A commentary by Nicholas J. Giori, MD, PhD, is linked to the online version of this article at jbjs.org.

Five to Ten-Year Results of the Birmingham Hip Resurfacing Implant in the U.S.

A Single Institution's Experience

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Background: International surgeon series and registry data have demonstrated positive outcomes and long-term survival of the Birmingham Hip Resurfacing (BHR) implant. We report the 5 to 10-year results from a single center in the U.S.

Methods: Three hundred and fourteen patients (360 hips) underwent surface replacement arthroplasty with use of the BHR implant and consented to study participation. Patient-reported outcomes and complication and revision data were collected at a minimum of 5 years of follow-up for 93% (324 of 350) of the hips in surviving patients. A matched-cohort analysis was used to compare clinical outcomes between use of the BHR and total hip arthroplasty.

Results: Mean modified Harris hip score (mHHS) and University of California, Los Angeles (UCLA) scores significantly improved postoperatively, to 89.9 and 8.0, respectively ($p < 0.001$). The Kaplan-Meier estimated rate of survival for all-cause revision was 97.2% (95% confidence interval [CI], 94.7% to 98.5%) and 93.8% (95% CI, 88.8% to 96.7%) at 5 and 10 years, respectively. In a subgroup analysis of patients fitting our current BHR inclusion criteria (males <60 years of age with a diagnosis of osteoarthritis and anatomy conducive to a femoral head component of ≥48 mm), survival free of aseptic revision was 99.5% (95% CI, 96.6% to 99.9%) at 5 years and 98.2% (95% CI, 94.4% to 99.4%) at 10 years. Fourteen patients (4.3% of all hips) required revision. Postoperative UCLA scores were significantly greater for BHR compared with total hip arthroplasty (mean score of 8.0 ± 2.0 versus 7.6 ± 1.8; $p = 0.040$) in a matched-cohort analysis, with patients matched according to preoperative UCLA score, diagnosis, age, sex, and body mass index. Among matched patients who were highly active preoperatively (UCLA score of 9 to 10), BHR provided a smaller median decrease in the postoperative UCLA score (0.0 versus 1.0; $p < 0.001$), which was clinically important according to the minimal clinically important difference (MCID, 0.92). Furthermore, BHR provided a greater likelihood of remaining highly active compared with total hip arthroplasty (61% compared with 20%; $p < 0.001$).

Conclusions: BHR demonstrated excellent survivorship and clinical outcomes at 5 to 10 years in selected patients. As compared with total hip arthroplasty, the use of the BHR may provide highly active patients with clinically important advantages in postoperative activity as well as a greater likelihood of remaining highly active. Continued follow-up is necessary to validate long-term BHR outcomes.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Disclosure: No external funding was received for this study. On the **Disclosure of Potential Conflicts of Interest** forms, *which are provided with the online version of the article*, one or more of the authors checked "yes" to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work (http://links.lww.com/JBJS/E955).

Metal-on-metal (MoM) surface replacement arthroplasty has demonstrated promise as a treatment for osteoarthritis of the hip, especially in young, active males[1]. Poor outcomes and frequent adverse local tissue reactions (ALTRs) associated with MoM total hip arthroplasty, however, have led to generalized caution regarding the use of MoM devices. Furthermore, the 2010 recall of the ASR implant (DePuy) and a 2008 study by Pandit et al.[2], reporting pseudotumors in 17 female patients (20 hips) who underwent surface replacement arthroplasty, have contributed to diminished utilization of MoM surface replacement arthroplasty systems.

Results of MoM surface replacement arthroplasty, however, are highly dependent on the specific device being utilized as well as the demographics of the patient population being treated. In 2016, the Australian Orthopaedic Association National Joint Replacement Registry reported favorable 15-year revision rates for surface replacement arthroplasty, but only 3 of the 11 surface replacement arthroplasty device combinations under investigation demonstrated implant survival similar to that of total hip arthroplasty: the ADEPT (MatOrtho), the MITCH TRH (Stryker), and the Birmingham Hip Resurfacing (BHR; Smith & Nephew) devices[3]. Although the BHR implant has been available in the U.K. for 20 years, it only received U.S. Food and Drug Administration (FDA) approval in 2006, and it remains the only surface replacement arthroplasty implant available and approved for use in the U.S. Furthermore, it is only 1 of 2 surface replacement arthroplasty implants to have received a 10A rating or greater from the Orthopaedic Device Evaluation Panel in the U.K., and the only surface replacement arthroplasty implant to receive the maximum possible rating of 10A*[4].

Surface replacement arthroplasty has potential advantages, including the restoration of native hip biomechanics, decreased incidence of instability, decreased morbidity with revision surgery, and improved function with high-demand activities[5-9]. However, because surface replacement arthroplasty is a more technically demanding procedure with a greater cost compared with total hip arthroplasty[10], it must demonstrate similar complication rates and survivorship, as well as potential clinical advantages, in order to justify its use.

While BHR data from foreign studies and registries have demonstrated survivorship equal to that of total hip arthroplasty in select patient groups[8,11-15], no U.S. study that we are aware of has reported on survivorship beyond the mid-term. The primary aim of the current study was to report BHR survivorship and outcomes at 5 to 10 years. A secondary aim of this study was to compare the clinical outcomes of matched BHR and total hip arthroplasty cohorts in order to determine if BHR use confers relative advantages among highly active patients.

Materials and Methods

Study Cohort

Our study cohort represents a consecutive series of 314 patients (360 hips) who received BHR implants between June 2006 and December 2011 and consented to study participation; the procedures were performed by 3 surgeons (R.L.B., J.C.C., and R.M.N.). Seven patients (10 hips) died before reaching the minimum 5-year follow-up, leaving 307 patients (350 hips) for inclusion in the study. Minimum 5-year follow-up data were collected for 93% (324) of the hips (283 patients), while 7% (26) of the hips (24 patients) were lost to follow-up (Fig. 1). Patient characteristics are shown in Table I.

Indications

At our institution and others, the use of BHR is currently limited to active males <60 years of age with a primary diagnosis of osteoarthritis and anatomy conducive to a femoral head component of ≥48 mm, on the basis of FDA

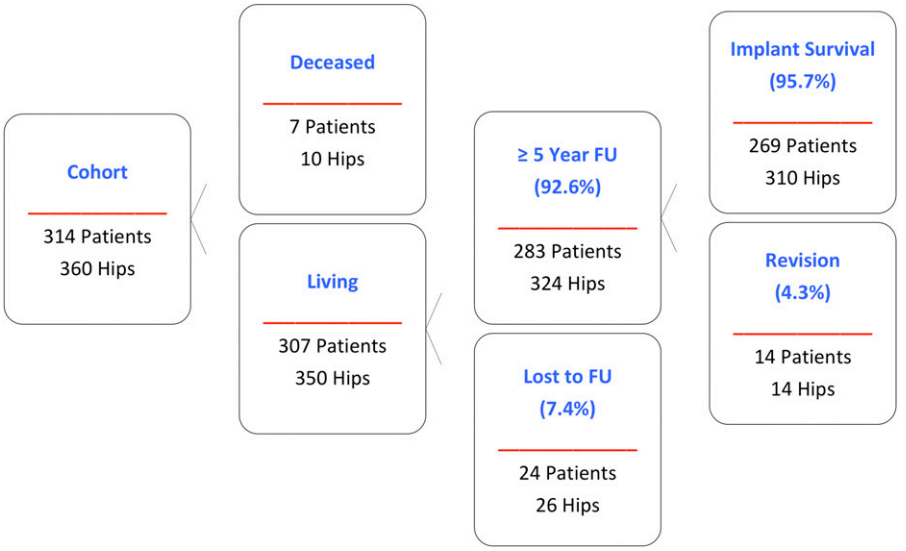

Fig. 1
Patient flow diagram. FU = follow-up.

TABLE I Patient Characteristics*

	Values
Age *(yr)*	52.0 ± 7.5 (22.8-81.6)
Sex	
Male	280 (86.4)
Female	44 (13.6)
BMI *(kg/m²)*	27.0 ± 3.5 (17.4-40.0)
ASA score	1.89 ± 0.5 (1-4)
Osteoarthritis	304 (93.8)
Rheumatoid arthritis	1 (0.3)
Head destruction	3 (0.9)
Osteonecrosis	10 (3.1)
Posttraumatic arthritis	6 (1.9)

*The values for age, BMI, and ASA score are given as the mean and standard deviation, with the range in parentheses. All other values are given as the number of hips (n = 324), with the percentage in parentheses.

TABLE II Surgical Data*

	Values
Extensile posterior approach	324 (100)
Implant femoral head size *(mm)*	50.1 ± 3.3 (42-58)
Implant acetabular shell size *(mm)*	56.8 ± 3.1 (48-66)
Implant anteversion *(°)*	23.0 ± 7.2 (−5-52)
Implant inclination *(°)*	42.0 ± 5.2 (25-60)
Implant femoral neck-shaft angle *(°)*	138.9 ± 6.1 (112-160)

*The values for extensile posterior approach are given as the number of hips, with the percentage in parentheses. All other values are given as the mean and standard deviation, with the range in parentheses.

recommendations and implant availability as well as of prior studies describing optimal BHR utilization[3,16,17]. Because this study includes our institution's initial experience with the use of BHR prior to the implementation of these criteria, 36% of our included patients had at least 1 factor that would have excluded them on the basis of our current criteria. Therefore, we investigated outcomes for the general cohort as well as for the subgroup representing the current inclusion criteria, allowing us to determine the expected performance of the BHR implant in today's population.

Surgical Procedure

An extensile posterior approach, as described by Daniel et al., was used in all cases[12]. As per FDA guidelines, routine metal ion levels and advanced imaging were not assessed for asymptomatic patients[18]. Surgical data are shown in Table II.

Clinical and Patient-Reported Outcomes

Preoperative patient demographic data, including age, sex, and body mass index (BMI); disease diagnosis; and American Society of Anesthesiologists (ASA) score (Table I) as well as patient-reported outcomes data, such as modified Harris hip score (mHHS) and University of California, Los Angeles (UCLA) activity score, were obtained from an institutional registry.

Postoperatively, patient-reported outcomes data including mHHS, UCLA score, satisfaction level (1 = unsatisfied, 2 = somewhat satisfied, 3 = satisfied, 4 = very satisfied, and 5 = extremely satisfied), and a binary satisfaction response (yes or no) for all patients with a minimum of 5 years of follow-up were collected from our institutional registry. Patients lacking 5-year follow-up data were contacted via telephone to complete patient-reported outcomes surveys and answer questions regarding failure of the procedure and complications. Data are presented as of the most recent follow-up or at the time of failure. All failed cases, with "failure" defined as the need for revision hip surgery, as well as the time to failure and reasons for failure, were recorded.

Radiographic Outcomes

Minimum 5-year radiographic follow-up was available for 280 (86.4%) of the hips. Two of the authors (M.C.F. and M.D.H.) independently assessed anteroposterior and cross-table lateral radiographs for radiolucencies, component loosening, femoral-neck narrowing, and heterotopic ossification as well as acetabular inclination and anteversion and femoral neck-shaft angle. Acetabular and femoral component radiolucencies were assessed in accordance with previously described methods[19,20]

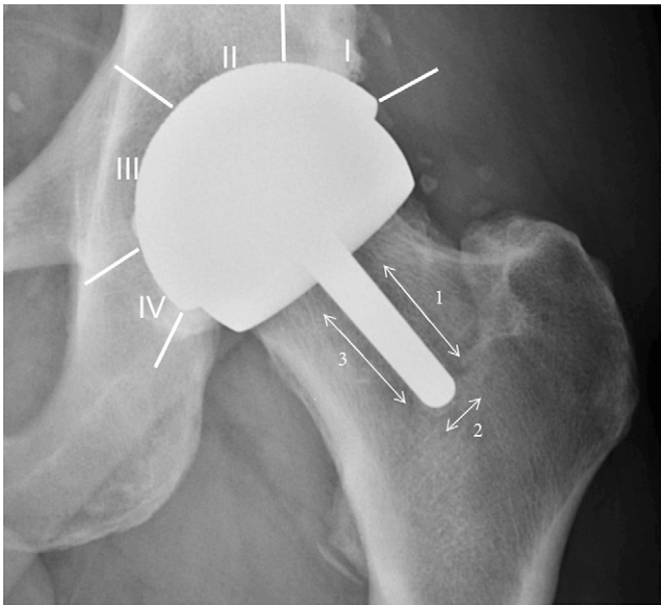

Fig. 2

Assessment of radiolucency surrounding the femoral component. Numbers 1 to 3 represent the zones of the femoral stem, while Roman numerals I to IV represent the Charnley zones[19-21].

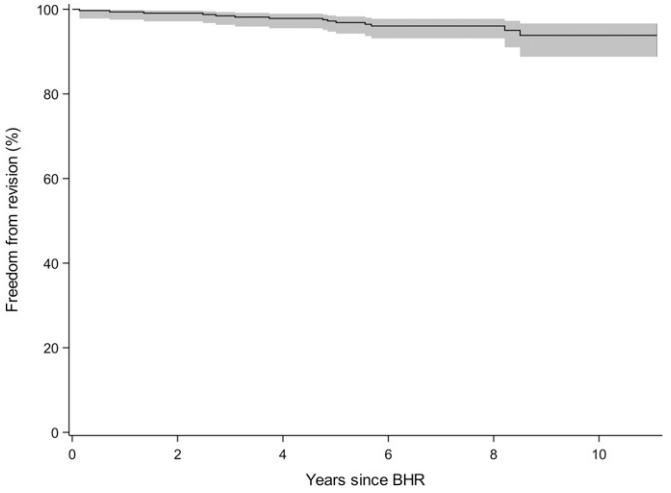

Fig. 3-A

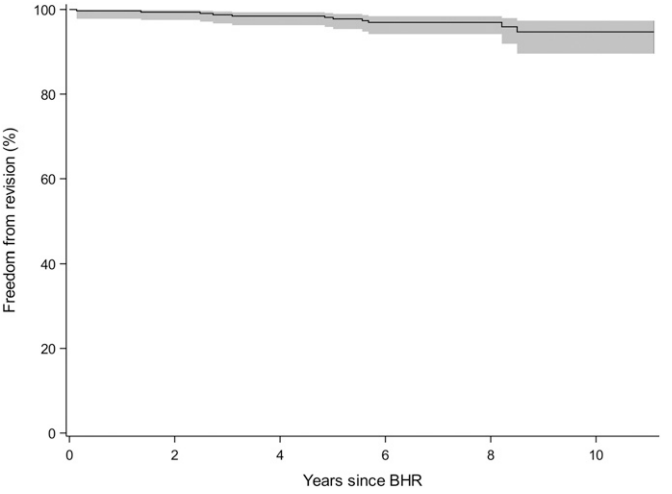

Fig. 3-B

Fig. 3-A Kaplan-Meier estimated survival for all-cause revision. The rate of survival free from revision for any cause (n = 324, 100% of the cohort) was 97.2% (95% confidence interval [CI], 94.7% to 98.5%) at 5 years and 93.8% (95% CI, 88.8% to 96.7%) at 10 years. The shaded area represents the 95% CI. BHR = Birmingham Hip Resurfacing. **Fig. 3-B** Kaplan-Meier estimated survival for aseptic revision. The rate of survival free from aseptic revision (n = 321, 99.1%) was 98.1% (95% CI, 95.9% to 99.2%) at 5 years and 94.7% (95% CI, 89.6% to 97.4%) at 10 years. The shaded area represents the 95% CI. BHR = Birmingham Hip Resurfacing.

(Fig. 2). Femoral-neck narrowing was assessed as described by Hing et al., with narrowing defined as a reduction in the femoral neck of >10%[21]. The average value for each measure was utilized in the final analysis.

Matched Total Hip Arthroplasty Cohort

Postoperative BHR outcomes were then compared with outcomes following total hip arthroplasty obtained from our institutional outcomes database. The use of BHR is reserved for

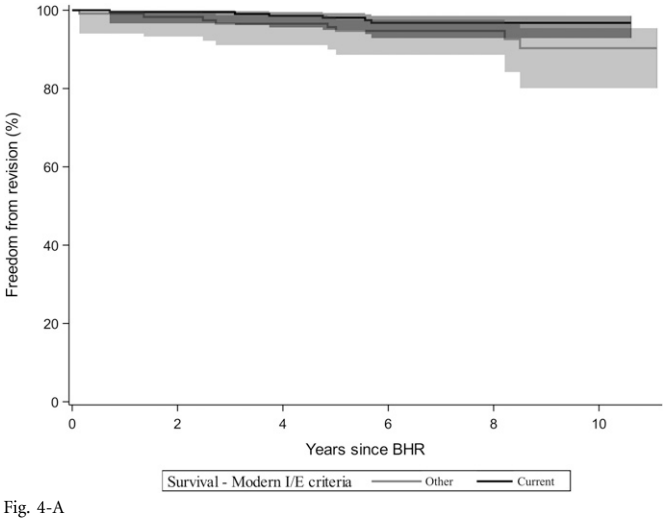

Fig. 4-A

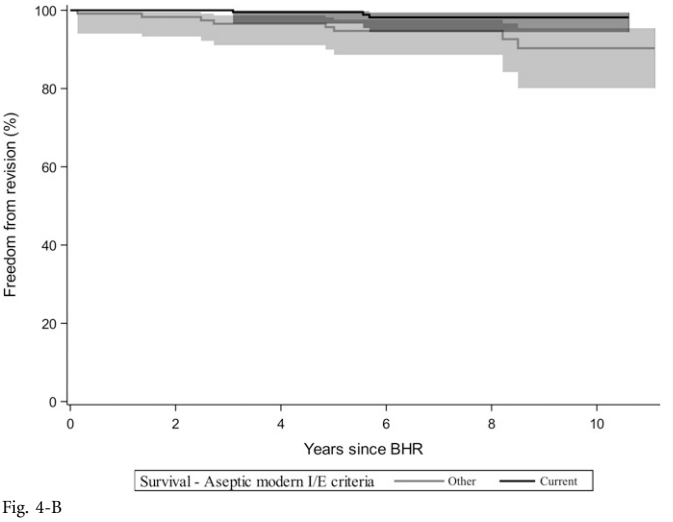

Fig. 4-B

Fig. 4-A Kaplan-Meier estimated survival for all-cause revision among patients meeting the current inclusion and exclusion (I/E) criteria compared with the rest of the cohort. The current inclusion criteria are male patients <60 years of age with a preoperative diagnosis of osteoarthritis and anatomy conducive to a femoral head component of ≥48 mm. The rate of survival free from revision for any cause for this subgroup (n = 208, 64.2%) was 98.1% (95% CI, 95.0% to 99.3%) at 5 years and 96.8% (95% CI, 92.9% to 98.6%) at 10 years compared with 95.7% (95% CI, 90.0% to 98.2%) at 5 years and 90.3% (95% CI, 80.1% to 95.4%) at 10 years for the remaining cohort (n = 116, 35.8%). The shaded areas represent the 95% CI. BHR = Birmingham Hip Resurfacing. **Fig. 4-B** Kaplan-Meier estimated survival for aseptic revision among patients meeting the current inclusion and exclusion (I/E) criteria compared with the rest of the cohort. The current inclusion criteria are male patients <60 years of age with a preoperative diagnosis of osteoarthritis and anatomy conducive to a femoral head component of ≥48 mm. The estimated rate of survival free from aseptic revision for this subgroup (n = 205, 63.3%) was 99.5% (95% CI, 96.6% to 99.9%) at 5 years and 98.2% (95% CI, 94.4% to 99.4%) at 10 years compared with 95.7% (95% CI, 90.0% to 98.2%) at 5 years and 90.3% (95% CI, 80.1% to 95.4%) at 10 years for the remaining cohort (n = 119, 36.7%). The shaded areas represent the 95% CI. BHR = Birmingham Hip Resurfacing.

TABLE III Associations Between Patient and Procedural Characteristics and Failure Using a Multivariate Cox Regression Analysis

Characteristic	Successful Treatment*	Failed Treatment*	No. with Failure	Hazard Ratio (95% CI)	P Value
Age *(yr)*	52.1 ± 7.41	50.27 ± 9.11	—	0.97 (0.90-1.04)	0.370
Sex					
Female (n = 44)	—	—	5	3.41 (1.14-10.20)	0.028††
Male (n = 280)	—	—	9		
BMI *(kg/m²)*	27.13 ± 3.52	26.24 ± 4.37	—	0.93 (0.79-1.09)	0.379
Osteoarthritis (n = 297)	—	—	13	0.97 (0.13-7.42)	0.976
Acetabular inclination *(°)*	42.03 ± 5.19	41.29 ± 5.55	—	0.97 (0.87-1.07)	0.523
Acetabular anteversion *(°)*	23.04 ± 7.17	21.82 ± 8.83	—	0.96 (0.88-1.05)	0.364
Femoral head size					
<48 mm (n = 91)	—	—	6	3.4 (1.18-9.80)	0.023†§
≥48 mm (n = 233)	—	—	8		

*The values are given as the mean and standard deviation. †Significant. ‡0.290 in the multivariate analysis. §0.138 in the multivariate analysis.

highly active patients who often specifically request it in order to remain competitive in high-demand activities, precluding an accurate comparison of BHR results and outcomes of total hip arthroplasty in the general population. We therefore performed a 1:1 matched-cohort analysis based on the following parameters: (1) a preoperative diagnosis of osteoarthritis, (2) patient age of <60 years, (3) male sex, (4) BMI within 3 kg/m², and (5) a preoperative UCLA score within 1. In order to determine whether highly active patients received an additional benefit from BHR compared with total hip arthroplasty, we performed a subgroup analysis comparing median postoperative UCLA scores between BHR and total hip arthroplasty patients who had preoperative UCLA scores of 9 to 10 (patients capable of participating in impact sports[22]). On the basis of the findings of SooHoo et al. establishing the minimal clinically important difference (MCID) for the UCLA score, we set the threshold for clinical importance at 0.92[23]. Finally, we compared the postoperative likelihood of remaining highly active between BHR patients and total hip arthroplasty patients who were highly active preoperatively.

Statistical Analysis

Statistical analyses were performed using SAS (version 9.4; SAS Institute). Preoperative and postoperative mHHS and UCLA scores were compared using a paired t test. Kaplan-Meier analysis was used to estimate the 5 and 10-year rates of survival free from revision for any cause and from aseptic revision for the full cohort as well as for a cohort representing the current BHR inclusion criteria (males of <60 years of age with osteoarthritis and anatomy conducive to a femoral head component of ≥48 mm). A log-rank test was used to compare the current-indication subgroup with the greater cohort. Univariable and multivariable Cox regression analyses were performed in order to assess the relationship between demographic risk factors and implant failure. BHR and total hip arthroplasty patients were matched using the "greedy" matching algorithm in the gmatch SAS macro[24] and analyzed using a paired t test (UCLA and mHHS), Wilcoxon signed-rank test (satisfaction ranking), and McNemar test (satisfaction, yes or no). Differences in the median change in UCLA score for total hip arthroplasty and BHR subjects with preoperative scores of 9 to 10 were compared using a median regression analysis.

Results

Survivorship Outcomes

The Kaplan-Meier estimated rate of survival free from revision for any cause (n = 324, 100% of the cohort) was 97.2% (95% confidence interval [CI], 94.7% to 98.5%) at 5 years and 93.8% (95% CI, 88.8% to 96.7%) at 10 years (Fig. 3-A). The rate of survival free from aseptic revision (n = 321, 99.1%) was 98.1% (95% CI, 95.9% to 99.2%) at 5 years and 94.7% (95% CI, 89.6% to 97.4%) at 10 years (Fig. 3-B). In a subgroup analysis assessing implant survival among patients representative of our current BHR inclusion criteria (n = 208, 64.2%), the estimated rate of survival free from revision for any cause for this subgroup was 98.1% (95% CI, 95.0% to 99.3%) at 5 years and 96.8% (95% CI, 92.9% to 98.6%) at 10 years compared with 95.7% (95% CI, 90.0% to 98.2%) at 5 years and 90.3% (95% CI, 80.1% to 95.4%) at 10 years for the remaining cohort (n = 116,

TABLE IV Perioperative Complications

Complication	No. of Cases
Dislocation	1
Heterotopic ossification	4
Pulmonary embolism	1
Myocardial infarction	1
Cardiac arrhythmia	1

TABLE V Patient and Procedural Characteristics of Cases That Underwent BHR Revision*

	Sex	Age at Surgery (yr)	Preop. Diagnosis	Head Size (mm)	Acetabular Inclination (°)	Acetabular Anteversion (°)	Femoral Neck-Shaft Angle (°)	Time to Revision (yr)	Reason for Revision
High risk									
	M	41.4	Osteonecrosis	42	39	16	125	8.5	Femoral neck fracture
	F	54.0	OA	42	36	20	156	8.2	Undiagnosed pain
	F	34.4	OA	42	43	35	150	1.4	Fibrous ingrowth of cup
	F	53.8	OA	46	40	40	141	5.0	ALTR and/or pseudotumor
	F	52.7	OA	46	45	24	137	2.5	Persistent dislocation
	F	52.2	OA	46	37	23	132	2.7	ALTR and/or pseudotumor
	M	53.0	OA	48	36	30	140	5.6	Undiagnosed pain
	M	42.1	OA	48	36	30	140	3.1	ALTR and/or pseudotumor
	M	63.8	OA	50	37	22	137	4.8	ALTR and/or pseudotumor
	M	65.2	OA	54	38	20	143	0.1	Fibrous ingrowth of cup
Low risk									
	M	52.3	OA	50	42	19	112	5.7	Femoral component loosening
	M	36.8	OA	50	55	7	146	3.7	Infection
	M	46.2	OA	52	37	15	138	0.7	Infection
	M	55.7	OA	54	44	11	134	4.8	Infection

*OA = osteoarthritis, and ALTR = adverse local tissue reaction.

35.8%) (Fig. 4-A). The estimated rate of survival free from aseptic revision in this subgroup (n = 205, 63.3%) was 99.5% (95% CI, 96.6% to 99.9%) at 5 years and 98.2% (95% CI, 94.4% to 99.4%) at 10 years compared with 95.7% (95% CI, 90.0% to 98.2%) at 5 years and 90.3% (95% CI, 80.1% to 95.4%) at 10 years for the remaining cohort (n = 119, 36.7%) (Fig. 4-B).

Patient sex and femoral component size were found to be significant predictors of implant failure. Female patients had a 3.4 (95% CI, 1.1 to 10.2)-times greater risk of all-cause failure compared with male patients ($p = 0.028$). Femoral head sizes of <48 mm had a 3.4 (95% CI, 1.2 to 9.8)-times greater risk of all-cause failure compared with those of ≥48 mm ($p = 0.023$). The effect of sex and femoral component size was not apparent in our multivariate analysis ($p > 0.05$), but it is unclear whether this was because of the correlation between sex and head size or the underpowered nature of this analysis. The hazard ratios for various patient and procedural characteristics are presented in Table III.

Patient-Reported Outcomes

The average mHHS (and standard deviation) was 54.3 ± 13.6 (range, 3.3 to 92.4) preoperatively, which improved to 89.9 ± 14.4 (range, 22.0 to 100.1) at the time of final follow-up. This average increase in the mHHS of 35.6 ± 18.4 (95% CI, 33.5 to 37.7) was significant ($p < 0.001$). The average UCLA score

TABLE VI Matched-Cohort Analysis

Variable	BHR	THA*	Paired Difference	P Value
No. of hips	159	159	—	—
Median satisfaction level	5	5	0 (−1, 1)†	0.99
Postop. mHHS†	91.6 ± 12.9	88.8 ± 16.0	2.9 ± 19.0	0.068
Postop. UCLA score†	8.0 ± 2.0	7.6 ± 1.8	0.4 ± 2.6	0.040§
Median decrease in UCLA score among highly active patients (UCLA 9-10)	0.0	1.0	1.0 ± 0.45	<0.001§
Percentage of highly active patients (UCLA 9-10) remaining highly active postop.	61%	20%	—	<0.001§

*THA = total hip arthroplasty. †The 95% confidence interval is given in parentheses. ‡The values are given as the mean and standard deviation. §Significant.

was 7.0 ± 2.5 (range, 2 to 10) preoperatively, improving to 8.0 ± 2.0 (range, 2 to 10) at the time of final follow-up. This average increase in the UCLA score of 1.0 ± 2.5 (95% CI, 0.7 to 1.3) was significant ($p < 0.001$). The average patient-satisfaction level was 4.5 ± 0.9 (range, 1 to 5) at the time of final follow-up.

Complications and Revisions

Perioperative complications are reported in Table IV. Fourteen patients underwent BHR revision at an average of 4.1 years (range, 0.1 to 8.5 years). Table V reports surgical and demographic details for each revision case.

Radiographic Results

Of the 280 radiographs available for interpretation, 4 hips had an acetabular radiolucent line in Charnley zone I only; 1 hip, in Charnley zone II; 1 hip, in Charnley zone III; 1 hip, in both Charnley zones I and II; and 1 hip, in both Charnley zones II and III. Six hips showed a femoral radiolucent line in stem zone 1 only; 3 hips, in stem zone 2; 1 hip, in stem zone 3; 2 hips, in both stem zones 1 and 2; and 1 hip, in all 3 stem zones. Only 1 hip showed evidence of femoral notching. No patient had continuous radiolucency or migration of either component.

Matched Cohort

A matched-cohort analysis demonstrated a significant, 0.4 ± 2.6-point advantage for BHR compared with total hip arthroplasty in mean postoperative UCLA score ($p = 0.040$). The median satisfaction level and mean mHHS did not differ significantly between the 2 types of procedures. A subgroup analysis of the highly active patients in the matched cohorts demonstrated that, among patients with preoperative UCLA scores of 9 to 10, a significantly smaller median decrease in postoperative UCLA score (0.0 compared with 1.0; $p < 0.001$) was noted for BHR compared with total hip arthroplasty, which was clinically important according to the MCID of 0.92. Furthermore, use of the BHR provided a greater likelihood of remaining highly active compared with total hip arthroplasty (61% versus 20%; $p < 0.001$). The failure rate in the total hip arthroplasty group was similar to that in the BHR matched cohort, with 3 revisions at an average of 4.8 years (1.5 to 7.0 years) due to infection, to femoral component failure, and to taper corrosion. Results are summarized in Table VI.

Discussion

Although several international series have reported excellent results for various surface replacement arthroplasty designs[25-27], we are the first, to our knowledge, to describe the intermediate-to-long-term BHR results from a U.S. series. In 324 hips with an average follow-up of 7.2 years, we demonstrated an estimated rate of survival of 97.2% and 93.8% at 5 and 10 years, respectively. Furthermore, in patients fitting our institution's current inclusion criteria, the survival rate was 98.1% and 96.8% at 5 and 10 years, respectively. BHR patients showed significant improvements in mHHS and UCLA activity scores, with postoperative scores comparing favorably to those of the designing-surgeon series[12]. Additionally, 98.4% of the patients were satisfied with their BHR. These findings corroborate the excellent clinical outcomes and survivorship demonstrated in international trials and short-term studies from within the U.S.[8,14,17,28].

When matched on the basis of preoperative UCLA score, diagnosis, age, sex, and BMI, the BHR patients demonstrated significant improvements in the postoperative UCLA score compared with those undergoing total hip arthroplasty. More importantly, when assessing the highly active subset of patients with preoperative UCLA scores of 9 to 10 (participation in impact sports), the BHR patients demonstrated both statistically significant and clinically important advantages compared with total hip arthroplasty according to the MCID for the UCLA established by SooHoo et al. (0.92)[23]. Despite similar preoperative activity levels, this subset of BHR patients was 41% more likely to participate in impact sports postoperatively. These results may suggest that, even when matched by preoperative activity level and relevant demographic factors, BHR patients attain greater levels of activity after surgery. Such findings may support an indication for the use of BHR in highly active patients who wish to remain active after hip arthroplasty. These results corroborate the findings of previous studies describing advantages for surface replacement arthroplasty with respect to postoperative activity and return to sport[6,29].

It is important to note, however, that patients most often self-select for BHR procedures. Observed differences in the postoperative UCLA score, therefore, may be due to a higher degree of patient motivation resulting from this selection bias. Furthermore, surgeon-imposed limitations may contribute to these differences. While we routinely allow unrestricted activity in BHR patients at 6 months postoperatively, many arthroplasty surgeons recommend against high-impact sports following total hip arthroplasty[30]. A consensus survey of arthroplasty surgeons, for example, recommended against participation in racquetball/squash, jogging, contact sports, baseball/softball, and high-impact aerobics following total hip arthroplasty[31].

We report 14 revisions. Two cases underwent revision at an outside hospital for continued idiopathic pain. Neither of these patients had evidence of bone-on-bone osteoarthritis on preoperative radiographs, which may be a risk factor for dissatisfaction following hip arthroplasty[32]. One of the 2 patients demonstrated no improvement following conversion to total hip arthroplasty and had the lowest UCLA and mHHS values among all revision BHR patients in our cohort. The other patient with unexplained pain who underwent revision at an outside institution has since been lost to follow-up.

Eight (73%) of the 11 aseptic revisions had smaller components, with a femoral head size of <50 mm. This mirrors other reports of increased complication and failure rates among patients with a component head size of <50 mm[17,33]. Of the 3 aseptic revisions with larger head sizes, 1 patient had a cyst that was grafted intraoperatively and subsequently experienced femoral component loosening requiring revision at 5.7 years (Fig. 5). Two of 5 cases with grafting of cysts (1 osteonecrotic, 1 arthritic cyst) went on to femoral failure. Another patient with persistent pain postoperatively (head size of 54 mm) was revised at 6 weeks. Although radiographs did not demonstrate clear technical issues,

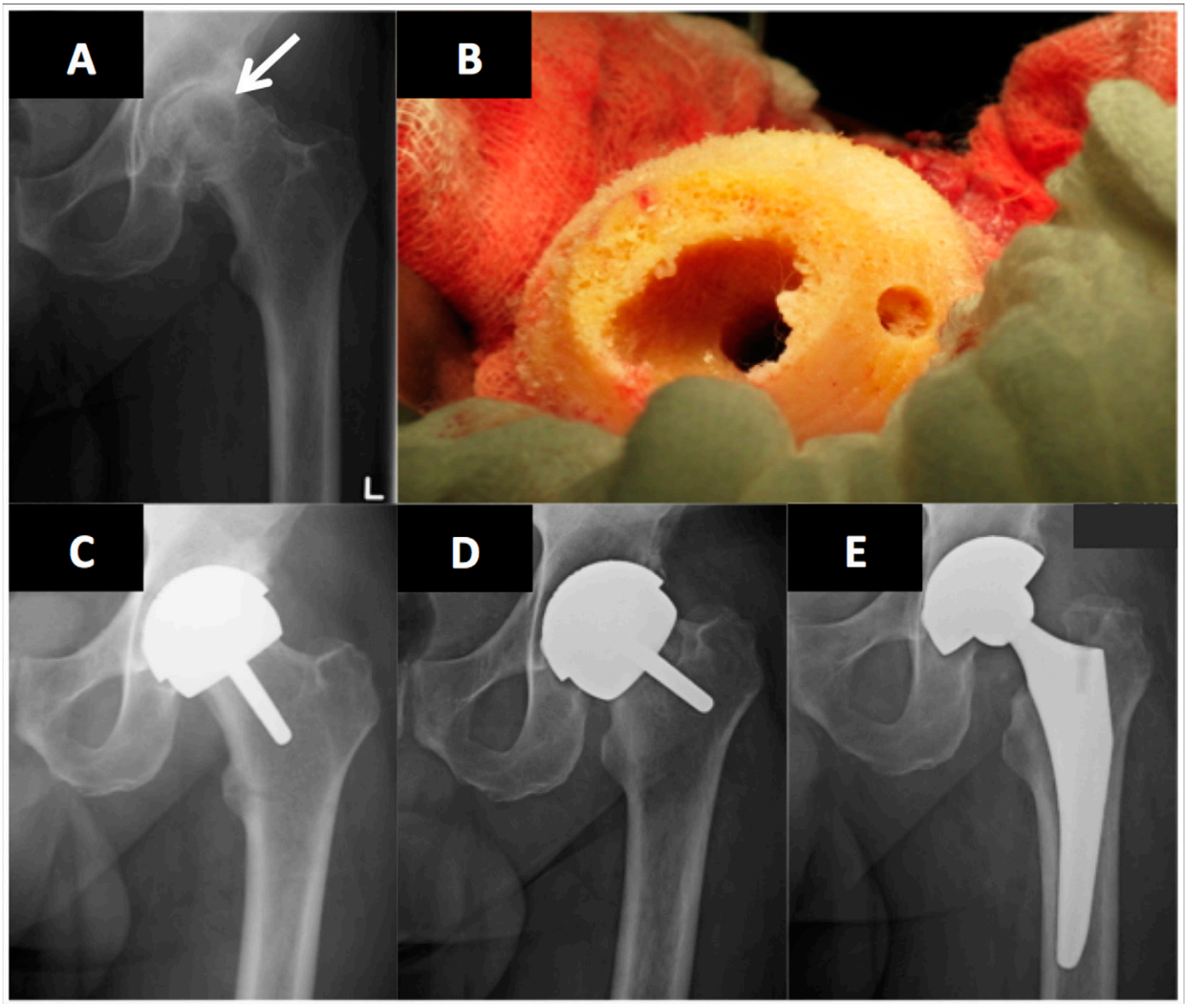

Fig. 5

Figs. 5-A through 5-E A patient with a cyst grafted intraoperatively who underwent revision for femoral component loosening at 5.7 years following the BHR procedure. **Fig. 5-A** Preoperative anteroposterior radiograph demonstrating cystic change in the femoral head. **Fig. 5-B** Intraoperative image demonstrating a large cyst of the femoral head. **Fig. 5-C** Postoperative anteroposterior radiograph demonstrating a well-aligned, well-fixed BHR implant. **Fig. 5-D** The patient did well for 5.7 years, then experienced the onset of groin pain, with postoperative anteroposterior radiographs demonstrating femoral component loosening prior to conversion to total hip arthroplasty. **Fig. 5-E** Postoperative anteroposterior radiograph demonstrating well-aligned, well-fixed revision total hip arthroplasty components. Revision was straightforward, with the BHR shell retained and the cementless stem combined with a dual mobility articulation.

incomplete seating/impaction of the implant may have contributed to the early revision.

This study had many limitations. First, it was performed retrospectively and involved multiple surgeons. While the ideal study would randomize surgical candidates to BHR or total hip arthroplasty to allow for comparison, Haddad et al. demonstrated difficulty enrolling study patients in a prospective randomized trial comparing BHR and total hip arthroplasty due to many patients specifically seeking out surface replacement arthroplasty[6].

In conclusion, the current study demonstrated excellent survivorship and clinical outcomes at 5 to 10-year follow-up for BHR procedures performed at a single center in the U.S. In patients representing the current BHR inclusion criteria at this center, implant survival was extremely high, with nearly all patients attaining their goal of remaining extremely active, significantly more often than a matched cohort of standard total hip arthroplasty patients. These results are at intermediate term, however (5 to 10 years), and further follow-up is necessary to ensure the safety and efficacy in this young, active

patient population. In addition, with the numerous reports of complications of MoM surface replacement and the overall higher revision rate of surface replacement arthroplasty versus total hip arthroplasty in registry reports[3], careful patient selection must be emphasized. Finally, because complication rates with surface replacement arthroplasty are nearly 4 times lower among high-volume hip specialists compared with lower-volume surgeons[10], results of the current study may not be generalizable to lower-volume surgeons. ■

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