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Birmingham hip resurfacing: a systematic review of outcomes at minimum 10-years follow-up

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Although controversy surrounding the use of metal-on-metal (MoM) arthroplasty implants continues to exist, satisfactory clinical and radiological outcomes have been reported following Birmingham Hip Resurfacing (BHR) at long-term follow-up, leading to an Orthopaedic Data Evaluation Panel (ODEP) rating of 13A. The purpose of this study was to systematically review the literature to evaluate the functional outcomes, radiological outcomes and revision rates following BHR at a minimum of 10 years follow-up. Using the PRISMA guidelines, two independent reviewers performed a literature search using Pubmed, Embase and Scopus databases. Only studies reporting on outcomes of BHR with a minimum of 10 years' follow-up were considered for inclusion. A total of 12 studies including 7132 hips (64.8% males), with mean follow-up of 11.5 years (10-15.3), met our inclusion criteria. Of included patients, 94.3% of patient underwent BHR for osteoarthritis at a mean age was 52.0 years (48-52). At final follow-up, 96% of patients reported being satisfied with their BHR, with mean Harris Hip Scores of 93.6 and Oxford Hip Scores of 16.5. Rates of radiological femoral neck narrowing of greater than 10% and non-progressive radiological loosening were reported as 2.0% and 3.8% respectively. At final follow-up, the overall revision rate was 4.9% (334/7132), deep infection rate was 0.4%, metal allergy/insensitivity rate was 1.6%, metal reaction rate was 0.3%, rate of peri-prosthetic fracture was 0.9% and aseptic loosening rates were 1.6%. This systematic review demonstrates that BHR results in satisfactory clinical outcomes, acceptable implant survivorship, low complication rates and modest surgical revision rates in the long-term at minimum 10-year follow-up.

Keywords: Birmingham hip, hip resurfacing, metal-on-metal, long-term, 10 years.

INTRODUCTION

As the place of metal on metal (MoM) total hip replacement (THR) in its resurfacing and stemmed forms has not been formally agreed, the Birmingham Hip Resurfacing (BHR) implant (Smith & Nephew Inc., London, U.K.) was developed in the 1990s with the hope of addressing the early failure and subsequent high revision rates of other MoM THR implants[1]. Design of the BHR sought for reduction in wear on the MoM interface of the articular surface of each implant, whilst increasing stability with a large diameter femoral head component, particularly in the young, active male patient who seek to remain active post-operatively[2,3]. As early studies reported excellent BHR survivorship at 5-years follow-up, an ever-growing cohort of arthroplasty surgeons adopted its use in the 1990s and 2000[4].

Whilst satisfactory clinical outcomes have been reported at medium-term follow-up post-BHR[5], previous studies have highlighted that due consideration of the complications specific to hip resurfacing (HR) in the long-term is warranted when electing for BHR. Regular interval monitoring of raising serum metal ion levels is of utmost importance post-MoM device utilization, as trends in such data may be indicative of potential complications, implant fatigue, or even failure[6,7]. While utilization of BHR offers a more bone conserving alternative in managing the younger patient in the setting of severe osteoarthritis (OA) of the hip, complications including adverse reaction to metal debris (ARMD), metal hypersensitivity or allergies, and peri-prosthetic fracture (PPF), particularly of the femoral component, amongst others, are also reported with BHR in the longer-term and therefore should also be considered when weighing up surgical options[8].

Although controversy persists in relation to varying rates of post-operative complications and surgical revisions with MoM THR or HR implants, the volume of literature reporting satisfactory clinical and radiological findings following BHR in the medium-to-long term continues to grow[5,9]. Furthermore, while a

variety of studies have reported their experiences with BHR in patients with a minimum of 10-years follow-up[4], to the best knowledge of the authors of this study no systematic review has previously been performed to evaluate such outcomes further for BHR alone despite renewed interest in BHR continuing to grow in to the 21st century[10]. Therefore, the purpose of this study was to systematically review the literature to evaluate the clinical outcomes, radiological outcomes and revision rates following BHR at a minimum of 10 years follow-up.

MATERIALS & METHODS

A systematic review of the literature was performed using two independent reviewers (M.S.D. and K.M.) with specific reference to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. A search of the PubMed, Embase and Scopus databases was carried out as a literature search on 21st March 2021 the using the following search terms: ((long-term or long term or 10 or ten or follow-up or follow-up) and (hip resurfacing or hip arthroplasty) and (metal-on-metal hip or birmingham hip). Prior to search commencement, the authors agreed that no time limit would be applied to the search. After removing duplicate studies, both reviewers manually screened the titles and abstracts of all studies independently from the initial search whilst applying our exclusion criteria, with the senior author (C.G.M.) acting as an arbitrator in cases whereby discrepancies in opinion between the two reviewers. Following this, both independent reviewers assessed the full texts of all potentially eligible studies using pre-determined inclusion criteria. When studies were selected for inclusion and analysis, the reference lists of such studies was thereafter screened to ensure no further studies had not been identified using our search strategy.

Prior to commencement of the search, both independent reviewers and senior author agreed on the pre-determined inclusion, exclusion criteria and data collection sheet for this study. The inclusion criteria for this study included the following parameters; (1) any study reporting clinical or radiological outcomes of BHR, (2) minimum of 10-years mean follow-up, (3) published in the English language, and (4) manuscript published in a peer-reviewed journal. The exclusion criteria included; (1) studies focusing on the outcomes of MoM implants other than BHR, (2) studies evaluating BHR as a revision procedure, (3) studies with a mean follow-up of over 10-years, however minimum follow-up of less than 10-years, (3) biomechanical studies, (5) cadaveric studies, (6) abstract only or conference papers, and (6) case reports.

The pre-determined data collection sheet was utiized by both independent reviewers in evaluation of each of the published manuscripts of the included studies with a focus of gathered all relevant data.

Study characteristics and patient demographics of interest included: (1) mean follow-up, (2) minimum follow-up, (3) study design, (4) level of evidence (LOE), (5) methodological quality of evidence (MQOE), (6) number of included hips which underwent BHR, (7) mean patient age, (8) patient gender, and (9) number of patients who under BHR for hip OA. The criteria previously described by Wright et al.(11) and Robertson et al.(12) were applied in evaluation of the LOE and MQOE of each included study respectively.

Clinical outcomes of interest included; (1) reported pain levels, (2) range of motion, (3) patient satisfaction, (4) mean pre-operative and post-operative (a) Harris Hip scores (HHS), (b) Oxford hip scores (OHS), and (c) University of California Los Angeles (UCLA) scores. Complications highlighted as outcomes of interest included; (1) deep infection, (2) residual pain, (3) subluxation, (4) dislocation, (5) aseptic loosening of the (a) femoral component, or (b) acetabular component, (6) metal allergy/sensitivity, (7) ARMD, (8) PPF, (9) necrosis, and (10) surgical revisions.

Radiological outcomes of interest included; (1) femoral stem-neck angles, (2) femoral neck narrowing of greater than 10%, (3) acetabular cup (a) inclination, and (b) anteversion, (4) non-progressive radiological loosening, and (5) osteolysis of (a) the femoral component, or (b) the acetabular component. Biochemical outcomes of interest included; (1) cobalt (Co), and (2) chromium (Cr) levels at final follow-up.

All collected data was stored on the pre-determined data sheet. This was thereafter tabulated with subsequent quantitative statistical analysis was performed using Microsoft Excel (Redmond, WA, USA).

RESULTS

The initial literature search resulted in a total of 4242 studies. After the removal of 1169 duplicate studies, the remaining 3073 studies were screened using our pre-determined exclusion criteria. Thereafter, our pre-determined inclusion criteria was applied to the full texts of the remaining 303 studies in order to evaluate for eligibility. Overall, a total of 12 clinical studies including 7132 hips met the inclusion criteria of this study[4,9,13-22]. A summary of the literature search

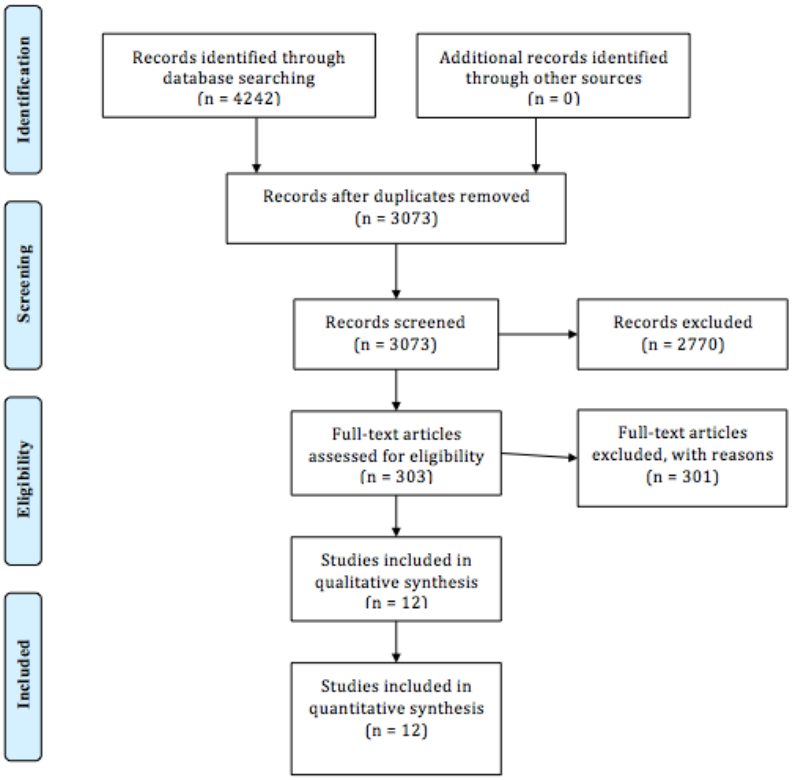

Figure 1. — Literature search with respect to PRISMA guidelines.

with respect to PRISMA guidelines is illustrated in Figure 1.

The 12 included studies composed of 7132 hips that underwent BHR at minimum 10-years follow-up. All included studies represented level III evidence, with a mean MQOE of 55.9 (43-61). Overall, 94.3% of patients underwent BHR for OA of the hip (6239/6619). Additionally, 64.8% of included patients were male with a mean age of 52.0 years ± 2.3 and mean follow-up of 11.5 ± 2.3 years. A summary of study characteristics and patient demographics is further illustrated in Table I.

The most commonly utilized outcome score was the HHS, which was reported in 5 studies. A total of 3 studies (n=440) reported mean pre-operative HHS of 50, with a total of 5 studies (n=1547) reported mean post-operative HHS of 93.6 at minimum 10-years follow-up. Additionally, a total of 4 studies (n=1307)

Table I. — Patient demographics & study characteristics

Authors	Year	LOE	Mean F/U (Yrs)	Range (Yrs)	Hips N	Males	OA	Mean Age (Yrs)
Azam et al.	2016	III	12.05	10-15	244	153	244	57
Daniel et al.	2014	III	13.7	12.3-15.3	1000	665	763	NR
Hastie et al.	2021	III	Min 13	Min 13	123	NR	NR	NR
Hollandet al.	2012	III	11.5	10-13	100	74	79	51.3
Hunter et al.	2018	III	Min 10	Min 10	121	76	104	52.5
Jonas et al.	2019	III	17.6	NR	63	41	NR	NR
Malek et a.	2011	III	10	10-13	100	66	NR	51
Mehra et al.	2015	III	10.8	10-14	120	63	68	50
Moroni et al.	2017	III	10.8	Min 10	100	56	66	48.9
Stoney et al.	2020	III	11	NR	4790	4790	4790	52
Treacy et al.	2011	III	10.9	10.2-12.2	144	107	125	52
Van Der Straeten et al.	2013	III	10.8	10-13.6	227	136	NR	50.5
F/U; Follow-Up, LOE; Level of Evidence, N; Number, NR; Not reported, OA; Osteoarthritis, Yrs; Years								

Table II. — Clinical & biochemical outcomes

Outcomes	N Studies	N	N Patients
Pain	4	23	6024
Satisfiied	4	1234	1283
Pre-op HHS	3	50 ± 6.9	320
Post-Op HHS	5	93.6 ±5.9	1547
Post-Op OHS	3	16.5 ± 18.0	1307
Post-Op UCLA	2	7.1 ± 1.6	200
Serum Co	3	1.1 ± 0.5	427
Serum Cr	3	1.8 ±0.3	427

Co; Cobalt, Cr; Chromium, HHS; Harris Hip Score, N; Number, OHS; Oxford Hip Score, UCLA; University of California Los Angeles.

reported mean pre-operative OHS of 16.5 at minimum 10-years follow-up.

Patient reported satisfaction was reported in a total of 4 studies with 96.2% of patients being satisfied (2354/2446) at minimum 10-years follow-up. Additionally, residual pain was reported in a total of 4 studies with 0.9% of patients reporting residual pain in any anatomical location believed to be secondary to the BHR (23/6024) at minimum 10-years follow-up.

Overall, 3 studies including 427 patients reported mean Co and Cr levels at minimum 10-years follow-up. The mean Co and Cr levels were 1.1 µg/L and 1.8 µg/L respectively. A summary of clinical and biochemical outcomes is further illustrated in Table II.

A total of 7 of the included studies (n=1935) reported on radiological outcomes at minimum 10-years follow-up. The most commonly reported radiological finding was mean acetabular cup inclination, which was reported in 6 studies as 44.3^0 (n=1691). Additionally, a total of 3 studies each reported mean acetabular cup anteversion as 13.9^0 (n=447) and mean femoral stem-neck angles as 142.2^0 (n=1244).

Overall, the rate of radiological osteolysis was reported as 2.0% in 4 studies (29/1471). This included a total rate of femoral and acetabular osteolysis of 1.1% (16/1471) and 0.9% (13/1471) respectively. A total of 3 reported the overall rates of radiological loosening as 3.8% (18/471). Additionally, a total of 2 studies reported the rate of femoral component narrowing of greater than 10% to be 2.0% (22/1100).

Overall implant survivorship was reported in 11 of the included studies (n=7032), with a mean BHR implant survivorship of 94.0% at minimum 10-years follow-up. All included studies reported rates of surgical revisions, with the total rate of surgical revisions was 4.7% at minimum 10-years follow-up. The most commonly

Table III. —Radiological outcomes, complications & revision surgeries

Outcomes	N Studies	Outcome	N Total
Acet Cup Anteversion	3	13.9 deg	447
Acet Cup Inclinication	6	13.9 deg	1691
Acet Osteolysis	4	13	1471
Fem Osteolysis	4	16	1471
Fem Neck Narrowing >10%	2	22	1100
Feml Stem-Neck Angle	3	142.2 deg	1244
Loosening	3	18	471
ARMD	5	21	6133
Deep Infection	7	28	6519
Dislocation	4	5	5254
Loosening	8	106	6619
Metal I/A	2	6	371
Necrosis	5	16	5264
Osteolysis	3	25	6019
Pain	3	14	5161
Subluxation	4	1	608
PPF	11	64	7032
Surgical Revisions	12	334	7132

Acet; Acetabular, ARMD; Adverse Reaction to Metal Debris, Deg; Degrees, Fem; Femoral, I/A; Insensitivity/Allergy, N; Number, PPF; Peri-Prosthetic Fracture.

reported complication following BHR was PPF, which was reported in 11 studies as 0.9% (64/7032).

The overall rate of aseptic loosening was reported as 1.9% in 8 studies (106/6619), with 7 and 4 studies reporting aseptic loosening of the femoral and acetabular components as 1.8% (34/1935) and 0.3% (4/1508) respectively. A total of 5 and 2 studies reported the rates of ARMD and metal allergy/insensitivity as 0.3% (21/6133) and 1.6% (6/371). Furthermore, the overall rates of dislocation and subluxation were reported in 4 studies each as 0.1% (5/5254) and 0.2% (1/608). Additionally, the rates of deep infection, residual pain and necrosis were 0.4% (28/6519), 0.3% (14/5161) and 0.3% (16/5264) respectively. A summary of radiological findings, complications and surgical revisions is further illustrated in Table III.

DISCUSSION

The most important findings in this study were that BHR resulted in excellent clinical outcomes, high rates of patient reported satisfaction and excellent radiological outcomes at minimum 10-years follow-up. Additionally, this study found excellent implant

survivorship with low complication rates and modest revision rates following BHR at long term follow-up.

Initially designed as a highly durable implant which preserves larger quantities of bone stock in hope of greatly reducing the risk of dislocation, the emergence of BHR in the 1990s sought to enable the young, active patient a similar quality of life to their active peers[2]. In a previous systematic review, satisfactory functional outcomes were reported following BHR, suggesting that in the medium-term this may indeed be the case[5]. Our study found similar outcomes in the long-term, with excellent post-operative HHS and OHS as well as very high rates of patient-reported satisfaction at minimum 10-years follow-up post-BHR. Furthermore, the authors not only acknowledge the excellent functional outcomes reported in the literature following BHR[23], but the high rates of return to physical activity also in the athletic patient[24,25]. Therefore, the findings of this study support previous literature suggesting that there is no apparent step-off of functional outcomes during the transition from medium- to longer-term follow-up post-BHR.

Concerns have previously been raised in relation to elevated serum metal ion levels with MoM implant usage[26]. De Smet et al. reported that measurements of serum Co and Cr concentrations can be used to estimate the amount of wear taking place in MoM hip-replacement devices, as well as potential metallosis[27]. Following an expert consensus meeting on the topic, a consensus was found that serum ion concentration levels greater than 10 µg/L of Co or Cr are concerning for excessive wear of metal articular surfaces[28]. Furthermore, Savarino et al. found that in the context of MoM implant utility, serum Co and Cr levels appear to be higher post-HR versus THR implantation at baseline[29]. This study found low concentrations of serum Co and Cr ions at long-term follow-up post-BHR, with these findings echoed by the excellent clinical results and low failure rates reported in this review. Despite the low metal ion levels reported in this review, the authors do respect that implementation of regular, interval biochemical monitoring of patients following BHR as routine is should be deemed mandatory to ensure early detection of any potential failures of BHR in future.

This study found low rates of subluxations and dislocations post-BHR at long-term follow-up. Van der Straeten et al. found that 118 hip resurfacing experts reached a consensus not to perform hip resurfacing in case of a femoral head size smaller than 46 mm in diameter[28]. The BHR implant possesses a large diameter femoral head, intent on reducing subluxation and dislocation rates with respect to those reported following conventional THR[30]. Therefore, the enhanced stability afforded by the large diameter implant design is evidenced in the results reported in our study; with minimal dislocation and subluxation rates reported at minimum 10-years follow-up post-BHR[31].

Despite predominantly positive clinical and biochemical outcomes reported at long-term follow-up, the use of MoM hip implants remains controversial over the past 3 decades. Cohen et al. reported rates of failure of MoM HR and THR of approximately 12% and 13% at 8-years follow-up respectively, compared to rates of less than 5% when non-MoM implants are utilized[32]. This study reports findings in contrary to such literature, with a surgical revision rate of less than 5% reported in this study. Furthermore, all included studies reported a revision rate of less than 10% at minimum 10 years follow-up, with overall pooled survivorship of BHR of approximately 94%. Given the globally high revision rates reported for resurfacing implants in the previously published 17th National Joint Registry report, the authors of this study feel that perhaps dissociation of the BHR implant from other models of hip resurfacing implants is necessary when reporting long-term outcomes of these procedures in future[33]. With respect to these results, the authors of this study therefore suggest the use of BHR is at least comparable, if not superior in the young, active patient in the context of surgical management of hip pain, particular related to OA.

This study is a systematic review of the literature, so it therefore inherently suffers from the innate limitations of all included studies. Furthermore, all 12 included studies in this review are retrospective in nature, therefore representing studies of lower LOE. Analysis of the data gathered for this study is limited, with the majority of quantitative analysis being pooled by pre-determined outcome of interest. Additionally, a number of the included studies in this systematic review failed to report results that represent the outcomes of interest outlined in this study. Finally, there is potential for many surgical approaches or techniques to be used for BHR; this may ultimately vary amongst the included studies themselves, which may potentially be a confounding variable, which may influence the outcomes of this study.

CONCLUSION

This systematic review demonstrates that BHR results in satisfactory clinical outcomes, acceptable implant survivorship, low complication rates and modest surgical revision rates in the long-term at minimum 10-year follow-up.

REFERENCES

1. Sershon R, Balkissoon R, Valle CJD. Current indications for hip resurfacing arthroplasty in 2016. Current reviews in musculoskeletal medicine. 2016;9(1):84-92.
2. Moonot P, Singh P, Cronin M, Kalairajah Y, Kavanagh T, Field R. Birmingham hip resurfacing - Is acetabular bone conserved? The Journal of bone and joint surgery British volume. 2008;90:319-23.
3. Vendittoli PA, Lavigne M, Girard J, Roy AG. A randomised study comparing resection of acetabular bone at resurfacing and total hip replacement. The Journal of bone and joint surgery British volume. 2006;88(8):997-1002.
4. Treacy RB, McBryde CW, Shears E, Pynsent PB. Birmingham hip resurfacing: a minimum follow-up of ten years. The Journal of bone and joint surgery British volume. 2011;93(1):27-33.
5. Karas S. Outcomes of birmingham hip resurfacing: a systematic review. Asian journal of sports medicine. 2012;3(1):1-7.
6. Daniel J, Ziaee H, Pradhan C, Pynsent PB, McMinn DJ. Blood and urine metal ion levels in young and active patients after Birmingham hip resurfacing arthroplasty: four-year results of a prospective longitudinal study. The Journal of bone and joint surgery British volume. 2007;89(2):169-73.
7. Vendittoli PA, Ganapathi M, Lavigne M. Blood and urine metal ion levels in young and active patients after Birmingham hip resurfacing arthroplasty. The Journal of bone and joint surgery British volume. 2007;89(7):989; author reply -90.
8. Matharu GS, Pynsent PB, Dunlop DJ. Revision of metal-on-metal hip replacements and resurfacings for adverse reaction to metal debris: a systematic review of outcomes. Hip international : the journal of clinical and experimental research on hip pathology and therapy. 2014;24(4):311-20.
9. Hunter TJA, Moores TS, Morley D, Manoharan G, Collier SG, Shaylor PJ. 10-year results of the Birmingham Hip Resurfacing: a non-designer case series. Hip international : the journal of clinical and experimental research on hip pathology and therapy. 2018;28(1):50-2.
10. Bozic KJ, Kurtz S, Lau E, Ong K, Chiu V, Vail TP, et al. The epidemiology of bearing surface usage in total hip arthroplasty in the United States. The Journal of bone and joint surgery American volume. 2009;91(7):1614-20.
11. Wright JG, Einhorn TA, Heckman JD. Grades of recommendation. The Journal of bone and joint surgery American volume. 2005;87(9):1909-10.
12. Robertson C, Ramsay C, Gurung T, Mowatt G, Pickard R, Sharma P. Practicalities of using a modified version of the Cochrane Collaboration risk of bias tool for randomised and non-randomised study designs applied in a health technology assessment setting. Research synthesis methods. 2014;5(3):200-11.
13. Azam MQ, McMahon S, Hawdon G, Sankineani SR. Survivorship and clinical outcome of Birmingham hip resurfacing: a minimum ten years' follow-up. International orthopaedics. 2016;40(1):1-7.
14. Daniel J, Pradhan C, Ziaee H, Pynsent PB, McMinn DJ. Results of Birmingham hip resurfacing at 12 to 15 years: a single-surgeon series. The bone & joint journal. 2014;96-b(10):1298-306.
15. Hastie GR, Collinson SC, Aqil A, Basu S, Temperley DE, Board TN, et al. Study to Assess the Rate of Adverse Reaction to Metal Debris in Hip Resurfacing at a Minimum 13-year Follow-up. The Journal of arthroplasty. 2021;36(3):1055-9.
16. Holland JP, Langton DJ, Hashmi M. Ten-year clinical, radiological and metal ion analysis of the Birmingham Hip Resurfacing: from a single, non-designer surgeon. The Journal of bone and joint surgery British volume. 2012;94(4):471-6.
17. Jonas SC, Whitehouse MR, Bick S, Bannister GC, Baker RP. An 18-year comparison of hybrid total hip replacement and Birmingham hip resurfacing in active young patients. Hip international : the journal of clinical and experimental research on hip pathology and therapy. 2019;29(6):630-7.
18. Malek IA, Hashmi M, Holland JP. Socio-economic impact of Birmingham hip resurfacing on patient employment after ten years. International orthopaedics. 2011;35(10):1467-70.
19. Mehra A, Berryman F, Matharu GS, Pynsent PB, Isbister ES. Birmingham Hip Resurfacing: A Single Surgeon Series Reported at a Minimum of 10 Years Follow-Up. The Journal of arthroplasty. 2015;30(7):1160-6.
20. Moroni A, Miscione MT, Orsini R, Micera G, Mosca S, Sinapi F, et al. Clinical and radiographic outcomes of the Birmingham Hip Resurfacing arthroplasty at a minimum follow-up of 10 years: results from an independent centre. Hip international : the journal of clinical and experimental research on hip pathology and therapy. 2017;27(2):134-9.
21. Stoney J, Graves SE, de Steiger RN, Rainbird S, Kelly TL, Hatton A. Is the Survivorship of Birmingham Hip Resurfacing Better Than Selected Conventional Hip Arthroplasties in Men Younger Than 65 Years of Age? A Study from the Australian Orthopaedic Association National Joint Replacement Registry. Clin Orthop Relat Res. 2020;478(11):2625-36.
22. Van Der Straeten C, Van Quickenborne D, De Roest B, Calistri A, Victor J, De Smet K. Metal ion levels from well-functioning Birmingham Hip Resurfacings decline significantly at ten years. The bone & joint journal. 2013;95-b(10):1332-8.
23. Szymanski C, Thouvarecq R, Dujardin F, Migaud H, Maynou C, Girard J. Functional performance after hip resurfacing or total hip replacement: A comparative assessment with non-operated subjects. Orthopaedics & Traumatology: Surgery & Research. 2012;98(1):1-7.
24. Girard J, Miletic B, Deny A, Migaud H, Fouilleron N. Can patients return to high-impact physical activities after hip resurfacing? A prospective study. International orthopaedics. 2013;37(6):1019-24.
25. Girard J, Lons A, Pommepuy T, Isida R, Benad K, Putman S. High-impact sport after hip resurfacing: The Ironman triathlon. Orthopaedics & Traumatology: Surgery & Research. 2017;103(5):675-8.
26. Van Der Straeten C, Grammatopoulos G, Gill HS, Calistri A, Campbell P, De Smet KA. The 2012 Otto Aufranc Award: The interpretation of metal ion levels in unilateral and bilateral hip resurfacing. Clin Orthop Relat Res. 2013;471(2):377-85.
27. De Smet K, De Haan R, Calistri A, Campbell PA, Ebramzadeh E, Pattyn C, et al. Metal ion measurement as a diagnostic tool to identify problems with metal-on-metal hip resurfacing. The Journal of bone and joint surgery American volume. 2008;90 Suppl 4:202-8.
28. Van Der Straeten C, De Smet KA. Current expert views on metal-on-metal hip resurfacing arthroplasty. Consensus of the 6th advanced Hip resurfacing course, Ghent, Belgium, May 2014. Hip international : the journal of clinical and experimental research on hip pathology and therapy. 2016;26(1):1-7.
29. Savarino L, Cadossi M, Chiarello E, Baldini N, Giannini S. Do ion levels in metal-on-metal hip resurfacing differ from those in metal-on-metal THA at long-term followup? Clin Orthop Relat Res. 2013;471(9):2964-71.
30. Matharu GS, Pandit HG, Murray DW, Treacy RB. The future role of metal-on-metal hip resurfacing. International orthopaedics. 2015;39(10):2031-6.
31. Agency MaHpR. All metal-on-metal (MoM) hip replacements: updated advice for follow-up of patients. 2017.
32. Cohen D. Revision rates for metal on metal hip joints are double that of other materials. BMJ (Clinical research ed). 2011;343:d5977.
33. Reports N. NJR 17th Annual Report 2020.