].

Alternatively, hip resurfacing may address these specific limitations associated with hip arthroplasty in young patients. The design of the resurfacing prosthesis is associated with less linear wear, higher excursion distance, and more bone preservation; hence, it promotes improved longevity, enhanced stability, and increased bone stock at the time of revision, respectively [3,4]. However, the design of the resurfacing prosthesis also imposes some limitations. In terms of patient selection, the indications for hip resurfacing are generally limited to males who are younger than 60 years and have a larger habitus [5]. Furthermore, in contrast to the more versatile THA, resurfacing is mostly performed via the PA [3].

Previous studies have investigated outcomes of hip resurfacing compared to THA by matching for the surgical approach [4,6–8]. However, considering the rising popularity of DAA THA and the lack on routinely performed anterior approach resurfacing, young male patients prior to hip arthroplasty are typically forced to decide between a DAA THA and resurfacing. Therefore, to allow for judicious and prudent decision-making, it is crucial to investigate the outcomes of a hip resurfacing relative to both a DAA and a PA THA. This study aims (1) to investigate the patient-reported outcomes (PROs) of a Birmingham hip resurfacing (BHR) with a minimum 5-year follow-up and (2) to compare the BHR outcomes to 2 matched control groups of patients undergoing a DAA THA and PA THA. This study hypothesized that patients undergoing BHR with minimum 4-year follow-up demonstrate good functional outcomes that are not significantly different from patients undergoing a DAA THA or PA THA.

Methods

Prospectively collected data on patients who underwent a THA or BHR by the senior author (B.G.D.) between September 2008 and April 2015 were retrospectively reviewed. All patients included in this study provided informed consent to participate. Furthermore, while this study represents a unique analysis, data on some patients in this study may have been reported in other studies. This study received Institutional Review Board approval. No funding was received for this study.

Surgical Indications

Patients were selected for surgical management if they endured significant pain and functional limitations due to advanced osteoarthritis of the hip and were not improving despite at least 3 months of nonsurgical management, such as activity modification, physical therapy, and nonsteroidal anti-inflammatory medication. A BHR or THA was indicated in patients based on their medical history, physical examination, and radiographic imaging. BHR was available, in addition to a THA, for young active males with satisfactory bone quality of the proximal femur and normal kidney function [3].

Surgical Technique

A hip posterior position in the lateral decubitus position was used for the BHR and PA THA. All DAA THAs were done in supine position. All procedures were performed by the senior author (B.G.D.). TraumaCad software (TraumaCAD; Voyant Health, Germany) was utilized in calculating offset, measuring leg-length discrepancies, and templating implants. THAs were performed using a noncemented cup with polyethylene liner, noncemented stem, and a ceramic head with 1 PA THA performed using a metal head and liner. The metal-on-metal BHR system was used for all hip resurfacing surgeries.

Patient Selection and Matching Process

Male patients were eligible for final analysis if they underwent a THR or BHR. Patients were included in the PA THA control group if they underwent PA THA, while patients were included in the DAA THA control group if they underwent a DAA THA. Patients were included in the study group if they underwent a BHR.

Comparable groups were constructed through propensity score matching using a 1:1 match. Matching was performed utilizing the statistical program RStudio, version 1.2.1335 (R Foundation for Statistical Computing, Vienna, Austria). The propensity score was determined using a multiple logistic regression model that incorporated age and body mass index (BMI) as covariates. The patients who did not match on the propensity score were excluded from the analysis as they were deemed noncomparable in the adjusted comparison. Three groups were created: DAA THA, PA THA, and BHR. The following demographic variables were compared: age, BMI, follow-up time, worker's compensation, and previous ipsilateral surgery.

Outcomes Evaluation

Outcomes were evaluated through the following PRO scores: Harris Hip Score (HHS), Forgotten Joint Score (FJS), Veterans RAND 12-Item Health Survey Mental Component and Physical Component, and Short Form 12 (SF-12) Physical and Mental Component. Pain was captured through a visual analog scale (VAS) with a scale from 0 (no pain) to 10 (worst pain). Satisfaction was postoperatively scored on a scale from 0 to 10, with 10 representing the highest satisfaction. PRO scores were obtained through clinic appointment, encrypted email, or telephone interview. Patients who underwent secondary surgery or a revision surgery on the operative hip were noted.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel (Redmond, WA). Differences were evaluated between propensity-score matched PA THA and BHR groups, as well as propensity-score matched DAA THA and BHR groups. To evaluate differences in continuous variables, an *F*-test was performed to evaluate variance and the Shapiro-Wilk test was utilized to evaluate distribution with $P > .05$ indicating equal variance and equal distribution for each test, respectively. The independent-samples *t*-test and equivalent parametric tests were performed for unpaired data comparisons between 2 groups. To evaluate differences in the proportions of categorical data between groups, the chi-squared and Fisher's exact test were utilized. For the HHS, previous literature determined a score between 80 and 90 as a threshold for identifying good outcomes and a score between 90 and 100 as excellent outcomes [9]. For the FJS threshold, previous literature validating the PRO demonstrated a score of 50 as a patient with "seldom" awareness of their joint during activities of daily living following THA [10]. Statistical significance was set to 0.05.

Results

Cohort Characteristics

A total of 267 hips were eligible for inclusion in the study, of which 232 (86.9%) had minimum 5-year follow-up. Within this cohort, 50 patients underwent BHR, 94 patients underwent DAA THA, and 88 patients underwent PA THA. All 50 BHR cases were successfully propensity-score matched to 50 PA THA. In addition, all

Table 1
Demographic Characteristics.

Characteristic	BHR (n = 50)	DAA THA (n = 50)	P-Value Between BHR and DAA THA	PA THA (n = 50)	P-Value Between BHR and PA THA
Age (y), mean $\pm$ SD (range)	49.05 $\pm$ 7.41 (33.19–65.72)	51.35 $\pm$ 6.60 (34.21–65.79)	.10	52.01 $\pm$ 7.26 (37.64–63.90)	.04
BMI (kg/m ²), mean $\pm$ SD (range)	29.99 $\pm$ 5.29 (23.22–41.50)	30.28 $\pm$ 3.93 (23.25–39.17)	.75	30.81 $\pm$ 4.59 (20.98–41.87)	.23
Worker's compensation	3	2	.65	6	.29
Prior ipsilateral surgeries	13	12	.82	16	.51
Follow-up time (mo), mean $\pm$ SD (range)	74.59 $\pm$ 13.59 (60.00–109.36)	66.36 $\pm$ 6.41 (60.04–97.76)	<.001	78.60 $\pm$ 17.23 (60.01–126.42)	.37

PA, posterior approach; DAA, direct anterior approach; BHR, Birmingham hip resurfacing; THA, total hip arthroplasty; BMI, body mass index; SD, standard deviation.

50 BHR cases were successfully propensity-score matched to 50 DAA THA.

Posterior Approach Total Hip Arthroplasty vs Birmingham Hip Resurfacing

Within the BHR cohort and PA THA group, the average age at surgery was 49.05 $\pm$ 7.41 and 52.01 $\pm$ 7.26, respectively ($P = .04$). For the BHR group, the average BMI was 29.99 $\pm$ 5.29, and the average follow-up time was 74.59 $\pm$ 13.59. Within the PA THA group, the average BMI was 30.81 $\pm$ 4.59, and the average follow-up time was 78.60 $\pm$ 17.23. Further baseline characteristics are reported in Table 1. There were no statistically significant differences in 5-year outcome measures (Table 2). The BHR cohort compared favorably to the PA THA group with no significant differences in their average FJS score (77.9, 79.4, $P = .84$, respectively) and the number of patients reporting a score greater than or equal to 50 were also comparable, 41 (82%), 42 (84%), $P = .79$ respectively. In addition, 41 (82%) hips and 38 (76%) hips achieved good to excellent HHS outcomes in the BHR and PA THA groups, respectively ($P = .46$).

In the BHR group, 4 hips (8.0%) underwent revision surgeries—1 hip due to Brooker IV heterotopic ossification and 3 hips due to aseptic loosening of the femoral stem. In the propensity-score matched PA THA group, 2 of the 50 (4.0%) hips underwent a revision due to aseptic loosening of the femoral stem. All patients had resolved symptoms. There were no significant differences in rates of revision ($P = .40$).

Anterior Approach Total Hip Arthroplasty vs Birmingham Hip Resurfacing

Within the DAA THA group, the average age at surgery was 51.35 $\pm$ 6.60 and the average BMI was 30.28 $\pm$ 3.93. Age and BMI were not significantly different between the groups (Table 1). The average follow-up time for the DAA THA group was 66.36 $\pm$ 6.41—this was significantly different than the BHR cohort ($P < .001$). There were no statistically significant differences in 5-year outcome measures

(Table 2). Furthermore, the BHR cohort compared favorably to the DAA THA group with no significant differences in their average FJS scores (77.9, 76.6, $P = .93$ respectively) as well as in the number of patients achieving a score greater than or equal to 50, 41 (82%), 38 (76%), $P = .46$ respectively. In addition, 34 (68%) hips achieved good to excellent HHS outcomes ($P = .11$).

Of the 50 propensity-score matched hips in the DAA THA group, 3 hips (6.0%) received a secondary surgery. Two of these hips underwent a revision THA—1 due to aseptic loosening of the femoral stem and 1 due to heterotopic ossification with a subsided stem. One hip underwent a secondary arthroscopy and iliopsoas bursectomy due to persisting pain. All patients had resolved symptoms. Compared to the 4 hips in the BHR group, there were no significant differences in rates of secondary surgeries ($P = .70$).

Discussion

The purpose of the study is to investigate and compare the outcomes for patients undergoing BHR, PA THA, and DAA THA with minimum 5-year follow-up. Overall, 150 male patients were enrolled in the study after propensity-score matching in a 1:1 ratio for age and BMI. Patients with minimum 5-year follow-up after BHR report good functional outcomes, similar to the control groups, PA THA and DAA THA.

The study investigated midterm follow-up outcomes in patients undergoing BHR. Oxbloom et al compared PROs in patients undergoing hip resurfacing with a matched control group [8]. Overall, 569 patients were enrolled in the study. Mean follow-up was 7 years (2.2–13) with a 25% and 24% female patient population in the study group and control group, respectively. The authors found that hip resurfacing was associated with better scores in Hip disability and Osteoarthritis Outcome Score (HOOS) Activities of Daily Living (ADL) and Sport/Recreation. Furthermore, no significant differences were found between the type of prosthesis and the remaining HOOS subscales, EuroQol-5 Dimension (EQ-5D) index, and VAS for hip pain and satisfaction. In contrast to Oxbloom et al, this study found no difference in the reported PROs, including HHS, FJS,

Table 2
Patient-Reported Outcomes.

Outcome Measure	BHR (n = 50), Mean $\pm$ SD (Range)	DAA THA (n = 50), Mean $\pm$ SD (Range)	P-Value Between BHR and DAA THA	PA THA (n = 50), Mean $\pm$ SD (Range)	P-Value Between BHR and PA THA
HHS	91.73 $\pm$ 12.39 (39.03–100.00)	88.74 $\pm$ 15.86 (35.39–100.00)	.70	89.54 $\pm$ 14.54 (39.03–100.00)	.45
FJS	77.91 $\pm$ 24.83 (0.00–100.00)	76.63 $\pm$ 27.40 (2.08–100.00)	.93	79.38 $\pm$ 23.43 (8.33–100.00)	.84
VR-12 Mental	62.35 $\pm$ 5.62 (43.06–67.40)	60.96 $\pm$ 10.28 (17.57–68.01)	.42	60.64 $\pm$ 6.38 (42.15–68.82)	.07
VR-12 Physical	51.73 $\pm$ 7.58 (23.09–58.64)	51.15 $\pm$ 9.04 (21.01–57.89)	.81	51.19 $\pm$ 7.05 (19.31–57.94)	.31
SF-12 Mental	57.57 $\pm$ 5.07 (41.91–63.40)	56.45 $\pm$ 9.05 (19.06–64.06)	.47	55.66 $\pm$ 6.63 (32.90–64.71)	.10
SF-12 Physical	50.84 $\pm$ 7.42 (24.09–57.52)	50.13 $\pm$ 8.97 (22.09–56.58)	.9	50.08 $\pm$ 7.38 (17.54–56.69)	.30
VAS	1.08 $\pm$ 1.65 (0.00–6.74)	1.31 $\pm$ 2.19 (0.00–10.00)	.94	1.36 $\pm$ 2.02 (0.00–7.50)	.49
Satisfaction	8.46 $\pm$ 2.44 (0.00–10.00)	9.26 $\pm$ 1.78 (0.00–10.00)	.07	9.00 $\pm$ 2.22 (1.00–10.00)	.09

PA, posterior approach; DAA, direct anterior approach; SD, standard deviation; BHR, Birmingham hip resurfacing; THA, total hip arthroplasty; HHS, Harris Hip Score; FJS, Forgotten Joint Score; VAS, visual analog scale for pain; VR-12, Veterans RANDS 12; SF-12, Short Form 12.

Veterans RAND 12-Item Health Survey Mental and Physical Component, SF-12 Mental and Physical Component, VAS for pain, and patient satisfaction. Several factors may explain the difference between the studies. First, both the number of patients and the mean follow-up were higher in Oxblo et al study. However, this study minimized heterogeneity with a minimum follow-up of 5 years and only male participants, which coincides with current recommendations in the literature for hip resurfacing [5]. Despite these differences, Oxblo et al demonstrated overall comparable outcomes with differences in only the minority of the PROs between the cohorts, similar to this study.

Concerning revisions following hip arthroplasty, Stoney et al [11] investigated the survivorship of BHR relative to THA in males younger than 65 years of age. Overall, 4790 BHR procedures and 2696 THA procedures were conducted between 1999 and 2018. The mean age for the BHR and THA groups was 52 and 56 years of age, respectively. The mean follow-up for the BHR and THA groups was 11.9 and 9.3 years, respectively. The BHR prosthesis had a statistically higher rate of revisions at 17 years than the THA group (6.7% vs 3.4%, respectively). No difference in risk for revision rate was evident in the first 2.5 years. The BHR group demonstrated a higher rate of revision rate for loosening after 2 years and a higher fracture rate during the entire period. In contrast, there was a lower infection rate for the BHR group in the first 5 years. Corroborating with Stoney et al, this study demonstrated 8.0%, 6.0%, and 4.0% revision rate for the BHR, DAA THA, and PA THA, respectively. Albeit not statistically significant, this difference should be a consideration during the preoperative decision-making and discussion between the surgeon and the patient.

Considering the common arsenal of arthroplasty procedures available for young male patients, a possible conflict between resurfacing and DAA THA may occupy both patients and clinicians. Higgins et al [12] conducted a systematic review and meta-analysis comparing DAA THA and PA THA. Overall, 17 studies enrolling 2302 patients were included in the study and follow-up ranged between 12 and 24 months within studies assessing clinical outcomes. The authors investigated the following PROs: HHS, Medical Outcome Study (SF-12 or SF-36), VAS for pain, Hip Outcome Score, Western Ontario & McMaster Universities Arthritis Index, HOOS, Merle d'Aubigne and Postel score, University of California Los Angeles (UCLA) Activity Scale, Oxford Hip Score, and Japanese Orthopedic Association Hip Score. Neither the PA THA nor the DAA THA demonstrated superiority relative to the other. The authors concluded that surgical approach for a THA should be based on the patient's characteristics, the surgeon's experience, and the preferences of the surgeon and patient. Concurring with Higgins et al, this study found no statistically significant differences in outcomes between the study group and the propensity-score matched DAA THA and PA THA control groups at mid-term follow-up. Additionally, upon the validation of FJS, Behrend et al utilized a control group composed of healthy individuals. The mean average FJS score for healthy males and females was 86.6 and 79.3, respectively [10]. Although one of the strongest attributes of FJS is its lack of a ceiling effect, it should be emphasized that the expected rates of patients achieving high scores is less likely compared to other PROs. Thus, decision-making for young males with arthritic hips should consider factors other than the surgical approach, such as the expected risk for revisions and secondary surgeries, the surgeon's and patient's preferences, physical demand, and participation in high impact activities.

Limitations

This study has some limitations. First, the investigated cohorts are limited in size as BHR is only indicated in relatively young males and patients were matched in a 1:1 ratio. Furthermore, this is a single-surgeon case series. These limit the generalizability of our conclusions. However, this study includes a high follow-up rate (86.9%) to minimize follow-up bias. Furthermore, although the control groups and study groups were propensity-score matched to minimize heterogeneity, there were slight statistical differences between the age of the BHR and PA THA group. Although statistically significant, it may not have clinical impact on the results. Finally, since the blood ion levels and postoperative radiographic analysis were not routinely documented, comparison of these parameters could not be conducted.

Conclusion

BHR yielded good functional status and outcomes, which compared favorably with control groups of DAA and PA THA. Thus, decision-making should be based upon other factors such as potential risk factors, surgeon's and patient's preferences, and patient's physical demand.

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