Title

Lower Rates of Ceramic Femoral Head Use in Non-White Patients in the United States, a National Registry Study

Journal

The Journal of Arthroplasty, 37(8)

ISSN

0883-5403

Authors

Upfill-Brown, Alexander M
Paisner, Noah D
Donnelly, Patrick C
et al.

Publication Date

2022-08-01

DOI

10.1016/j.arth.2022.03.050

Peer reviewed

HHS Public Access
Author manuscript
J Arthroplasty. Author manuscript; available in PMC 2022 August 18.

Published in final edited form as:
J Arthroplasty. 2022 August ; 37(8 Suppl): S919–S924.e2. doi:10.1016/j.arth.2022.03.050.

Lower Rates of Ceramic Femoral Head Use in Non-White Patients in the United States, a National Registry Study

Alexander M. Upfill-Brown, MD, MSc[a], **Noah D. Paisner, BS**[b], **Patrick C. Donnelly, MS**[c], **Ayushmita De, PhD**[c], **Adam A. Sassoon, MD, MS**[a,*]

[a]Department of Orthopaedic Surgery, David Geffen School of Medicine at UCLA, Los Angeles, CA

[b]Pacific Northwest University School of Health Sciences, Yakima, WA

[c]American Joint Replacement Registry, American Academy of Orthopaedic Surgery, Rosemont, IL

Abstract

Background: The purpose of our study was to investigate the association of race and ethnicity with the use of the newest technology and postoperative outcomes in total hip arthroplasty (THA) using the American Academy of Orthopaedic Surgeons (AAOS) American Joint Replacement Registry (AJRR).

Methods: Adult THA procedures were queried from the AJRR from 2012 to 2020. A mixed-effects multivariate regression model was used to evaluate the association of race and ethnicity with the use of the newest technology (ceramic femoral head, dual-mobility implant, and robotic assist) at 30-day, and 90-day readmission. A proportional subdistribution hazard model was used to model a risk of revision THA.

Results: There were 85,188 THAs with complete data for an analysis of outcomes and 103,218 for an analysis of ceramic head usage. The median length of follow-up was 37.9 months (interquartile range [IQR] 21.6 to 56.3 months). In multivariate models, compared to White non-Hispanic patients, Black (odds ratio [OR] 0.79, 95% confidence interval [CI] 0.69–0.92, $P < .001$), Hispanic (OR 0.76, CI 0.59–0.99, $P = .037$), Asian (OR 0.74, CI 0.55–1.00, $P = .045$), and Native American (OR 0.52, CI 0.30–0.87, $P = .004$) patients all had significantly lower rates of ceramic head use in THA. Compared to White non-Hispanic patients, Asian (hazard ratio [HR] 0.39, CI 0.18–0.86, $P = .008$) and Hispanic (HR 0.43, CI 0.19–0.98, $P = .043$) patients had significantly lower rates of revision. No differences in 30-day or 90-day readmission rates were seen.

*Address correspondence to: Adam A. Sassoon, MD, MS, Department of Orthopaedic Surgery, David Geffen School of Medicine at UCLA, 1250 16th, Street, Suite 2100, Santa Monica, CA 90404.

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.2022.03.050.

Conflicts of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Conclusion: Black, Hispanic, Native American, and Asian patients had lower rates of ceramic head use in THA when compared to White patients. These differences did not translate into worse clinical outcomes on a short-term follow-up. In fact, Asian patients had lower revision rates compared to non-Hispanic White patients. Additional study is necessary to evaluate the long-term consequence of lower ceramic head use in non-White patients in the United States.

Keywords

total hip arthroplasty; ceramic femoral head; racial disparities; joint replacement registry; surgical outcomes; resource utilization

Research on racial and ethnic inequities in total joint arthroplasty (TJA) so far has been consistent with broader trends well-described in other domains of social determinants of health in the United States (US) [1–3]. The experience of non-White patients (especially Black and Hispanic) undergoing TJA is substantially different to their White counterparts. Non-White patients have more severe arthritis and deceased function at the time of surgery [4–7], decreased utilization of TJA [8,9], increased perioperative mortality and complications [10,11], longer hospital stays [12–14], higher rates of nonhome discharge [12,13,14], and higher rates of revision TJA [12–14]. The drivers of these disparities are complex and multifactorial and include access to care and health insurance, quality of care, poverty, lower education and medical literacy, decreased trust in the healthcare system, and racism and discrimination [15–17]. Research to date on disparities in quality of care have examined referral patterns and decreased access to high volume surgeons as potential drivers of poorer outcomes [18–20]. Access to the newest surgical and implant technology with potential clinical benefits such as ceramic implants, robotic-assisted (RA) surgery, and dual mobility implants have not been analyzed as potential contributors to decreased perioperative outcomes.

Over the past few decades, multiple advances have been made to total hip arthroplasty (THA) to improve implant function and survival. Ceramic components in THA have become increasingly popular due to their favorable mechanical and tribological properties compared to metal-on-polyethylene or metal-on-metal components [21,22]. Ceramic femoral head use is associated with significantly longer implant survival in a single institution and large registry studies [23–25]. While the use of these components is increasing in parts of the world, cost remains a limiting factor [21,23]. RA technology for hip arthroplasty has grown significantly in the last several decades, with 17% of THA performed in 2015 using robotics [26]. While data supports its use for improving implant positioning and alignment, its effect on clinical outcomes remains unclear [27]. Finally, dual mobility components initially used in revision and fracture settings to decrease instability and dislocation are increasingly used in primary THA with good outcomes [28,29]. The utilization of some of the newest technologies, that is, “cutting-edge” features, such as ceramic components and RA-THA, have been shown to be higher in patients with private insurance compared to Medicare or Medicaid, likely a result of higher associated costs [26,30].

As none of these components are universally used, we hypothesized that racial disparities in access will manifest in the decreased use of cutting-edge surgical features in non-White patients. Furthermore, we hypothesized that disparities in the use of cutting-edge surgical features would contribute to disparities in THA outcomes. Herein, we undertake an analysis of THA patients from the American Joint Replacement Registry (AJRR) examining racial disparities in the use of "cutting-edge" surgical features, readmissions, and revision THA.

Methods

Primary THA procedures from 2012 to 2020 were queried from the AJRR maintained by the American Academy of Orthopaedic Surgeons (AAOS). Patients aged 18 years or older at the time of primary THA were included in the study. Those who had missing values for race and ethnicity, THA head type, liner type, and age were excluded from the study. For a readmission and revision analysis, patients with missing outcome information were excluded from the analysis. Variables collected included age, race, ethnicity, gender, Charlson Comorbidity Index (CCI), hospital of operation, and elective versus nonelective operation. Outcome variables included implant femoral head type (ceramic versus metal), use of RA surgery, use of dual mobility implants, all cause revision at 30 days, all cause revision at 90 days, and any revision THA over the course of the study.

The following racial-ethnic categories collected by the AJRR were analyzed: Whites, African Americans, Hispanic-White, Hispanic-Other, Native American, and Asian. The Hispanic categories were created using the race and ethnicity variables in AJRR. Those who identified as Hispanic ethnicity and White race were categorized as Hispanic-White. Those who identified as Hispanic ethnicity and non-White race or had missing values for race were categorized as Hispanic-Other. Patients identifying as non-Hispanic ethnicity and Native Hawaiian or other Pacific Islander were excluded due to the small number of patients. Patient identifying non-Hispanic ethnicity and two or more racial categories were excluded, given the limitation regarding interpretability. Similarly, patients who had missing values for ethnicity and race or age were excluded from the study.

Multilevel multivariate logistic regression was used to examine the association of race and ethnicity with the use of different cutting-edge features (ceramic head use, robotic surgery, and dual mobility use). Age was included as a covariate in the model due to significant differences found between racial groups. The hospital site was treated as a random intercept, to account for the correlation of patients clustered within each hospital. When the global statistical test for the inclusion of race/ethnicity in multivariate models was found to be significantly associated with the cutting-edge feature use, pairwise group differences were tested using the Tukey-Kramer method to adjust for multiple comparisons [31,32]. The global statistical test is a likelihood ratio test of regression models with and without a given categorical variable; this additional step is used to minimize the type 1 error when performing multiple pairwise comparisons [33]. The analysis was conducted using the Laplace approximation method [34].

Similarly, multivariate multilevel logistic regression models were used to evaluate the association of patient race with all-cause 30-day readmission and 90-day readmission. The hospital was specified as a random effect to account for clustering of patients within the same centers. A revision risk was evaluated with a proportional subdistribution hazards model, with death treated as a competing risk for revision events. In the revision model, the robust sandwich covariance estimate was used to account for clustering within the hospital. All models controlled for age, CCI, elective versus nonelective procedures, and ceramic head use. When the global statistical test of race was statistically significant, pairwise comparisons were tested and adjusted for multiple comparisons using a simulation-based approach. For the readmission models, the ceramic head variable caused a large-scale gradient that resulted in a missing standard error for the head type variable. Therefore, separate models were run stratified by whether a ceramic or metal femoral head was used. All analyses were performed in SAS, version 9.4.

Results

A total of 785,559 patients were identified in the AJRR undergoing THA during our study period. There were varying numbers of patients with incomplete data across different outcomes of interest. A total of 10,378 patients were excluded as they identified as 2 or more racial groups (n = 9,701) or Native Hawaiian or other Pacific Islander (n = 677) ("Other", Table 1). Of the total identified, 102,121 patients were included in the ceramic head analysis, 239,997 in the RA analysis, 602, 602,211 in the dual mobility analysis, and 85,188 in the analysis of readmission and revision surgery.

The mean patient age was 68.1 years for all patients (Table 1). White patients were significantly older and had higher levels of medical comorbidity compared to Black and Hispanic patients ($P < .001$ for both, Table 1). On an unadjusted analysis, race and ethnicity was significantly associated with the use of all cutting-edge features and outcomes of interest (Table 1). White patients had lower rates of ceramic head use (43.9%) compared to Black patients (53.8%) but higher rates compared to Asian (39.7%) and Native American (35.8%) patients ($P < .001$). With regard to dual mobility, White patients (7.2%) had higher utilization than Black patients (6.6%) but lower rates than both groups of Hispanic patients (9.4 and 8.4%, $P < .001$). Univariate results regarding readmission and revision were mixed as well (Table 1). The proportion of patients missing cutting-edge feature data varied significantly by the racial-ethnic group for dual mobility and RA surgery but not ceramic head use (Table 1). The proportion of patients missing revision follow-up data also varied significantly by racial group (Table 1).

A summary of patient characteristics for those receiving ceramic femoral heads is presented in Table 2. Overall, ceramic heads were used in 44.4% of patients. The mean age of patients receiving ceramic heads was significantly lower (64.7 years) compared to those receiving nonceramic heads (74.5 years, $P < .0001$, Table 2). Ceramic head patients also had a lower average CCI and a higher rate of elective THA compared to nonceramic head patients ($P < .0001$ for all comparisons).

Ceramic Femoral Head Use and Other Cutting-Edge Surgical Features

Younger patients were significantly more likely to receive ceramic heads, with the odds increasing 1.12 times ($P < .0001$) for each year decrease in patient age (Table S3). The global test of race/ethnicity in the multivariate model indicated that it was significantly ($P < .0001$) associated with ceramic head use and therefore pairwise testing was performed to determine which specific groups were significantly different in their likelihood of receiving ceramic heads (Table 2). Compared to White patients, both Black (odds ratio [OR] 0.79, $P < .001$) and Hispanic-White patients (OR 0.76, $P = .037$) had significantly lower rates of ceramic head use in THA. Asian (OR 0.74, $P = .045$), Native American (OR 0.52, $P = .0041$), and Other-Hispanic racial groups (OR 0.65, $P = .0016$) were also less likely to undergo THA with a ceramic head compared to White patients. The pairwise differences between Asians, Hispanic-Whites, Hispanic-Other, and Native-Americans were not statistically significant (Table 2).

For the use of robotic surgery, the global test of race and ethnicity in the multivariate model (Table S4) indicated that it was significantly ($P = .0075$) associated with RA use. Therefore, pairwise testing was performed; however, no specific groups were significantly different in their likelihood of receiving robotic surgery (Table S1). Regarding dual mobility implants, the global test of race and ethnicity in the multivariate model (Table S5) indicated that it was significantly ($P = .037$) associated with their use; however, no specific groups were significantly different in their likelihood of receiving dual mobility implants (Table S3).

Analysis of Readmission and Revision Total Hip Arthroplasty

There were 85,188 THAs with complete data for readmission and revision analysis. The median follow-up was 37.9 months, with an interquartile range (IQR) of 21.6 to 56.3 months. Race and ethnicity were not statistically significant predictors of 30-day readmission in both the ceramic and metal head subgroups ($P = .07$ and .58, respectively). Race and ethnicity were also not significant predictors of 90-day readmission in both subgroups (ceramic $P = .81$ and metal $P = .83$). Race and ethnicity were statistically significant predictors of a revision risk ($P = .0002$) in the full hazard model (Table S6). On pairwise testing, Asian patients had a lower risk of revision than White patients (hazard ratio [HR] 0.39, $P = .0075$), and patients identified as Hispanic-Other had a lower risk of revision than White patients (HR 0.43, $P = .043$, Table 4).

Discussion

Racial disparities following THA are persistent and multifactorial. One unexplored component is disparity in access to new technologies with potential clinical benefits. Previous research has focused on disparities in access to high-volume centers as one aspect of quality, with one potential consequence being differential access to the newest surgical technologies. Here, we examined disparities in cutting-edge surgical features as another contributing, if related, factor affecting quality. Most significantly, we find that Black, Hispanic, Native American, and Asian patients had lower rates of ceramic femoral head use when compared to White patients when controlling for patient age, medical comorbidity, and hospital where the procedure was performed. There were no significant pairwise differences between racial groups with regard to dual mobility implant use and RA surgery on a regression analysis. When femoral head type was controlled for, we found no differences between racial groups regarding 30-day and 90-day readmission or a risk of revision THA.

Our finding of racial disparities in ceramic femoral head use is somewhat surprising, given their popularity in primary THA [21,22]. As per the AJRR annual report, ceramic femoral head use in primary THA has increased 38% in 2012 to 71% in 2020 [22]. It is well known that ceramic heads are durable components with 20-year follow-up data demonstrating lower rates of polyethylene wear and osteolysis and less taper corrosion when compared to metal heads [35–37]. Fracture of the ceramic is a concern, but design changes have reduced the fracture rate [38]. While the advantages of ceramic femoral heads are well known to fellowship-trained arthroplasty surgeons, it is possible that general orthopedic surgeons performing fewer THA operations may be less familiar with this technology. However, there are no studies examining the rates of femoral head usage by the surgeon-training type to support or refute this hypothesis; however, a survey of arthroplasty thought leaders have shown high rates of ceramic head use [21]. This is consistent with prior research demonstrating racial disparities in access to high-volume arthroplasty centers [19,20].

Another limiting factor for more widespread ceramic head use may be cost, which Nandi et al found as the most common reason for arthroplasty surgeons to not use ceramic heads [21]. The racial difference in ceramic head utilization may be driven at least in part by differences in insurance status. It has been shown that Black, Hispanic, and Native American individuals are more likely to be uninsured or underinsured, which may drive the use of cheaper implants in these patients [39,40]. However, Asian Americans have essentially equal rates of insurance coverage compared to White patients, so insurance status alone does not entirely explain these differences [41]. The etiology of femoral head choice is likely multifactorial and is informed by a host of the hospital, surgeon, and patient factors. Further study is necessary to fully understand drivers of this disparity.

Although our study did not uncover race-based and ethnicity-based disparities in clinical outcomes after controlling for ceramic femoral head use, our median length of follow-up of 38 months is relatively short. Ceramic femoral heads reduce long-term rates of polyethylene wear and taper corrosion compared to metal counterparts and so the effect of disparities in their use will likely take years to become observable [42–44]. A recent registry study of the United Kingdom found significantly lower revision rates at two years for ceramic-on-polyethylene bearings compared to metal-on-polyethylene bearings [25].

Unlike our findings here, prior literature has uncovered important and statistically significant racial disparities in readmission and revision surgery [9,10,12–14]. Ezomo et al found that when compared to White patients, Black and Hispanic patients were more likely to develop surgical complications following THA and that Native American patients were more likely to undergo reoperation [11]. Interestingly, Okike et al found a similar rate of readmission and reoperations following THA in a universally insured population in the western United States [45]. Disparities in access and utilization of primary arthroplasty have been well documented [19,46]. If similar patterns existed for revision arthroplasty, reduced access may result in erroneously similar estimated revision rates between groups due in part to limited follow-up and later intervention, if any in some cases. Ramirez et al examined the travel burden associated with centralized revision arthroplasty centers and did not find a significant disparity along racial and ethnic lines [47]. However, parity in travel distance does not necessarily imply equality in utilization. Further research is needed to examine disparities in revision arthroplasty utilization.

Finally, given prior research showing non-White patients tend to present for arthroplasty later in disease progression, with more severe arthritis, we were surprised that in our study population Black patients were younger (62.3 vs 68.6) and had lower medical comorbidity (CCI of 2.45 vs 2.92) compared to White non-Hispanic patients. In administrative database and retrospective institutional studies, non-White patients have been found to have higher rates of baseline comorbidity at the time of primary and revision arthroplasty [9,45,48,49]. It is unclear why comorbidity levels were lower in non-White patients in our study, although this likely reflects a difference in the underlying population captured by the AJRR. Indeed, AJRR THA patients are younger and slightly more likely to identify as White compared to THA patients identified in the National Inpatient Sample database, the largest nationally representative administrative database [50]. Multiple studies have found the average age of non-White patients undergoing primary arthroplasty to be lower than White patients, as we find here [9,11,45].

The present study is not without its limitations. We recognize the inherent weakness in a large retrospective registry study including the potential for errors in coding and data entry. Furthermore, the AJRR does not collect information on income, education level, or insurance status all of which may be associated with race and/or ethnicity and are additional mechanisms of disparity. In addition, information on patient's local environment, such as distance to healthcare providers and overall neighborhood socioeconomic status, is also not available. These neighborhood effects have been well-studied in the health disparities literature and are associated with an overall level of medical comorbidity and mortality, obesity, access to green space, and levels of physical activity as well has THA outcomes [51–54]. Furthermore, one of the categories was Hispanic-Other, which refers to those of Hispanic ethnicity, but either were not identified as Hispanic-White or just had missing values for the race variable. In addition, certain outcomes have a high-level of missingness in the AJRR. Specifically, the missingness varied significantly by the racial group in RA surgery, dual mobility implants, and revision THA. Interpretation of results related to these outcomes must therefore be limited. Although this exclusion of these patients likely reflects the representativeness of this study, this is a limitation of registry studies that rely on self-reporting of statistics from a vast number of different institutions. Overall, the representativeness of the AJRR has shown to correlate well with nationally representative administrative databases [50]. Finally, while we have identified some THA features as cutting-edge, we acknowledge that there are no published guidelines recommending their use. Rather, we have identified them as newer technologies with potential clinical benefits reflecting differential surgeon access. Further study, including cost-benefit analyses, are necessary before such guidelines are issued.

Conclusion

Our findings indicate that compared to White patients, Black, Hispanic, Native American, and Asian patients have lower rates of ceramic femoral head placement in THA. These differences exist despite the growing popularity of ceramic femoral head use in modern arthroplasty and may contribute to a growing divide in THA outcomes between these groups. Interestingly, when controlling for femoral head type, we found no differences in revision THA in a short-term follow-up, although a longer-term follow-up is necessary to address this question. The disparity in ceramic femoral head use may be driven by differential access to fellowship-trained arthroplasty surgeons or lower reimbursement driving the selection of cheaper implants by hospitals and health systems. Further research is necessary to uncover the etiology of this disparity to address these causes and reduce the impact of femoral head use on long-term outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

[1]. Best MJ, McFarland EG, Thakkar SC, Srikumaran U. Racial disparities in the use of surgical procedures in the US. JAMA Surg 2021;156:274–81. 10.1001/jamasurg.2020.6257. [PubMed: 33439237]

[2]. O'Campo P, Burke JG, Culhane J, Elo IT, Eyster J, Holzman C, et al. Neighborhood deprivation and preterm birth among non-Hispanic Black and white women in eight geographic areas in the United States. Am J Epidemiol 2008;167:155–63. 10.1093/aje/kwm277. [PubMed: 17989062]

[3]. Subramanian SV, Chen JT, Rehkopf DH, Waterman PD, Krieger N. Racial disparities in context: a multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. Am J Public Health 2005;95:260–5. 10.2105/AJPH.2003.034132. [PubMed: 15671462]

[4]. Neuburger J, Hutchings A, Allwood D, Black N, Van Der Meulen JH. Socio-demographic differences in the severity and duration of disease amongst patients undergoing hip or knee replacement surgery. J Public Health (Oxf) 2012;34:421–9. 10.1093/pubmed/fdr119. [PubMed: 22267293]

[5]. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of knee symptoms and radiographic and symptomatic knee osteoarthritis in African Americans and Caucasians: the Johnston county osteoarthritis project. J Rheumatol 2007;34:172–80. [PubMed: 17216685]

[6]. Jordan JM, Helmick CG, Renner JB, Luta G, Dragomir AD, Woodard J, et al. Prevalence of hip symptoms and radiographic and symptomatic hip osteoarthritis in African Americans and Caucasians: the Johnston County osteoarthritis project. J Rheumatol 2009;36:809–15. 10.3899/jrheum.080677. [PubMed: 19286855]

[7]. Lavernia CJ, Alcerro JC, Contreras JS, Rossi MD. Ethnic and racial factors influencing well-being, perceived pain, and physical function after primary total joint arthroplasty. Clin Orthop Relat Res 2011;469:1838–45. 10.1007/s11999-011-1841-y. [PubMed: 21409460]

[8]. Amen TB, Varady NH, Rajaee S, Chen AF. Persistent racial disparities in utilization rates and perioperative metrics in total joint arthroplasty in the U.S. J Bone Joint Surg Am 2020;102:811–20. 10.2106/jbjs.19.01194. [PubMed: 32379122]

[9]. Singh JA, Lu X, Rosenthal GE, Ibrahim S, Cram P. Racial disparities in knee and hip total joint arthroplasty: an 18-year analysis of national medicare data. Ann Rheum Dis 2014;73:2107–15. 10.1136/annrheumdis-2013-203494. [PubMed: 24047869]

[10]. Johnson MA, Sloan M, Lopez VS, Andah G, Sheth N, Nelson C. Racial disparities in perioperative complications following primary total hip arthroplasty. J Orthop 2020;21:155–60. 10.1016/j.jor.2020.03.037. [PubMed: 32255997]

[11]. Ezomo OT, Sun D, Gronbeck C, Harrington MA, Halawi MJ. Where do we stand today on racial and ethnic health disparities? An analysis of primary total hip arthroplasty from a 2011–

2017 national database. Arthroplast Today 2020;6: 872–6. 10.1016/j.artd.2020.10.002. [PubMed: 33163602]

[12]. Bass AR, McHugh K, Fields K, Goto R, Parks ML, Goodman SM. Higher total knee arthroplasty revision rates among United States blacks than whites a systematic literature review and meta-analysis. J Bone Joint Surg Am 2016;98: 2103–8. 10.2106/JBJS.15.00976. [PubMed: 28002374]

[13]. Groeneveld PW, Kwoh CK, Mor MK, Appelt CJ, Geng M, Gutierrez JC, et al. Racial differences in expectations of joint replacement surgery outcomes. Arthritis Care Res 2008;59:730–7. 10.1002/art.23565.

[14]. Allen Butler R, Rosenzweig S, Myers L, Barrack RL. The frank stinchfield award: the impact of socioeconomic factors on outcome after THA: a prospective, randomized study. Clin Orthop Relat Res 2011;469:339–47. 10.1007/s11999-010-1519-x. [PubMed: 20717856]

[15]. Hanchate AD, Zhang Y, Felson DT, Ash AS. Exploring the determinants of racial and ethnic disparities in total knee arthroplasty: health insurance, income, and assets. Med Care 2008;46:481–8. 10.1097/MLR.0b013e3181621e9c. [PubMed: 18438196]

[16]. Allen KD, Golightly YM, Callahan LF, Helmick CG, Ibrahim SA, Kwoh CK, et al. Race and sex differences in willingness to undergo total joint replacement: the Johnston County Osteoarthritis Project. Arthritis Care Res 2014;66: 1193–202. 10.1002/acr.22295.

[17]. Mays VM, Cochran SD, Barnes NW. Race, race-based discrimination, and health outcomes among African Americans. Annu Rev Psychol 2007;58: 201–25. 10.1146/annurev.psych.57.102904.190212. [PubMed: 16953796]

[18]. Ghomrawi HMK, Funk RJ, Parks ML, Owen-Smith J, Hollingsworth JM. Physician referral patterns and racial disparities in total hip replacement: a network analysis approach. PLoS One 2018;13:1–10. 10.1371/journal.pone.0193014.

[19]. SooHoo NF, Farng E, Zingmond DS. Disparities in the utilization of high-volume hospitals for total hip replacement. J Natl Med Assoc 2011;103: 31–5. 10.1016/S0027-9684(15)30240-6. [PubMed: 21329244]

[20]. Dy CJ, Marx RG, Ghomrawi HMK, Pan TJ, Westrich GH, Lyman S. The potential influence of regionalization strategies on delivery of care for elective total joint arthroplasty. J Arthroplasty 2015;30:1–6. 10.1016/j.arth.2014.08.017.

[21]. Nandi S, Austin MS. Choosing a femoral head: a survey study of academic adult reconstructive surgeons. J Arthroplasty 2017;32:1530–4. 10.1016/j.arth.2016.12.009. [PubMed: 28065626]

[22]. American Joint Replacement Registry (AJRR). The Eighth Annual Report of the AJRR on Hip and Knee Arthroplasty American Academy of Orthopaedic Surgeons Registry Program; 2021.

[23]. Kurtz SM, Lau EC, Baykal D, Odum SM, Springer BD, Fehring TK. Are ceramic bearings becoming cost-effective for all patients? J Arthroplasty 2018;33: 1352–8. 10.1016/j.arth.2017.12.011. [PubMed: 29336858]

[24]. Swarup I, Lee YY, Chiu YF, Sutherland R, Shields M, Figgie MP. Implant survival and patient-reported outcomes after total hip arthroplasty in young patients. J Arthroplasty 2018;33:2893–8. 10.1016/j.arth.2018.04.016. [PubMed: 29754980]

[25]. Holleyman RJ, Critchley RJ, Mason JM, Jameson SS, Reed MR, Malviya A. Ceramic bearings are associated with a significantly reduced revision rate in primary hip arthroplasty: an analysis from the national joint registry for England, Wales, Northern Ireland, and the Isle of Man. J Arthroplasty 2021;36: 3498–506. 10.1016/j.arth.2021.05.027. [PubMed: 34238620]

[26]. Boylan M, Suchman K, Vigdorchik J, Slover J, Bosco J. Technology-assisted hip and knee arthroplasties: an analysis of utilization trends. J Arthroplasty 2018;33:1019–23. 10.1016/j.arth.2017.11.033. [PubMed: 29290333]

[27]. Jacofsky DJ, Allen M. Robotics in arthroplasty: a comprehensive review. J Arthroplasty 2016;31:2353–63. 10.1016/j.arth.2016.05.026. [PubMed: 27325369]

[28]. Fessy MH, Jacquot L, Rollier JC, Chouteau J, Ait-Si-Selmi T, Bothorel H, et al. Midterm clinical and radiographic outcomes of a contemporary monoblock dual-mobility cup in uncemented total hip arthroplasty. J Arthroplasty 2019;34:2983–91. 10.1016/j.arth.2019.07.026. [PubMed: 31444020]

[29]. Jobory A, Karrholm J, Overgaard S, Pedersen AB, Hallan G, Gjertsen J-E, et al. Reduced revision risk for dual-mobility cup in total hip replacement due to hip fracture. J Bone Joint Surg Am 2019;101:1278–85. [PubMed: 31318807]

[30]. Heckmann ND, Sivasundaram L, Stefl MD, Kang HP, Basler ET, Lieberman JR. Total hip arthroplasty bearing surface trends in the United States from 2007 to 2014: the rise of ceramic on polyethylene. J Arthroplasty 2018;33: 1757–1763.e1. 10.1016/j.arth.2017.12.040. [PubMed: 29429883]

[31]. Tukey JW. The philosophy of multiple comparisons. Stat Sci 1991;6:100–16. 10.1214/ss/1177011945.

[32]. Kramer CY. Extension of multiple range tests to group means with unequal numbers of replications. Biometrics 1956;12:307. 10.2307/3001469.

[33]. Vittinghoff E, Glidden DV, Shiboski SC, McCulloch CE. Survival Analysis. Regres. Methods Biostat. Linear, Logist. Surviv. Repeated Meas. Model Boston, MA: Springer US; 2012. p. 203–59. 10.1007/978-1-4614-1353-0_6.

[34]. Raudenbush SW, Yang M-L, Yosef M. Maximum likelihood for generalized linear models with nested random effects via high-order, multivariate Laplace approximation. J Comput Graph Stat 2000;9:141–57. 10.1080/10618600.2000.10474870.

[35]. Beckmann NA, Gotterbarm T, Innmann MM, Merle C, Bruckner T, Kretzer JP, et al. Long-term durability of alumina ceramic heads in THA. BMC Musculoskelet Disord 2015;16:249. 10.1186/s12891-015-0703-2. [PubMed: 26363981]

[36]. Kim Y-H, Park J-W, Patel C, Kim D-Y. Polyethylene wear and osteolysis after cementless total hip arthroplasty with alumina-on-highly cross-linked polyethylene bearings in patients younger than thirty years of age. J Bone Joint Surg Am 2013;95:1088–93. 10.2106/JBJS.L.01211. [PubMed: 23783205]

[37]. Kurtz SM, Kocagöz SB, Hanzlik JA, Underwood RJ, Gilbert JL, MacDonald DW, et al. Do ceramic femoral heads reduce taper fretting corrosion in hip arthroplasty? A retrieval study. Clin Orthop Relat Res 2013;471:3270–82. 10.1007/s11999-013-3096-2. [PubMed: 23761174]

[38]. Massin P, Lopes R, Masson B, Mainard D. Does Biolox® Delta ceramic reduce the rate of component fractures in total hip replacement? Orthop Traumatol Surg Res 2014;100:S317–21. 10.1016/j.otsr.2014.05.010. [PubMed: 25130763]

[39]. Buchmueller TC, Levinson ZM, Levy HG, Wolfe BL. Effect of the affordable care act on racial and ethnic disparities in health insurance coverage. Am J Public Health 2016;106:1416–21. 10.2105/AJPH.2016.303155. [PubMed: 27196653]

[40]. Andrews CM, Guerrero EG, Wooten NR, Lengnick-Hall R. The Medicaid expansion gap and racial and ethnic minorities with substance use disorders. Am J Public Health 2015;105:S452–4. 10.2105/AJPH.2015.302560. [PubMed: 25905851]

[41]. Park JJ, Humble S, Sommers BD, Colditz GA, Epstein AM, Koh HK. Health insurance for Asian Americans, Native Hawaiians, and Pacific Islanders under the affordable care act. JAMA Intern Med 2018;178:1128. 10.1001/jamainternmed.2018.1476. [PubMed: 29710340]

[42]. Dahl J, Snorrason F, Nordsletten L, Rohrl SM. More than 50% reduction of wear in polyethylene liners with alumina heads compared to cobalt-chrome heads in hip replacements. Acta Orthop 2013;84:360–4. 10.3109/17453674.2013.810516. [PubMed: 23795579]

[43]. Cafri G, Paxton EW, Love R, Bini SA, Kurtz SM. Is there a difference in revision risk between metal and ceramic heads on highly crosslinked polyethylene liners? Clin Orthop Relat Res 2017;475:1349–55. 10.1007/s11999-016-4966-1. [PubMed: 27385222]

[44]. Semlitsch M, Lehmann M, Weber H, Doerre E, Willert HG. New prospects for a prolonged functional life-span of artificial hip joints by using the material combination polyethylene/aluminium oxide ceramic/metal. J Biomed Mater Res 1977;11:537–52. 10.1002/jbm.820110409. [PubMed: 559675]

[45]. Okike K, Chan PH, Prentice HA, Navarro RA, Hinman AD, Paxton EW. Association of race and ethnicity with total hip arthroplasty outcomes in a universally insured population. J Bone Joint Surg Am 2019;101:1160–7. 10.2106/JBJS.18.01316. [PubMed: 31274717]

[46]. Hartnett DA, Brodeur PG, Kosinski LR, Cruz AI, Gil JA, Cohen EM. Socioeconomic disparities in the utilization of total hip arthroplasty. J Arthroplasty 2022;37:213–218.e1. 10.1016/j.arth.2021.10.021. [PubMed: 34748913]

[47]. Ramirez G, Myers TG, Thirukumaran CP, Ricciardi BF. Does hypothetical centralization of revision THA and TKA exacerbate existing geographic or demographic disparities in access to care by increased patient travel distances or times? A large-database study. Clin Orthop Relat Res 2021. 10.1097/CORR.0000000000002072.

[48]. Wu M, Belay E, Cochrane N, O'Donnell J, Seyler T. Comorbidity burden contributing to racial disparities in outpatient versus inpatient total knee arthroplasty. J Am Acad Orthop Surg 2021;29:537–43. 10.5435/JAAOS-D-20-01038. [PubMed: 33720079]

[49]. Klemt C, Walker P, Padmanabha A, Tirumala V, Xiong L, Kwon YM. Minority race and ethnicity is associated with higher complication rates after revision surgery for failed total hip and knee joint arthroplasty. J Arthroplasty 2021;36:1393–400. 10.1016/j.arth.2020.10.043. [PubMed: 33190994]

[50]. Porter KR, Illgen RL, Springer BD, Bozic KJ, Sporer SM, Huddleston JI, et al. Is American joint replacement registry data representative of national data? A comparative analysis. J Am Acad Orthop Surg 2022;30:e124–30. 10.5435/JAAOS-D-21-00530. [PubMed: 34437310]

[51]. Boone-Heinonen J, Diez Roux AV, Kiefe CI, Lewis CE, Guilkey DK, Gordon-Larsen P. Neighborhood socioeconomic status predictors of physical activity through young to middle adulthood: the CARDIA study. Soc Sci Med 2011;72: 641–9. 10.1016/j.socscimed.2010.12.013. [PubMed: 21316829]

[52]. Powell-Wiley TM, Ayers C, Agyemang P, Leonard T, Berrigan D, Ballard-Barbash R, et al. Neighborhood-level socioeconomic deprivation predicts weight gain in a multi-ethnic population: longitudinal data from the Dallas Heart Study. Prev Med 2014;66:22–7. 10.1016/j.ypmed.2014.05.011. [PubMed: 24875231]

[53]. Duncan DT, Kawachi I, White K, Williams DR. The geography of recreational open space: influence of neighborhood racial composition and neighborhood poverty. J Urban Health 2013;90:618–31. 10.1007/s11524-012-9770-y. [PubMed: 23099625]

[54]. Goodman SM, Mehta B, Zhang M, Szymonifka J, Nguyen JT, Lee L, et al. Disparities in total hip arthroplasty outcomes: census tract data show interactions between race and community deprivation. J Am Acad Orthop Surg 2018;26:e457–64. 10.5435/JAAOS-D-17-00393. [PubMed: 30192253]

Table 1

Demographics and Unadjusted Rates of Cutting-Edge Feature Use and Outcomes for Study Patients by Racial Group.

Variable	White	Black	Hispanic-White	Hispanic-Other	Asian	Native American	Other	Total	*P* Value
	(N = 697,250)	(N = 44,511)	(N = 12,228)	(N = 7,125)	(N = 8,210)	(N = 5,857)		(N = 785,559)	
Age, Mean (SD)	68.55 (12.10)	62.26 (12.84)	65.54 (14.35)	62.97 (14.73)	67.77 (14.86)	67.45 (12.43)	66.46 (13.35)	68.05 (12.36)	<.001
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.00
CCI, Mean (SD)	2.92 (1.82)	2.45 (1.92)	2.69 (2.00)	2.56 (2.09)	2.96 (2.05)	2.65 (1.64)	2.63 (1.75)	2.88 (1.84)	<.001
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.00
Female	397,548 (57.26%)	24,035 (54.27%)	6,784 (55.57%)	3,884 (54.51%)	5,410 (66.13%)	3,353 (57.46%)	5,948 (57.33%)	446,962 (57.14%)	<.001
Missing	2 980 (0.43%)	227 (0.51%)	20 (0.16%)	0 (0%)	29 (0.35%)	22 (0.38%)	3 (0.03%)	3,281 (0.42%)	<.001
Cutting-Edge Features									
Ceramic head	40,490 (43.9%)	2,952 (53.8%)	715 (45.28%)	464 (44.92%)	470 (39.66%)	224 (35.84%)	509 (46.87%)	45,824 (44.40%)	<.001
Missing	605,042 (86.78%)	39,020 (87.66%)	10,649 (87.09%)	6,092 (85.5%)	7,025 (85.57%)	5,232 (89.33%)	9,292 (89.54%)	682,352 (86.86%)	.11
Robotic Assisted	12,772 (5.85%)	643 (5.26%)	175 (5.32%)	120 (5.51%)	105 (4.59%)	53 (3.35%)	36 (0.69%)	13,904 (5.67%)	<.001
Missing	478,804 (68.67%)	32,294 (72.55%)	8,939 (73.1%)	4,948 (69.45%)	5,923 (72.14%)	4,276 (73.01%)	5,136 (49.49%)	540,320 (68.78%)	<.001
Dual Mobility	38,880 (7.16%)	2,352 (6.64%)	842 (9.39%)	445 (8.35%)	483 (8.22%)	295 (8.18%)	575 (6.81%)	43,872 (7.18%)	<.001
Missing	154,245 (22.12%)	9,081 (20.4%)	3,265 (26.7%)	1,793 (25.16%)	2,336 (28.45%)	2,250 (38.42%)	1,940 (18.69%)	174,910 (22.27%)	<.001
Outcomes									
30-Day Readmission	4,391 (0.63%)	168 (0.38%)	80 (0.65%)	36 (0.51%)	66 (0.80%)	56 (0.96%)	34 (0.33%)	4,831 (0.61%)	<.001
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.00
90-Day Readmission	7,959 (1.14%)	322 (0.72%)	152 (1.24%)	68 (0.95%)	112 (1.36%)	119 (2.03%)	70 (0.67%)	8,802 (1.12%)	<.001
Missing	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1.00
Mean Follow-up (mo), Mean (SD)	41.37 (24.54)	39.75 (24.04)	37.92 (23.19)	37.18 (23.13)	39.78 (24.80)	29.48 (16.79)	46.47 (23.69)	41.14 (24.46)	<.001
Revision THA	17,227 (2.83%)	855 (2.09%)	286 (2.75%)	89 (1.44%)	106 (1.58%)	135 (2.55%)	170 (1.87%)	18,868 (2.75%)	<.001
Missing	89,458 (12.83%)	3,510 (7.89%)	1,844 (15.08%)	937 (13.15%)	1,504 (18.32%)	571 (9.75%)	1,265 (12.19%)	99,089 (12.61%)	<.001

Table 2

Summary Statistics for Study Patients by Ceramic Head Use.

Variable	Nonceramic Head n = 57,383	Ceramic Head n = 45,824	*P* Value
Age	74.47 (SD 11.91)	64.73 (SD 11.32)	<.0001
CCI	3.72 (SD 1.99)	2.47 (SD 1.57)	<.0001
Elective THA	38,366 (66.86%)	44,501 (97.11%)	<.0001
30-d readmission[a]	254 (0.64%)	183 (0.41%)	<.0001
90-d readmission[a]	496 (1.25%)	395 (0.87%)	<.0001
Revisions[a]	660 (1.59%)	556 (1.2%)	<.0001
Deaths[a]	488 (1.17%)	100 (.22%)	<.0001
Robotic assisted	339 (1.67%)	472 (3.7%)	<.0001
Dual mobility	2,399 (7.16%)	4,185 (10.43%)	<.0001
Race/Ethnicity			<.0001
White	51,718 (90.13%)	40,490 (88.36%)	
Black	2,539 (4.42%)	2,952 (6.44%)	
Hispanic-White	864 (1.51%)	715 (1.56%)	
Hispanic-Other	569 (0.99%)	464 (1.01%)	
Asian	715 (1.25%)	470 (1.03%)	
Native American	401 (0.7%)	224 (0.49%)	
Other Races	577 (1.01%)	509 (1.11%)	

[a]Totals from the outcome analysis were used for these variables, n = 85,118.

Table 3

Pairwise Multivariate Multilevel Regression Results for Ceramic Femoral Head Use by Racial/Ethnic Group.

Comparison	OR (95% CI)	More Ceramic Use	*P* Value
Native American vs Asian	0.70 (0.38, 1.27)	–	.57
Native American vs Hispanic-Other	0.80 (0.43, 1.48)	–	.94
Native American vs White	**0.52 (0.30, 0.87)**	**White**	**.0041**
Native American vs Hispanic-White	0.68 (0.38, 1.21)	–	.43
Native American vs Black	0.65 (0.38, 1.12)	–	.22
Asian vs Hispanic-Other	1.14 (0.74, 1.77)	–	.97
Asian vs White	**0.74 (0.55, 1.00)**	**White**	**.045**
Asian vs Hispanic-White	0.97 (0.66, 1.43)	–	.99
Asian vs Black	0.93 (0.67, 1.29)	–	.99
Hispanic-Other vs White	**0.65 (0.47, 0.90)**	**White**	**.0016**
Hispanic-Other vs Hispanic-White	0.85 (0.56, 1.27)	–	.89
Hispanic-Other vs Black	0.81 (0.57, 1.15)	–	.59
Hispanic-White vs White	**0.76 (0.59, 0.99)**	**White**	**.037**
Black vs White	**0.79 (0.69, 0.92)**	**White**	**<.0001**
Hispanic-White vs Black	0.96 (0.72, 1.28)	–	.99

Statistically signficant values are given in bold.

Table 4

Pairwise Multilevel Multivariate Proportional Hazard Regression Results for Risk of Revision Total Hip Arthroplasty by Racial Group.

Comparison	HR (95% CI)	*P* Value
Native American vs Asian	2.5317 (0.8579, 7.4716)	.13
Native American vs Hispanic-Other	2.329 (0.7808, 6.9474)	.23
Native American vs White	0.9947 (0.4726, 2.0937)	1
Native American vs Hispanic-White	1.0311 (0.3658, 2.9062)	1
Native American vs Black	1.1886 (0.5367, 2.6325)	.99
Asian vs Hispanic-Other	0.9199 (0.2975, 2.8443)	1.00
Asian vs White	**0.3929 (0.1797, 0.8591)**	**.0075**
Asian vs Hispanic-White	0.4073 (0.1514, 1.0953)	.10
Asian vs Black	0.4695 (0.2012, 1.0956)	.11
Hispanic-Other vs White	**0.4271 (0.1853, 0.9842)**	**.043**
Hispanic-Other vs Hispanic-White	0.4427 (0.1498, 1.3086)	.25
Hispanic-Other vs Black	0.5104 (0.2102, 1.2394)	.25
White vs Hispanic-White	1.0365 (0.5123, 2.0972)	1.00
White vs Black	1.1949 (0.9217, 1.5491)	.35
Hispanic-White vs Black	1.1528 (0.5421, 2.4514)	.99

Statistically signficant values are given in bold.