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REVIEW ARTICLE

Hip resurfacing: a systematic review of literature

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Abstract
Purpose We conducted a systematic review of the literature in order to take stock of hip resurfacing according to the principle of "evidence based medicine". Our main objective was to compare the rate of revision of resurfacing implants with survival limits set by the National Institute of Clinical Excellence (NICE).
Methods A systematic review was undertaken of all published (Medline, Cochrane, EMBASE) literature research databases up to July 2012 as recommended by the PRISMA statement. Data extraction focused on functional outcomes, complications and survival rates. The survival rates of implants were analysed according to the mean of the series in comparison to the NICE criteria.
Results Fifty-three studies were identified and included 26,456 cases with an average of 499.17 ± 856.7 (range, 38–5000) cases per study. The median survival was 95.57 % ± 3.7 % (range, 84–100). The percentage of studies which satisfied the criteria set by NICE was 69.8 %. In terms of cumulative revision rates pondered by the number of implants, BHR®, Conserve Plus® and Cormet® showed the best results. The mean postoperative score was 91.2 ± 7.72 (range, 68.3–98.6). There was no statistically significant difference between implants in terms of functional outcomes.
Conclusion On the basis of the current evidence base, this review of the literature emphasises the importance of certain parameters that can improve the results of resurfacing. The type of implant seems to play an important role as does patient selection.

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Introduction

After a period of popularity, hip resurfacing has seen a number of indications to be decreasing [1]. It is currently the subject of numerous concerns with regards to the presence of metal ions in the blood, even if there is no conclusive evidence of a carcinogenic effect [2]. Furthermore, many publications seem to show excellent results. We conducted a systematic review of the literature in order to take stock of this surgical technique according to the principle of "evidence based medicine."

Our main objective was to compare the rate of revision of resurfacing implants with survival limits set by the National Institute of Clinical Excellence (NICE) (maximum of 10 % at ten years), being part of the National Health System (NHS) in England and Wales [3–5]. The secondary objectives were to evaluate the functional outcome and complications associated with hip resurfacing as well as differences between these implants.

Materials and methods

The research was conducted on July 14, 2012 using the Cochrane databases, EMBASE and MEDLINE as recommended by The PRISMA statement [6]. The electronic

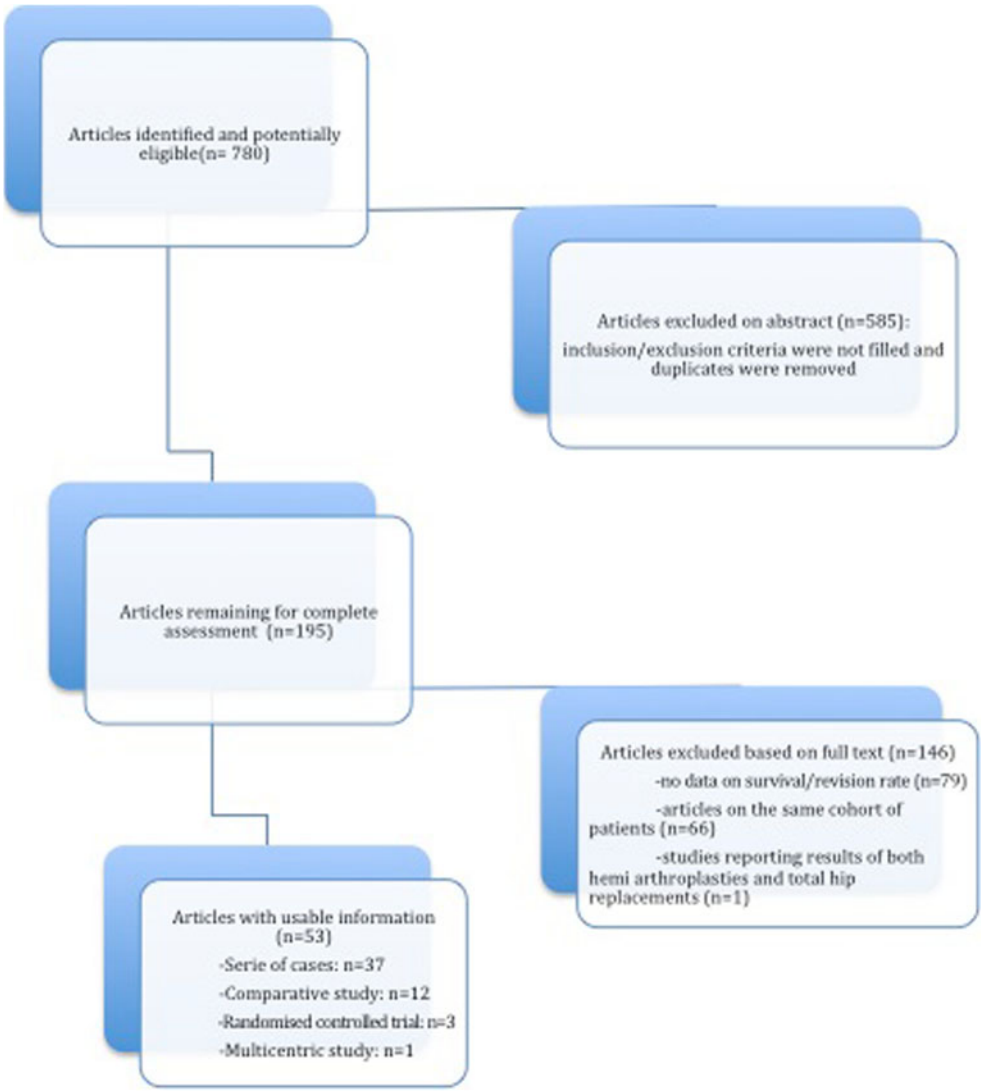

Fig. 1 Flow chart of the PRISMA procedure of systematic review of the literature

search included articles published until 25 July 2012. The following terms used the joints "AND", "NOT" and "OR": hips, femur head, femoral head, femur neck, femoral neck, resurfac* outcome, follow-up, FU, prosthesis failure, pseudotumor, pseudotumour, mechanical stress, gait, patient satisfaction, activity, activities, surviv* and risk factors. All titles and abstracts were reviewed by a single observer, and for studies meeting eligibility criteria the full article was obtained. The reference lists of meta-analysis and systematic reviews of the literature were examined to avoid missing studies not identified by the search. The inclusion criteria were: publication in English and studies reporting survival or revision of the implant with a minimum of at least six-months follow up. Exclusion criteria were: studies on hemi-arthroplasty, studies reporting results after revision of a resurfacing, retrospective studies on implant failures, technical note type studies, studies reporting only laboratory results, histological studies, in-vitro simulation study, bioengineering studies, radiological studies, studies of national registries, and clinical case studies of peri-prosthetic bone density. If articles described the same series of patients, we included the most recently published series with the largest number of patient population. The criteria for inclusion/exclusion was controlled by two different observers with the inclusion of a third in case of disagreement. Data extraction focused on the type of prosthesis, the design of the study, the baseline characteristics of patients, the mean follow-up, functional scores, survival rates, and the type and number of complications. Functional scores were standardised as far as possible on a scale of 0 to 100, with 100 representing the best possible functional outcome. The survival rate of implants was analysed according with respect to the mean of the series and compared with the NICE criteria. Quality of studies, in terms of level of evidence, was judged using the GRADE evaluation system (Grading of Recommendations Assessment, Development and Evaluations) classifying the quality of education in high, moderate, low and very low [7].

Table 1 Study results

Authors	Study design	Implant	Number of hips	Percent (%) males	Mean age	% OA primary/ OA secondary/Other	Mean follow-up (years)	Percent (%) lost to follow-up	Number of revisions	Survival rate % (95 % CI)
Amstutz et al. [10]	Series of cases	Conserve plus	1107	74	50	NS	6.8	0.2	44	96
Aulakh et al. [11]	Series of cases	BHR	202	75	42	50/0/50	7.5	0	6	97.7 AVN; 95 OA
Baker et al. [8]	Comparative study BHR vs THA	BHR	54 BHR vs 54 THA	74	50	100/0/0	9	NR	5 BHR vs 9 THA	NR
Beaulé et al. [12]	Series of cases	Conserve plus	116	81	47	81/9/10	3.2	1.9	2	98.1
Bergeron et al. [13]	Series of cases	ASR	228	80	54	97/0/3	4.6	3	8	94.8
Bose et al. [14]	Series of cases	BHR	96	84	39	0/100/0	5.4	0	3	95.4
Carrothers et al. [15]	Multicentric study	BHR	5000	67	53	NS	7.1	NR	182	96.3
Costa et al. [16]	Comparative study Cormet vs THA	Cormet	73 Cormet vs 137 THA	86 (cormet) vs 47(THA)	53	NS	2.4	NR	0 Cormet vs 3 THA	NR
Daniel et al. [17]	Series of cases	McMinn et BHR	446	79	48	100/0/0	3.3	0	1	99.8
Daniel et al. [18]	Series of cases	McMinn 2nde generation	184	59	54	82/0/18	10.5	0.5	30	84
De Smet et al. [19]	Series of cases	BHR	252	69	50	81/6/13	5	1.5	3	98.9
De Steiger et al. [9]	Comparative study ASR vs THA	ASR	1167 ASR	95	53	NR	5	NR		89.1
Della Valle et al. [20]	Series of cases	BHR	537	71	52	89/6/5	0.87	NR	14	NR
Delport et al. [21]	Comparative study BHR vs Recap	BHR et Recap	56	82	52	NS	4.8	NR	0	NR
Fowble et al. [22]	Comparative study Conserve plus vs THA	Conserve plus	50 Conserve plus vs 44 THA	62	50	98/1/1	3.2	NR	1 Conserve plus vs 0 THA	NR
Giannini et al. [23]	Series of cases	BHR	350	52	51	52/22/26	2	NS	4	98.8
Gravius et al. [24]	Series of cases	Durom	82	56	53	93/7/0	2.4	2.4	2	97.6
Gross et al. [25]	Series of cases	Cormet	100				8	NR	21	93
Heilpern et al. [26]	Series of cases	BHR	113	58	54	88/4/8	5	3	4	96.3 (92.8–99.8)
Hing et al. [27]	Series of cases	BHR	230	66	52	NS	5	0.5	2	97.8 (97.1–100)
Hulst et al. [28]	Series of cases	Conserve plus	643	67	49	65/15/20	10.4	NR	45	98.3
Jameson et al. [29]	Series of cases	ASR	214	60	56	68/5/27	3.6	0	12	93 (80–98)
Khan et al. [30]	Series of cases	BHR	679	60	51	NS	6	2	29	95.7 (94.4–97.4)
Killampalli et al. [31]	Series of cases	Cormet	100	61	56	97/1/2	5	0	0	100
Kim et al. [32]	Series of cases	Conserve plus	200	78	49	86/4/10	2.6	0	14	93
Klein et al. [33]	Series of cases	ASR	115	47	58	100/0/0	1	0	13	88.7
Langton et al. [34]	Comparative study BHR vs ASR	BHR et ASR	155 BHR vs 505 ASR	54	56	NS	2.9	NR	17 ASR vs 0 BHR	NR
Larbpaiboonpong et al. [35]	Series of cases	BHR	40	58	41.3	35/52/13	1.4	0	1	97.5
Lei et al. [36]	Series of cases	Durom	90	52	47	50/0/50	2.3	0	1	98.9
Mackenzie et al. [37]	Comparative study BHR vs THA	BHR	499	75.5	49.1	100/0/0	2	0	0	100
Madadi et al. [38]	Comparative study ON vs OA	Cormet	52	52	35	50/0/50	3.4	NR	6	88.4

Table 1 (continued)

Authors	Study design	Implant	Number of hips	Percent (%) males	Mean age	% OA primary/ OA secondary/Other	Mean follow-up (years)	Percent (%) lost to follow-up	Number of revisions	Survival rate % (95% CI)
Madhu et al. [39]	Series of cases	BHR	117	58	54	56/44/0	7	1	8	91.5 (85.4–97.6)
Malhotra et al. [40]	Series of cases	ASR	32	70	33	0/0/100	3.6	0	1	96.8
Marker et al. [41]	Series of cases	Conserve plus	361	71	50	74/15/11	4.9	NR	23	93.6
Marulanda et al. [42]	Series of cases	BHR	230	73	55	87/0/13	1.3	NS	3	98.7
McAndrew et al. [43]	Series of cases	BHR	180	NS	56	94/0/6	2	0	3	98.3
McBryde [44]	Series of cases	BHR	2123	62	55	100/0/0	3.46	0	48	97.5 (96.3–98.3)
McMinn et al. [45]	Series of cases	BHR	3095	NS	53		8	0	68	98
Mont et al. [46]	Comparative study Conserve plus vs THA	Conserve plus	54 Conserve plus vs 54 THA	75	52	100/0/0	3.5	0	2 Conserve plus vs 2 THA	NR
Mont et al. [47]	Series of cases	Conserve plus	1016	28	50	77/11/12	2.8	6.3	54	94.2 (90–96.7)
Naal et al. [48]	Series of cases	Durom	100	66	52	79/6/15	5	NR	11	88.2
Ollivere et al. [49]	Series of cases	BHR	463	66	56	NS	5	0.6	13	95.8 (94.1–96.8)
Sandiford et al. [50]	Comparative study BHR vs THA	BHR	141 BHR vs 141 THA	66	54	100/0/0	1.6	NS	0	NS
Siebel et al. [51]	Series of cases	ASR	300	64	57	NS	0.6	0	8	97.2
Smolders et al. [52]	Clinical randomised trial	Conserve plus	38 conserve plus vs 33 THA	55	58	90/0/10	1.7	NS	1 Conserve plus vs 2 THA	NS
Steffen et al. [53]	Series of cases	BHR	610	59	52	85/9/6	7	0.33	23	95 (95.3–99.2)
Stulberg et al. [54]	Series of cases	Cormet	337	68	50	86/0/14	2	8.3	24	92.9
Swank and Alkire [55]	Comparative study BHR vs THA	BHR	128 BHR vs 106 THA	62	51	71/5/24	1	0	2 BHR vs 0 THA	98.1
Takamura et al. [56]	Comparative study	Conserve plus	500	63	48	63/18/19	8	NR	34 without FNN vs 7 with FNN	86.7 with FNN vs 93.6 without FNN
Treacy et al. [57]	Series of cases	BHR	144		55	100/0/0	3.5	10	48	97.5 (96.3–98.3)
Vendittoli et al. [58]	Randomised controlled trial	Durom	109 Durom vs 100 THA	63	49	31/9/60	4.7	0	4 vs 2	96.3
Wang et al. [59]	Randomised controlled trial	Conserve plus	37 Conserve vs 39 THA	14	45.7	0/0/100	4.9	0	0	100
Witzleb et al. [60]	Series of cases	BHR	300	57	49	19/63/18	2	0.7	6	98

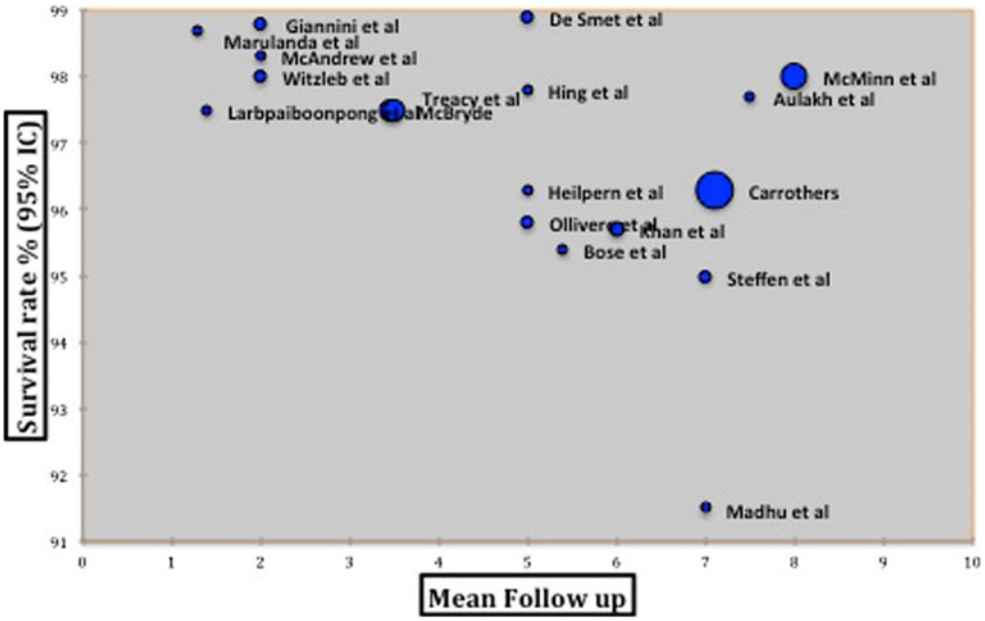

Fig. 2 Survival rate for the BHR implant

Results

Research has revealed 780 citations published between 1 January 2005 and 14 July 2012. The number of studies identified according to the criteria for inclusion/exclusion was 53 (Fig. 1).

Six studies examined the ASR Hip Resurfacing® implant (DePuy Orthopaedics Inc., Warsaw, Indiana), 22 the BHR implant® (Smith & Nephew Inc., Memphis, Tennessee), 11 the Conserve Plus® implant (Wright Medical Technology Inc, Arlington, Tennessee), five reviewed the Cormet 2000® implant (Corin Group PLC, Cirencester, United Kingdom) and four examined the Durom® implant (Zimmer, Warsaw, Indiana). One study reported the results of both BHR® and ASR® implants. Another study described the use of both the McMinn implant® (Corin Group PLC) and BHR® implant and another described only the second generation McMinn implant® (McMinn hybrid resurfacing; Corin Group PLC) which was only in use around 1996. One study compared the BHR® implant to the Recap® implant (Biomet Inc., Warsaw, Indiana). The data presented only six of the 11 resurfacing devices currently on the market. We were not able to identify studies that met our inclusion/exclusion for ACCIS® implants (Implantcast GmbH, Buxtehude, Germany), Adept® (Finsbury Orthopaedics), EskaBionik® (Eska Implants, Lübeck, Germany), Icon® (International Orthopaedics, Geisingen, Germany), and Mitch® (Stryker, Kalamazoo, Michigan).

Three randomised clinical trials and eight comparative studies compared the results of resurfacing implants to conventional total hip arthroplasty. The average survival rate for resurfacing implants was 94.84 % ± 4.7 (range, 89.1–100)

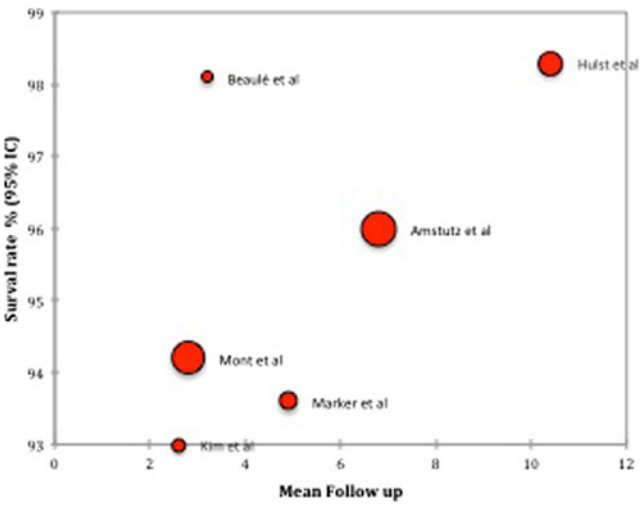

Fig. 3 Survival rate for implant Conserve Plus

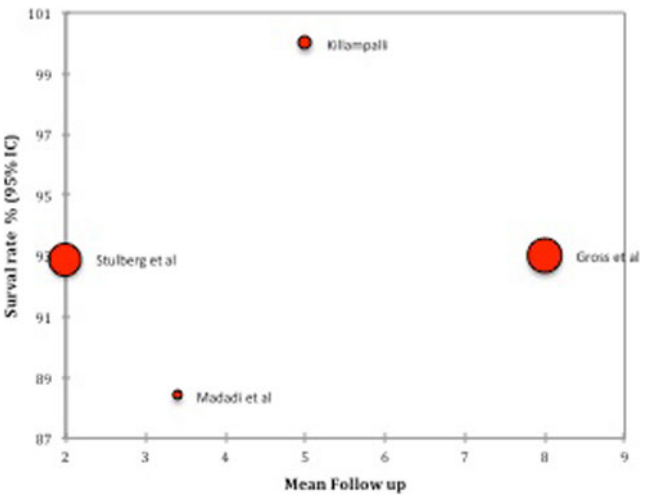

Fig. 4 Survival rate for implant Cormet

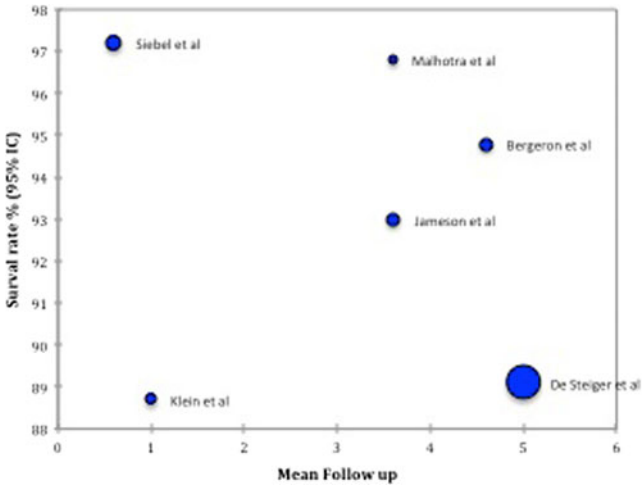

Fig. 5 Survival rate for the ASR implant

and functional scores were significantly better for them in all studies. The mean duration of follow-up for the majority of these studies was five years. The study by Baker et al. [8] reported a mean follow-up of nine years (range, 8.2–10.3) for the resurfacing group (BHR®) and 10.7 years (range, 7.5– 14.5) for the total hip arthroplasty group (THA). A randomised clinical trial had a mean follow-up of 4.7 years for both groups (Durom®).

Only two series directly compared the results of two different resurfacing implants. One study compared the results of 29 patients who underwent bilateral resurfacings, with a BHR® implant on one side and a ReCap® implant on the contralateral side. This study did not show any revision of either implants at a mean follow up of 4.8 years for the BHR® implant and 1.4 years for the ReCap® implant. Another study analysed a prospective series of 660 procedures with BHR® implants, ASR® and ASR® THA implants. This study found that 17 patients needed a revision (ASR® implant in all cases). The revision rate was 0 % for the BHR® implant, 3.2 % for ASR® and 6 % for THA® ASR. Steiger et al. [9] found similar results. The cumulative revision rate at five years was 10.9 % (95 % CI, 8.7–13.6) with the ASR implant and 4 % (95 % CI, 3.7–4.5) for other resurfacing implants. The cumulative revision rate due to metallosis was 1.7 % (95 % CI, 0.9–3.1) with the ASR® implant against 0.3 % (95 % CI, 0.2–0.5) for other implants.

Thirty-seven studies reported single arm results in terms of survival/revision for the different resurfacing implants (Table 1).

Of all the studies, the total number of resurfacing performed was 26,456 and the average number of cases per study was 499.17 ± 856.7 (range, 38–5000). The mean follow up was 4.3±2.54 (range, 0.6–10.5) years. The average age of patients was 50.75 years ±5.19 (range, 35–58). The percentage of males per study was 64.73 % ± 13.55 (range, 28–95). The median survival was 95.57 % ±3.7 (range, 84–100). The percentage of studies which satisfied the criteria set by NICE was 69.8 %. In terms of cumulative revision rates pondered by the number of implants BHR®, Conserve Plus®, Cormet® showed the best results (Figs. 2, 3, 4, and 5).

The details of the functional results for each study are reported in Table 2. The mean postoperative score was 91.2 ± 7.72 (range, 68.3–98.6). There was no statistically significant difference between implants in terms of functional outcomes.

The revision rate was 4.4 % if we considered all cases in these published series. The most frequent complications (Table 3; Fig. 6) were aseptic loosening 33.5 %, followed by femoral fractures.

According to the GRADE recommendation system, the quality of these studies in terms of level of evidence was very low except for a randomised clinical trial where the quality of results reported was low [7]. We could only find long-term studies for three types of implants: BHR, Conserve Plus, and Cormet. For these implants revision rates seemed to fit the criteria for NICE benchmarks. The implant ReCap had excellent results at 2.9 years of mean follow-up. The randomised clinical trial comparing the results of the Durom implant with those of a THA reported a higher rate of revision for the resurfacing implant. However, the difference was not statistically significant. The ASR implant did not fulfill the NICE criteria in any study.

Discussion

It is interesting to compare the results from the different national registries.

The Nordic Arthroplasty Register Association [10] has three national registries: Danish, Swedish and Norwegian. The total number of total hip replacements performed between 1995 and 2007 has reached a figure of 280,201, of which only 0.5 % represented resurfacing [61]. The revision rate at two years was reported as 2.4 % for all resurfacing vs 1.1 % for conventional THA. The main complications for resurfacings outlined were fractures and aseptic loosening. The Nordic register also highlighted a survival rate significantly higher in those centres performing greater than 70 cases per annum (98.8 %) than those performing fewer (95.5 %).

Analysis of the *Australian register* by Prosser et al. [1] succeeded the one of Buergi et al. [62] and examined 12,093 hip resurfacings performed between 1999 and 2008. The results were compared with those of conventional THA performed during the same period. Analysis of the registry showed that women had a higher revision rate than men. However, after adjusting the size of the femoral component

Table 2 Functional results

Authors	Implant	Number of hips	Functional score	Preoperative	Postoperative
Amstutz et al. [10]	Conserve plus	1107	UCLA	48	86.5
Aulakh et al. [11]	BHR	202	HHS	62 ON vs 58 OA	96 ON vs 95.8 OA
Baker et al. [8]	BHR	108	OXFORD		
Beaulé et al. [12]	Conserve plus	116	HHS	53.1	90.1
Bergeron et al. [13]	ASR	228	HHS	46.6	91
Bose et al. [14]	BHR	96	UCLA	NR	68.6
Carrothers et al. [15]	BHR	5000	HHS	NR	96
Costa et al. [16]	Cormet	73	NR	NR	NR
Daniel et al. [17]	McMinn and BHR	446	OXFORD	NR	77.5
Daniel et al. [18]	McMinn 2nd generation	184	OXFORD	NR	68.3
De Smet et al. [19]	BHR	252	HHS	NR	97.2
De Steiger et al. [9]	ASR	1167	NR	NR	NR
Della Valle et al. [20]	BHR	537	NR	NR	NR
Delport et al. [21]	BHR and Recap	56	HHS	45	96.3
Fowble et al. [22]	Conserve plus	50	HHS	45	97
Giannini et al. [23]	BHR	350	HHS	57	98.6
Gravius et al. [24]	Durom	82	HHS	40.1	94.6
Gross et al. [25]	Cormet	373	HHS	57	96
Heilpern et al. [26]	BHR	113	HHS	NR	96.4
Hing et al. [27]	BHR	230	HHS	62.2	95.2
Hulst et al. [28]	Conserve plus	643	NR	NR	NR
Jameson et al. [29]	ASR	214	HHS	51.3	94.5
Khan et al. [30]	BHR	679	HHS	47	95
Killampalli et al. [31]	Cormet	100	OXFORD	37.5	89.6
Kim et al. [32]	Conserve plus	200	HHS	55.8	92.1
Klein et al. [33]	ASR	115	HHS	59	96
Langton et al. [34]	BHR and ASR	660	HHS	NR	94 ASR vs 97 BHR vs 76 ASR THA
Larbpaiboonpong et al. [35]	BHR	40	HHS	35.1	96.4
Lei et al. [36]	Durom	90	HHS	57	93
Mackenzie et al. [37]	BHR	499	WOMAC	49.9 BHR vs 42.3 THA	91.9 BHR vs 87.1 THA
Madadi et al. [38]	Cormet	52	HHS	NR	96
Madhu et al. [39]	BHR	117	HHS	NR	84.4
Malhotra et al. [40]	ASR	32	HHS	39.6	88.4
Marker et al. [41]	Conserve plus	361	NR	NR	NR
Marulanda et al. [42]	BHR	230	OXFORD	27	78
McAndrew et al. [43]	BHR	180	HHS	44	72
McBryde [44]	BHR	2123	NR	NR	NR
McMinn et al. [45]	BHR	3095	OXFORD	NR	97.9 (13)
Mont et al. [46]	Conserve plus	54	HHS	52	90
Mont et al. [47]	Conserve plus	1016	HHS	NR	93.1
Naal et al. [48]	Durom	100	HHS	NR	94.7
Ollivere et al. [49]	BHR	463	HHS	NR	NR
Sandiford et al. [50]	BHR	141	HHS	54.1 HR vs 46.4 THA	96.8 HR vs 95.8 THA
Siebel et al. [51]	ASR	300	HHS	44	89
Smolders et al. [52]	Conserve plus	38	UCLA	NR	80 HR vs 70 THA

Table 2 (continued)

Authors	Implant	Number of hips	Functional score	Preoperative	Postoperative
Steffen et al. [53]	BHR	610	HHS	NR	93.1
Stulberg et al. [54]	Cormet	337	HHS	50.1	96.7
Swank and Alkire [55]	BHR	128	HHS	49	96
Takamura et al. [56]	Conserve plus	500	UCLA		
Treacy et al. [57]	BHR	2123	OXFORD	34.5	95.8
Vendittoli et al. [58]	Durom	109	WOMAC	45.1	90.6
Wang et al. [59]	Conserve plus	37	HHS	35.4 HR vs 35.9 THA	94.5 HR vs 95.1 THA
Witzleb et al. [60]	BHR	300	HHS	51	96

UCLA UCLA activity score, HHS Harris hip score, *OXFORD* Oxford hip score, *NR* not reported, *WOMAC* Western Ontario McMaster osteoarthritis index

revision rates were similar. Femoral implants of less than 50 mm in size had a higher revision rate than if the diameter was greater than or equal to 50 mm. At eight years the cumulative percentage revision for resurfacing was 5.3 (range, 4.6–6.2) against 4.0 (range, 3.8–4.2) for THA. However, in patients with primary hip OA, who were aged less than 55 years with a femoral implant size greater than or equal to 50 mm, the cumulative percentage revision was 3.0 (range, 2.2–4.2). Furthermore, Amstutz et al. [10] and McBryde et al. [44] found themselves documenting similar results for implants of smaller head sizes of less than 50 mm. The type of implant seemed to have an influence on the results. Durom implants, ASR, Cormet 2000 HAP and Recap had a higher revision rate and higher risk of fractures; this was statistically significant in comparison to other implants. The implant with the lowest fracture rate was the BHR implant with a five-year rate of 1.2 % (range, 1.0–1.5) against 3 % for ASR (range, 2–5), 2 % for Durom (range, 1–4) and 3 % (range, 1–9) for Recap. After adjusting for possible confounding factors, it appeared that the differences were only related to the designs of implants and surgical technique when preparing the femoral head. Finally, the registry highlighted that dysplastic hips were at a higher risk of revision.

Analysis of the *English register* was made by McMinn et al. [63] and included 283,365 procedures with a mean follow up of 3.6 years (range, 0.01–9.7). The objective of this analysis was unlike other registries, not only to study the revision rates after adjustment (with sex, age, size of implants, ASA / American Society of Anesthesiologists grade) but also to study the mortality rate. After adjusting for all known risk factors for revision surgery, mortality in men was statistically lower for the BHR implant in comparison to the uncemented THA group. The authors concluded for every 23 cases (males), there will be one less death in the BHR group in comparison to the cemented THA group at six years follow up.

In our review the percentage of studies that met the NICE criteria was 69.8 %. The average survival rate in these studies was significantly higher than the national registries. One explanation for this difference is that these studies are often single-operator led being experienced surgeons themselves. The most important series highlighted are those from design centres, which probably introduces a confounding factor.

However, analysis of records despite the large number of prosthesis is not provided to overestimate the information they provide. Indeed there are many confounding factors and bias that can lead to misinterpretation of the results.

First, record completeness is not guaranteed. So if the data collection seems close to 95 % for northern registers, it would be only 30 % for British records [64].

Second, the failure criteria is often the revision of the implant for whatever reason. This criteria is not necessarily impartial. This is because the sensitivity of the revision rate for clinical failure (insufficient functional score) is not identical between a resurfacing implant and a conventional total hip replacement. For example, as for knee arthroplasties, for hips with a poor functional outcome (HHS <30), only 12 % of THA may have been revised, as compared to 63 % of resurfacing with a similar score [63–65]. This calls into question the use of the revision rate for objectively comparing these two types of implants.

Third, the records do not account for the learning curve associated with the use of new implants [41, 66, 67]. Indeed for the implants on the market for over ten years there is no implication of a learning curve within the data held in the registries.

Finally, essential information is often missing: history of the patients, the ASA score, radiographic positioning of the implants, the presence of osteolysis, etc. This information is vital to determine the cause of failure, groups at risk and to compare similar groups of patients after adjustment for these criteria.

Table 3 Complications

Authors	Implant	Number of hips	Number of revisions	Neck fracture	Aseptic loosening	Infection	ALVAL	Dislocation	Malpositions	Persistent pain	Avascular necrosis	Other
Amstutz et al. [10]	Conserve plus	1107	44	9	26	2	0	1	0	0	0	6
Aulakh et al. [11]	BHR	202	6	3	1	1	0	0	0	0	1	0
Baker et al. [8]	BHR	108	5	0	0	0	0	0	0	0	5	0
Beaulé et al. [12]	Conserve plus	116	2	0	2	0	0	0	0	0	0	0
Bergeron et al. [13]	ASR	228	8	8	1	1	5	0	0	0	1	0
Bose et al. [14]	BHR	96	3	0	1	0	0	0	0	0	2	0
Carrothers et al. [15]	BHR	5000	182	54	56	17	15	5	3	0	30	2
Costa et al. [16]	Cormet	73	0	0	0	0	0	0	0	0	0	0
Daniel et al. [17]	McMinn and BHR	446	1	0	0	0	0	0	0	0	1	0
Daniel et al. [18]	McMinn 2nd generation	184	30	0	29	1	0	0	0	0	0	0
De Smet et al. [19]	BHR	252	3	1	0	1	0	0	0	0	1	0
De Steiger et al. [9]	ASR	1167	210	19	92	42	26	15	0	0	0	16
Della Valle et al. [20]	BHR	537	14	10	2	0	0	2	0	0	0	0
Delport et al. [21]	BHR and Recap	56	0	0	0	0	0	0	0	0	0	1
Fowble et al. [22]	Conserve plus	50	1	0	0	0	0	0	0	0	1	0
Giannini et al. [23]	BHR	350	4	3	0	0	0	0	0	0	1	0
Gravius et al. [24]	Durom	82	2	1	0	0	0	0	0	0	0	1
Gross et al. [25]	Cormet	373	21	5	12	2	2	0	0	0	0	0
Heilpern et al. [26]	BHR	113	4	1	2	0	0	0	0	0	1	0
Hing et al. [27]	BHR	230	2	0	1	0	0	0	0	0	1	0
Hulst et al. [28]	Conserve plus	643	45	0	5	0	0	0	0	0	0	0
Jameson et al. [29]	ASR	214	12	4	0	0	0	0	0	0	2	0
Khan et al. [30]	BHR	679	29	11	14	3	1	0	0	0	0	0
Killampalli et al. [31]	Cormet	100	0	0	0	0	0	0	0	0	0	0
Kim et al. [32]	Conserve plus	200	14	2	11	0	0	0	0	1	0	0
Klein et al. [33]	ASR	115	13	4	3	0	0	0	5	1	0	0
Langton et al. [34]	BHR and ASR	660	17	1	0	0	13	0	0	0	0	12
Larbpaiboonpong et al. [35]	BHR	40	1	1	0	0	0	0	0	0	0	0
Lei et al. [36]	Durom	90	1	1	1	0	0	0	0	0	0	0
Mackenzie et al. [37]	BHR	499	0	0	0	0	0	0	0	0	0	0
Madadi et al. [38]	Cormet	52	6	3	3	0	0	0	0	0	0	0
Madhu et al. [39]	BHR	117	8	5	0	1	0	0	0	0	2	0
Malhotra et al. [40]	ASR	32	1	1	0	0	0	0	0	0	0	0
Marker et al. [41]	Conserve plus	361	23	13	6	0	0	0	2	0	0	2

Table 3 (continued)

Authors	Implant	Number of hips	Number of revisions	Neck fracture	Aseptic loosening	Infection	ALVAL	Dislocation	Malpositions	Persistent pain	Avascular necrosis	Other
Marulanda et al. [42]	BHR	230	3	1	0	0	0	1	0	0	0	1
McAndrew et al. [43]	BHR	180	3	3	0	0	0	0	0	0	0	0
McBryde [44]	BHR	2123	48	13	9	4	0	0	2	7	6	3
McMinn et al. [45]	BHR	3095	68	12	2	14	10	2	0	2	25	1
Mont et al. [46]	Conserve plus	54	2	1	1	0	0	0	0	0	0	0
Mont et al. [47]	Conserve plus	1016	54	27	24	0	0	0	0	0	0	3
Naal et al. [48]	Durom	100	11	4	3	0	0	0	2	2	0	0
Ollivere et al. [49]	BHR	463	13	3	0	1	7	2	0	0	0	0
Sandiford et al. [50]	BHR	141	0	0	0	0	0	0	0	0	0	0
Siebel et al. [51]	ASR	300	8	5	1	0	0	1	0	0	0	1
Smolders et al. [52]	Conserve plus	38	1	0	0	0	0	0	0	0	1	0
Steffen et al. [53]	BHR	610	23	12	4	2	0	2	0	2	0	1
Stulberg et al. [54]	Cormet	337	24	8	15	0	0	1	0	0	0	0
Swank and Alkire [55]	BHR	128	2	1	0	0	0	0	0	0	0	0
Takamura et al. [56]	Conserve plus	500	41	6	26	1	0	1	1	0	0	4
Treacy et al. [57]	BHR	2123	48	1	1	3	0	1	0	0	3	1
Vendittoli et al. [58]	Durom	109	4	0	4	0	0	0	0	0	0	0
Wang et al. [59]	Conserve plus	37	0	0	0	0	0	1	0	0	0	0
Witzleb et al. [60]	BHR	300	6	1	1	2	0	0	1	1	0	0

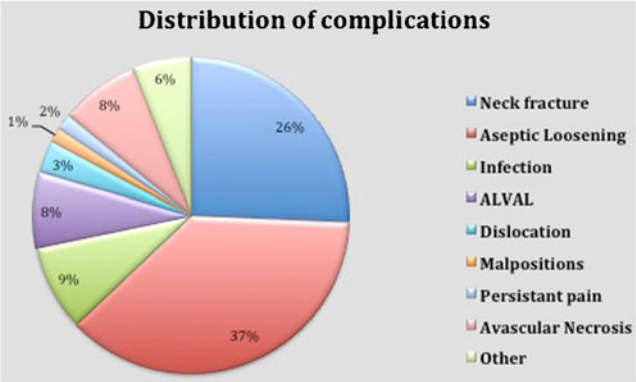

Fig. 6 Distribution of complications

In conclusion, this review of the literature emphasises the importance of certain parameters that can improve the results of resurfacing. The type of implant seems to play an important role as does patient selection. This should be based more on the expected size of the implant rather than the gender. Finally, it is clear that the resurfacing implants require a significant learning curve and implants are less "tolerant" than conventional THA, particularly for the orientation of the acetabular component [44, 61, 68].

Conflict of interest None.

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