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COMPARISON OF REVISION RISKS AND COMPLICATION RATES BETWEEN TOTAL HIP REPLACEMENT AND HIP RESURFACING WITHIN THE SIMILAR AGE GROUP

Short title: Revision Risk for total hip replacement and resurfacing

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COMPARISON OF REVISION RISKS AND COMPLICATION RATES BETWEEN TOTAL HIP REPLACEMENT AND HIP RESURFACING WITHIN THE SIMILAR AGE GROUP

Abstract

Background and Purpose: Currently it is not clear whether age is a factor affecting revisions in total hip replacement (THR) and hip resurfacing (HR). This study aimed to investigate which of THR or HR is a higher risk in terms of revision and complication within similar age groups.
Methods: A systemic review was performed for published literature research databases and local data and compared the two procedures under the condition that both groups of patients were age matched. Meta-analysis techniques were used to analyse revision and complication rates. Twenty-seven literature studies were included along with local audit data. In total, 2520 HR procedures were compared with age-matched 2526 of THR procedures.
Main findings: It was found that revision risk of HR is significantly higher than THR (risk ratio 1.65, 95% CI 1.28-2.31, $p<0.0001$), highlighting that HR has a slightly higher chance of reoperation when compared to THR within the similar age group population. In terms of complications, HR was found to have an advantage over THR (risk ratio 0.84, 95% CI 0.73-0.96, $p<0.01$).
Conclusion: THR had a lower revision risk but a slightly higher complication risk than HR under the condition that the two surgical procedures were applied to similar age groups of patients. In other words, age has not played an important role in revision and complication. Survivorship cannot be measured as follow-up periods were different in the studies used.

Keywords: Total hip replacement, Hip resurfacing, Age, Revision, Risk ratio.

Introduction

Total hip replacement (THR) is the surgical procedure for treating end-stage arthritis of the hips and to enhance the quality of life in elderly patients, with a survivorship of 90% at 10 years.[1] In young males under 55 years of age, survivorship reduces to 80% at 10 years and may drop as low as 58% at 15 years.[2] Thus, revision surgery becomes vital. Sometimes, depending on patient age, multiple revisions may be required.

Hip resurfacing (HR) has now advanced as a substitute to THR and is thought to have the potential to resolve the issue of survivorship in young patients with a survivorship greater than 95% at five years and can increase to 98%.[2, 3] The available literature is still inconsistent regarding rates of revision, incidences of complications, functional outcomes, patient satisfaction, and long-term results.[4, 5] Despite numerous theoretical advantages over THR, HR has been associated with specific complications, for example, periprosthetic femoral neck fractures and metal particle issues, which has therefore caused surgeons confusion in regard to using it as the standard treatment method for younger patients.[6]

Given that many believe that THR is suitable for the older age group whilst HR is better for the younger age group, the research question is whether age is a factor affecting revision and complication rates. In most studies, the patient data is divided for the two surgical procedures with different age, and the outcomes and therefore cannot be compared. Therefore, if the patients are matched for age, the efficacy of HR could then be appreciated. Although the literature studies have investigated these two surgical modalities and assessed the evidence base with respect to their clinical, functional and radiological results, there has been little formal meta-analysis regarding the revision and complication risk of HR and THR from the comparative studies. Very few studies have compared these two procedures performed simultaneously and there is no study which has compared them for similar age groups.

To investigate whether the efficacy of one surgical procedure over the other, this current study employed meta-analysis to investigate the two procedures within similar age groups. To our best knowledge, such analysis has not been carried out before and will provide more accurate risk assessment of the procedures, and can compare HR and THR more comprehensively.

Materials and Methods

Search strategy. The primary search was done from the databases of the search engines, including PubMed Medline, ScienceDirect, Web of Science, Embase and Scopus. These were searched via Ovid using key terms “hip resurfacing compared to total hip replacement and/or arthroplasty”, “revision rates of hip resurfacing and total hip replacement”, “survivorship after hip resurfacing” and “results of hip resurfacing and total hip replacement”. A secondary search was done from the reference list of relevant articles. Two authors carried out the selection of available articles.

Eligibility criteria. Using the obtained search results, relevant randomized controlled trials (RCTs) and observational studies (prospective and retrospective) were identified, which compared HR with THR. There was no language restriction in the search. There were no search specifications based on subject age, gender, preoperative diagnosis and type of prosthesis used. As the aim of the study was to look into specific factors like age group, the studies selected were where patient’s mean age difference between two modalities (HR and THR) were 5 or <5 years. To avoid surgical and clinical bias, articles included were only those that compared the two surgical procedures in terms of revisions, complications, functional results and survivorship. Thus, inclusion criteria were as follows: HR and THR comparative studies, studies having patient’s mean age difference 5/<5 years between HR and THR groups, and both procedures performed after the year 1990. The following studies were excluded: animal and cadaver studies, case reports, studies that report comparison outcomes of revision procedures, retrieval studies for failed implants, studies that compared either HR or THR with results of joint registries, meta-analysis, systematic reviews or editorial papers and studies which had either procedure performed before the year 1990. In total, 27 studies fitted all criteria (Figure 1).

[Figure 1]

Data extraction. Data were extracted from the included studies. The information collected was type of study (randomised, prospective or retrospective), patients' mean age, male and female ratio, average body mass index (BMI), number of patients in each cohort, time frame during which surgeries were performed, minimum follow-up, surgical approach used, type of prosthesis implanted, mean preoperative and postoperative Harris Hip Score (HHS), number of surgeons involved, number of complications, number of revisions with their reasons, and the overall survival. Another set of data was extracted from the xxxx (TAAG) database that was age and gender matched with all the same details as the studies from the literature. The TAAG database includes HR and THR surgeries performed during 2000-2014. TAAG data was analysed as one of the data sources parallel with the literature studies. The appropriate Caldicott ethical approval was obtained from the local University and NHS.

Primary outcome measure. The frequency of revision surgery due to any reason was the primary outcome measure.

Secondary outcomes measures. Included frequency of complications and preoperative and postoperative Harris Hip Score (HHS). Other outcome measures such as approach, duration of surgery, the length of hospital stay, radiological outcomes, quality of outcomes and immediate postoperative recovery status were not considered. All the complications (irrespective of their nature and time of occurrence) were grouped together for the outcome analysis.

Statistics. A meta-analysis was undertaken for the data extracted from the included studies and the local TAAG data. This was done using RevMan 5 software (version 5.3.5 Java 7 version for Mac OS X; The Nordic Cochrane Centre, Copenhagen, Denmark). IBM statistical package for social sciences (SPSS version 22) software was used to analyse the local data from the TAAG. Statistical heterogeneity was assessed with Chi^2 and I^2 tests. To assess any publication bias for the outcome measures, funnel plots were generated using the software RevMan 5, for revisions as well as for complications. The results of a comparable group were pooled using both the fixed-effect (Mantel-Haenszel test) and random-effect (DerSimonian and Laird method) models. Forest plots were created using the RevMan 5 software. A fixed-effect model was used for both the outcomes, as there was mild heterogeneity between studies for the outcomes of revision (I^2=6%) and no heterogeneity between studies for the outcomes of complications (I^2=0%). Mantel-Haenszel method was used to calculate risk ratio along with 95% confidence intervals (CI) for dichotomous data. For the outcomes, the current study used Risk Ratio (RR) as the summary static. RR was defined by the ratio of revision rates of HR to revision rates of THR. A revision rate was the ratio of the number of revision cases to the number of total cases. Similarly, the Risk Ratio for complications was the ratio of complication rates of HR to THR. In other words, if RR is larger than 1, HR has larger risk than THR, or vice versa. The p value <0.05 anywhere was considered significant.

Results

Cohort characteristics. From the 27 citations, 11 randomized controlled trials, 7 prospective and 9 retrospective studies were identified. The funnel plots revealed that no bias was present for the studies (Figures 2a and 2b). Altogether, there were 1862 HR procedures that were compared with 1899 THR procedures. From the local TAAG data, 658 HR were compared with age-matched 658 THR. In the included studies,[7-33] the mean age in the HR group was 51.3 years (SD 5.3) while the mean age in the THR

group was 52.8 years (SD 5.3). In the TAAG data, mean age was similar for the two groups 51.5 years (SD 8.3). In the included studies,[7-33] there were 1305 males and 516 females in the HR group. The THR group had 1240 males and 721 females. The TAAG data had 434 males and 224 females in the HR group, and 278 males and 380 females in the THR group. Twenty studies stated BMI, [7-33] for which means were 27.1 (SD, 1.4) and 28.1 (SD, 1.5) in HR and THR group respectively. Means of BMI in TAAG data were 27.8 (SD, 4.2) and 28.9 (SD, 5.8) for the HR and THR group respectively (Table 1). The follow-up of various studies ranged from the minimum of 6 months to maximum of 120 months. The demographic characteristics of all the included studies are shown in Table 1 and Table 2.

[Figures 2a and 2b]

[Tables 1 and 2]

Different types of prosthesis were used in the included studies.[7-33] The most common systems used for HR were Durom hybrid resurfacing [10-16] followed by Conserve plus.[7, 9, 20, 23, 26, 30] For the THR group the variety of implants used are shown in Table 3. In the TAAG data, the most commonly used system for resurfacing was Birmingham Hip Resurfacing (BHR) in 96% of cases. The collared polished tapered (CPT) and Exeter prosthesis accounted for 43% of the THR implants used. The most common indication for surgery was osteoarthritis.

[Table 3]

Meta-analysis

Risk Ratio for Revision rates. Of the included 27 literature studies, eight studies had zero revisions in both HR and THR groups. [11, 13, 18-21, 23, 31] Since there was marginal heterogeneity between studies for the outcome of revisions (I^2=5%), the fixed–effect model was used for the analysis. The pooled data, i.e. 27 literature studies and TAAG, showed a higher incidence of revision in the HR group than in the THR group with significant difference (RR, 1.65; 95% CI, 1.28-2.31; $p<0.0001$) and total revisions reaching 142 in the HR group and 86 in the THR group out of 2520 and 2556 cases respectively as seen in Figure 3. Moreover, when a random-effect model was used, the results were almost the same as the fixed-effect model (RR, 1.63; 95% CI, 1.20-2.20; $p<0.002$), favoured THR (Figure 4). With both the models (fixed-effect and random-effect), the overall effect remained significant ($p<0.0001$ and $p<0.002$) and the overall outcome favoured THR.

[Figs 3-4]

Risk Ratio for Complication rates. The complications were described in 22 literature studies and in the TAAG data. Five studies did not report complication rates.[13, 15-16, 23, 31] As there was no heterogeneity between studies for the outcome of complications (I^2=0), the fixed-effect model was used for the analysis. The overall complication risk in the literature studies and TAAG data was significant (RR, 0.84; 95% CI, 0.73-0.96; $p<0.01$) as seen in Figure 5. The causes of revisions for both HR and THR are described in Table 4 and Figure 6. The study by Stulberg et al (2009) had the maximum weight (34.9%), followed by local TAAG data (34.3%).[22] As the complication information was not fully reported by the literature studies, we report the complication details from TAAG only for reference. In the TAAG data, there were 86 complications for HR and 112

complications for THR (Table 5 and Figure 7). Other complications were systemic such as anaemia, pyrexia, postoperative hypotension, pressure sores etc. (encountered in both groups). It is not clear whether these complications were responsible for the revisions.

[Tables 4-5]

[Figures 5-7]

Discussion

The main findings of this study are that HR has a higher risk of revision when compared to THR ($p<0.001$) within the similar age groups. Regarding complications, HR had a lower ratio than THR ($p<0.01$). High rates of revision in HR could be related to many factors such as surgeon's experience, inappropriate patient and implant selection, but not to age. Currently, there is a lack of availability of long-term data on the modern HR designs. Still there is a lack of evidence to prove the clinical and functional superiority of HR over THR, but HR can provide similar functional results to THR, under experienced surgeon in a carefully selected patient in terms of age, gender and prosthesis design.

Revision rates described in early studies were poor with HR and related to factors such as early wear, osteolysis, and component loosening.[34] Whereas in another meta-analysis by Smith et al, HR had twice the revision risk as compared to THR.[35] A systemic review by Deborah et al [36] showed that revision rates are more frequent and early in HR when compared to THR. In all these studies, age has not been considered as a specific factor. Of the 27 included studies, five studies projected higher revisions risk in THR group as compared to HR group, [9, 16, 28-29, 32] eight studies could not estimate revision risks as there were no revisions in each group and 11 studies favoured THR by showing higher revision risk in HR. Three studies [7, 30, 33] showed exact equal revision rates with both procedures. Therefore, the current study, based on available literature and local data, provides relatively reliable evidence that HR is higher in revision than THR within similar age groups.

The current study also indicated that there may be an association between the type of prosthesis used and revision rates in the HR group. Seven of the included studies [10-16] used the Durom system, of which four had higher revisions for HR,[10, 12, 14-15] one study showed THR with higher risk [16] and the other two studies could not estimate the revision risk [11, 13]. Although the contributors to the failure of HR are multifactorial, component design, geometry, and acetabular component orientation could be the most important factors.

The current study also demonstrated that the complication risk in HR was better than THR ($p<0.01$). Nearly half of the described studies had high proportions of complications for THR as compared to HR. However, it was unclear what proportion of these complications were converted into revisions. Some of the complications, such as acute dislocation, sciatic nerve palsy, squeaking and trochanteric bursitis, were treated by re-operations rather than revising the existing components. Re-operations are a different entity from revisions and it was not known what proportion of these complications were actually revised or re-operated. In the TAAG data, the most common complications included infection (both deep and superficial), aseptic loosening and metallosis, accounting for approximately 75% of all complications. The revisions due to these three complications comprised approximately 70% of all the revisions. In

the THR group, common complications were infections (deep and superficial), periprosthetic fractures and aseptic loosening, which accounted for approximately 57% of all the complications and these were responsible for approximately 71% of the total revisions in the THR group. Marshall et al [37] concluded that revisions and reoperations were more frequent and occurred earlier with HR except when discontinued devices were removed from the analysis. Conversely, dislocations were more frequent with THR.

Strength and weaknesses. The strength of the current study is that it considered those comparative studies which had these procedures with similar mean age group, thereby minimising the surgical bias, which is the important key factor for the outcome of these procedures. Secondly, as HR had earlier poor results and unacceptably high rates of failures, it was taken into account only those studies that had these surgeries performed after the year 1990 when modern HR designs were first used. The strict selection criteria make this study unique. The study had a few limitations. Firstly, the included studies had inadequate length of follow-up, which are deficient in long-term follow-up data for modern HR when compared to conventional THR procedures. So, therefore no survivorship analysis was possible. Secondly, the included studies were not implant (prosthesis) specific. Thirdly, there could be a bias in revision risk, and it was not clear from available data what ratio of complications were converted to revisions. Finally, some of the included studies were operated by multi-level surgeons, which could affect the final outcome.

From the current study, it is still unclear regarding the superiority of one procedure over another. We can undoubtedly state that there is still argument and scope for further research on this topic. We need to review more isolated long-term randomized, prospective trials that will have a high level of evidence to the final outcome of the research. Moreover, research should also focus on other aspects such as surgical techniques, specific implant designs, and metallurgy.

Conclusion

The findings of the current study indicate that the revision risk of HR is significantly higher than THR within similar age group population. Literature studies have not reported this conclusion using age-matched data. In terms of complications, HR is found to have the advantage in comparison with THR. Survivorship cannot be measured as the follow-up periods were different in the studies used.

Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest.

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Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors. This study was approved by the local ethics research committee.

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Figure captions

Figure 1. Preferred reporting items for systematic reviews and meta-analysis (PRISMA) flow chart.

Figure 2. Funnel plots showing rare publication bias for a frequency of revision surgery on the left (2.a) and no publication bias for a frequency of complications on the right (2.b).
Note: Each dot represents a study/data source used; the vertical-axis shows study precision and the horizontal-axis gives the study's result. A symmetric inverted funnel shape means a 'good-quality' data set, in which publication bias is unlikely.

Figure 3. Forest plot to illustrate the difference in frequency of revision surgery between HR and THR using fixed-effect model.
Note: Forest plot shows risk ratios for each study (the point being the value and the line being associated confidence intervals), and the vertical line represents no effect. As risk ratio is calculated by HR/THR, and thus a value > 1 means that HR has higher risk than THR in revision.

Figure 4. Forest plot to illustrate the difference in frequency of revision surgery between HR and THR using random-effect model.
Note: The random-effect model is used to analyse data with bias. We use this model to double check the results from Figure 3 where a fixed-effect model was used. The results shows that both models gave similar results.

Figure 5. Forest plot to illustrate the difference in frequency of complications between HR and THR.
Note: As risk ratio is calculated by HR/THR, and thus a value > 1 means that HR has higher risk than THR in complication.

Figure 6. Proportion of complications in HR and THR in TAAG data.
Note: The results are displayed as clinical reference rather than statistical comparison

Figure 7. The reasons for revisions in HR and THR in both Literature studies and TAAG data.
Note: The results are displayed as clinical reference rather than statistical comparison

Table 1. Demographic characteristics of the Literature studies and TAAG data

Characteristics	**Literature Studies**		**TAAG Data**	
	HR Studies	**THR Studies**	**HR**	**THR**
No. of studies	**27**	**27**		
Total No. of hips	**1862**	**1899**	**658**	**658**
Gender M/F	1305/516	1240/721	434/224	278/380
Mean age, yrs (SD; range)	51.3 (5.3;34-64)	52.8 (5.3;35-64)	51.5 (8.3;21-75)	51.5 (8.3;21-75)
Mean BMI (kg/m^2) (SD; range)	27.1 (1.4;23.5-29)	28.1 (1.5;23.3-30)	27.8 (4.2;12.8-42.1)	28.9 (5.8;11.1-64.9)
Mean pre-op HHS, months (SD)	50.0 (6.85)	47.7 (6.37)	48.9 (11.5)	43.6 (10.9)
Mean post-op HHS, months (SD)	93.0 (3.89)	92.80 (4.5)	94.5 (9.8)	87.7 (11.4)
Diagnosis				
Osteoarthritis	1333	1256	575	501
Dysplastic Hip	90	80	38	21
Osteonecrosis	119	128	12	54
Post-traumatic arthritis	19	20	7	6
Ankylosing Spondylitis	0	0	6	6
Perthes' Disease	0	0	5	15
Rheumatoid Arthritis	19	20	1	24
Others	0	0	14	32
Not recorded	282	395	0	0
Surgical approach				
Posterior	1151 (16)	888(15)	636	206
Anterolateral	237 (4)	237 (4)	12	395
Lateral	0	0	9	27
Posterolateral	76 (2)	176 (3)	0	29
Not recorded	398 (5)	598 (5)	1	1
No. of complications	198	203	86	112
No. of revisions	77	45	65	41

Note: SD: standard deviation; HHS; Harris Hip Score; TAAG is local data used as one of data sources in meta-analysis.

Table 2. Demographic characteristics of the Randomized controlled trials and selected data sources

Randomized controlled trials	No. of hips	Males / Females	Mean age (years)	Mean BMI (kg/m^2)	Duration of Surgeries	Min. follow-up (months)
Bisseling et al[7]	HR-38	21/17	57.5	26.1	2007-2010	36
	THR-33	21/12	59.2	28	2007-2010	36
Gustafson et al[8]	HR-19	9/10	64	26	2005-2007	60
	THR-25	7/18	64	27	2005-2007	60
Smolders et al[9]	HR-38	21/17	57.5	26.1	2007-2010	24
	THR-34	21/13	59.1	28	2007-2010	24
Vendittoli et al[10]	HR-109	69/40	49.2	27	2003-2006	96
	THR-100	68/32	51	30	2003-2006	96
Lavigne et al[11]	HR-24	14/10	49.6	27.9	2006-2007	12
	THR-24	15/9	49.8	27.8	2006-2007	12
Vendittoli et al[12]	HR-64	42/22	49	27.1	2003-2006	24
	THR-53	33/20	51	29.2	2003-2006	24
Garbuz et al [13]	HR-48	45/3	51.5	28.3	2005-2008	12
	THR-56	50/6	52	28.2	2005-2008	12
Rama et al[14]	HR-56	65/38	50	27.3	2003-2005	12
	THR-97	66/31	50	29.7	2003-2005	12
Lavigne et al[15]	HR-81	53/28	48.4	27	-	27
	THR-71	51/20	50	28.7	-	27
Girard et al[16]	HR-49	31/18	47	27.3	2003-2005	12
	THR-55	34/21	48	29.6	2003-2005	12
Howie et al[17]	HR-11	6/5	46	-	1993-1995	101
	THR-13	9/4	50	-	1993-1995	101
Prospective studies						
Fink Barnes et al[18]	HR-89	80/0	52.7	28.6	2006-2010	24
	THR-47	43/0	57.4	30.3	2006-2010	24
Costa ML et al[19]	HR-60	38/22	56.3	28.6	2007-2010	12
	THR-66	36/30	56.6	28.7	2007-2010	12
Wang et al[20]	HR-37	5/29	45.7	23.5	2005-2006	59.4
	THR-39	9/29	46.5	23.3	2005-2006	60.6
Sandiford et al[21]	HR-141	93/44	55.3	26	2000-2002	19.2
	THR-141	75/59	53.9	26	2000-2002	13.4
Stulberg et al[22]	HR-337	228/109	50	-	2001-2003	24
	THR-266	165/101	53	-	2001-2003	24
Zywiel et al [23]	HR-33	23/10	53	28	2002-2005	42
	THR-33	23/10	53	29	2002-2005	42
Mont et al[24]	HR-30	18/12	34	-	1992-1996	84
	THR-30	18/12	35	-	1992-1996	90
Retrospective studies						
Parry et al[25]	HR-87	79/8	53	-	2004-2010	72
	THR-89	34/55	58	-	2004-2010	60
Arndt et al[26]	HR-55	38/17	49.6	-	2002-2005	48.6
	THR-100	74/26	56.5	-	1997-2001	56.8
Issa et al[27]	HR-120	114/0	50	28.2	2007-2009	40
	THR-120	117/0	53	28.7	2007-2009	40
Costa CR et al[28]	HR-73	63/4	51	28	2007-2009	30
	THR-137	65/60	54	28	2007-2009	30
Baker et al[29]	HR-63	40/11	49.8	25.7	1999-2001	108
	THR-54	40/13	50.4	27	1996-2001	108
Mont et al[30]	HR-54	36/18	55	29	2002-2005	39
	THR-54	36/18	55	29	2002-2005	39
Patel et al[31]	HR-12	9/3	55.9	-	-	24
	THR-12	9/3	57.8	-	-	24
Hall et al[32]	HR-33	27/6	53.7	-	2006-2007	6
	THR-99	81/18	55.3	-	2006-2007	6
Pollard et al[33]	HR-54	40/13	50	25.7	1999-2001	61
	THR-51	40/11	50	27	1996-2001	80
TAAG data	HR-658	434/224	51.5	27.8	2001-2011	120
	THR-658	278/380	51.5	28.9	2001-2011	120

Note: Selected studies have similar age groups in THR and HR; Follow-up are different.

Table 3. Varieties of prosthesis used in HR and THR in literature studies and local data

HR prosthesis type	**No. of patients (No. of literature studies) using the implant (n=1862)**	**No. of patients using the implant in TAAG data (n=658)**
Birmingham Hip Resurfacing system (Smith and Nephew, Warwick UK)	380 (4)	-
BHR-Midland Technologies, UK	66 (2)	622
Conserve Plus (Wright Medical Technology, Arlington, TN)	255 (6)	-
Durom hybrid resurfacing system (Zimmer, Warsaw, IN)	478 (7)	34
Cormet MoM (Corin, UK)	530 (3)	-
Stemless resurfacing system (Depuy, Warsaw, IND)	30 (1)	-
McMinn acetabular and mini stemmed McMinn femoral resurfacing component (Corin Medical Ltd, UK)	11 (1)	-
Recap Femoral Resurfacing System (Biomet,UK)	19 (1)	-
Mitch TRH (Stryker)	0 (0)	2
Not stated	93(2)	-
THR prosthesis type	**No. of patients (No. of literature studies) using the implant**	**No. of patients using the implant in TAAG data**
Zweymuller Classic (Zimmer)	67(2)	-
CLS Spotorno (Zimmer)	232(3)	54
CPT (Zimmer)	145(3)	188
VERSYS FMT (Zimmer)	100(1)	-
M/L Taper (ZIMMER)	56(1)	31
Exeter (Howmedica, Stryker)	92(3)	92
E-series (Stryker)	90(1)	-
Accolade (Stryker)	290(3)	10
SL Plus (Stryker)	39(1)	-
ABG I and II (Stryker)	266(3)	15
Aesculap (Aesculap)	-	17
Biomet (Biomet)	-	1
Summit and Pinnacle (Depuy)	89(1)	-
Corail pinnacle (Depuy)	141(1)	1
Charnley (Depuy)	-	51
Lubinus (LINK)	-	23
Mayo (Zimmer)	-	64
Polarstem (Smith and Nephew)	-	1
Profemur (Wright Medial)	-	1
S-ROM (Depuy)	-	1
Spectron (Smith and Nephew)	12(1)	3
Synergy (Smith and Nephew)	-	96
Taperloc (Biomet)	-	6

Table 4. Reasons for revision in HR and THR in both Literature studies and TAAG data

Reason for Revision	**No of revisions in Literature studies (% of total revisions)**		**No revisions in TAAG data (% of total revisions)**	
	HR	**THR**	**HR**	**THR**
Aseptic loosening of acetabulum/ femur	39 (50.6%)	15 (33.3%)	22 (33.8%)	8 (19.5%)
Infection	3 (3.9%)	8 (17.7%)	4 (6.1%)	4 (9.7%)
Peri-prosthetic fracture	19 (24.6%)	8 (17.7%)	5 (7.6%)	5 (12.2%)
Dislocation	3 (3.9%)	12 (26.6%)	3 (4.6%)	8 (19.5%)
Unexplained pain	3 (3.9%)	2 (4.4%)	11 (16.9%)	6 (14.6%)
Metallosis	6 (7.7%)	-	18 (27.6%)	10 (24.3%)
Avascular necrosis of femoral head	4 (5.1%)	-	2 (3%)	-
Total Revisions	77	45	65	41

Table 5. Common complications in the two groups of TAAG data

Complication	No of HR cases	No of THR cases
Superficial infection	13	21
Deep infection	5	17
Loose acetabulum/ femur	16	8
Peri-prosthetic fracture	5	18
Dislocation	4	13
Deep Vein Thrombus (DVT)	2	4
Metallosis	17	6
Sciatic Nerve palsy	3	5
Others (pyrexia, UTI, chest infections etc.,)	21	20

Figure 1

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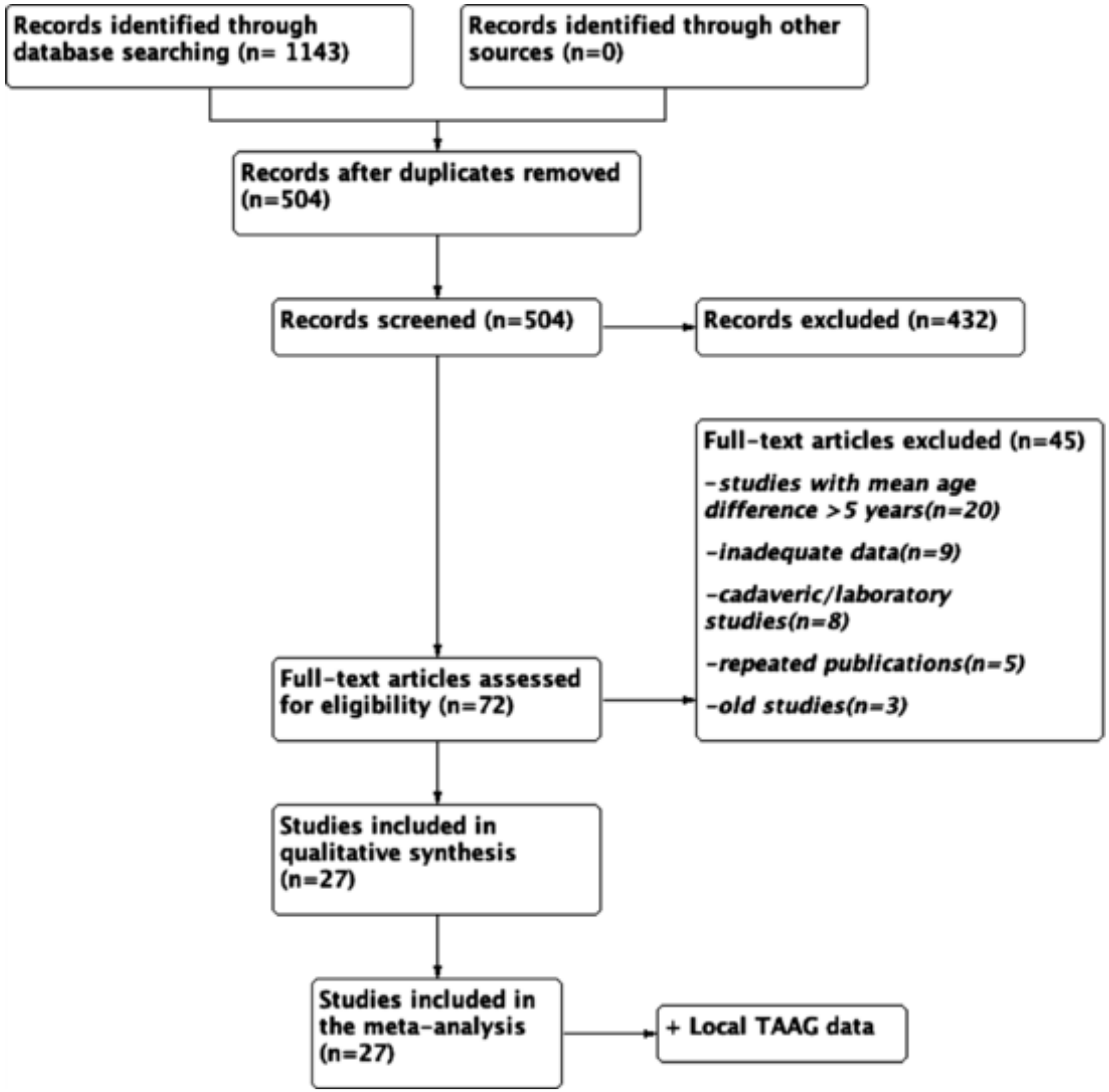

Figure 2a

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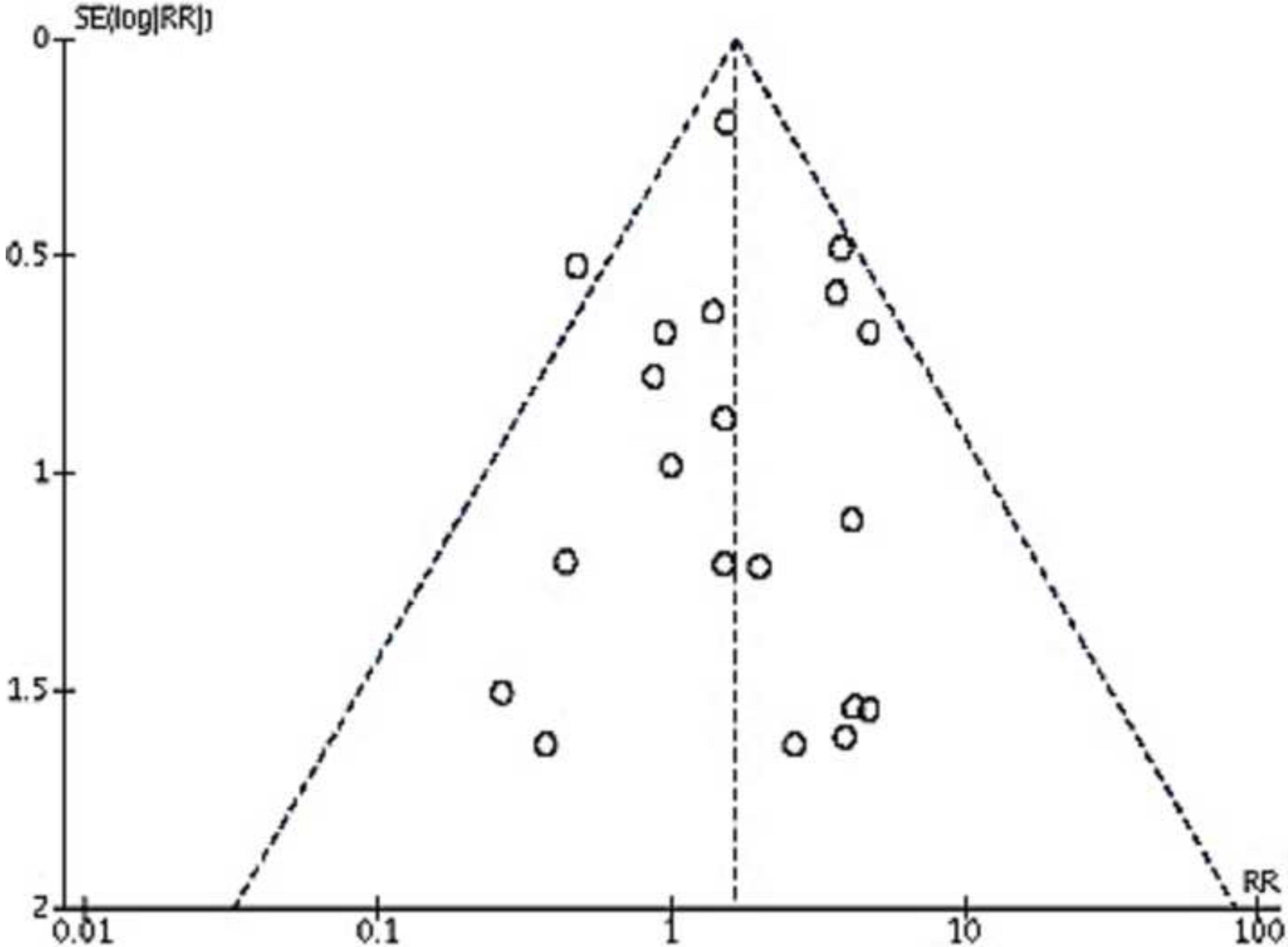

Figure 2b
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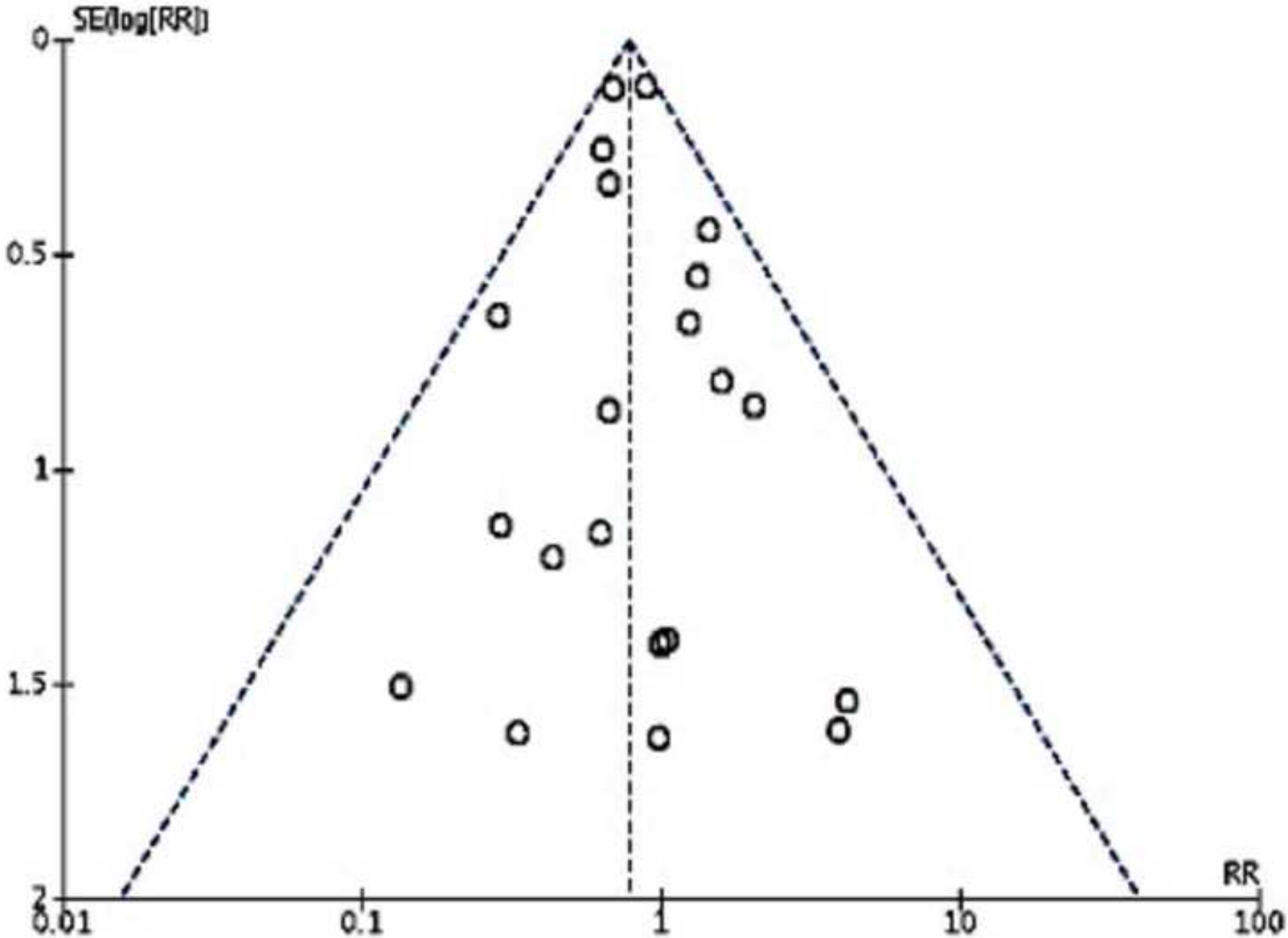

Figure 3

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Study or Subgroup	Hip resurfacing Events	Hip resurfacing Total	Total Hip Replacement Events	Total Hip Replacement Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Ardnt et al 2013	8	55	4	100	3.2%	3.64 [1.15, 11.53]
Baker et al 2011	5	63	9	54	11.1%	0.48 [0.17, 1.34]
Bisseling et al 2015	3	38	3	33	3.7%	0.87 [0.19, 4.01]
Costa CR et al 2011	0	73	3	137	2.8%	0.27 [0.01, 5.09]
Costa ML et al 2012	0	60	0	66		Not estimable
Fink Barnes et al 2014	0	89	0	47		Not estimable
Garbuz et al 2010	0	48	0	56		Not estimable
Girard et al 2006	0	49	1	55	1.6%	0.37 [0.02, 8.96]
Gustafson et al 2014	1	19	0	25	0.5%	3.90 [0.17, 90.74]
Hall et al 2009	1	33	2	99	1.1%	1.50 [0.14, 16.01]
Howie et al 2005	8	11	2	13	2.1%	4.73 [1.26, 17.79]
Issa et al 2013	2	120	1	120	1.1%	2.00 [0.18, 21.76]
Lavigne et al 2008	1	81	0	71	0.6%	2.63 [0.11, 63.65]
Lavigne et al 2010	0	24	0	24		Not estimable
Mont et al 2001	3	30	2	30	2.3%	1.50 [0.27, 8.34]
Mont et al 2009	2	54	2	54	2.3%	1.00 [0.15, 6.84]
Parry et al 2015	4	87	1	89	1.1%	4.09 [0.47, 35.88]
Patel et al 2009	0	12	0	12		Not estimable
Pollard et al 2006	4	54	4	51	4.7%	0.94 [0.25, 3.58]
Rama et al 2009	2	103	0	97	0.6%	4.71 [0.23, 96.91]
Sandiford et al 2010	0	141	0	141		Not estimable
Smolders et al 2013	1	38	2	33	2.4%	0.43 [0.04, 4.57]
Stulberg et al 2009	24	337	5	266	6.4%	3.79 [1.47, 9.80]
TAAG data	65	658	41	658	46.9%	1.59 [1.09, 2.31]
Vendittoli et al 2010	2	64	0	53	0.6%	4.15 [0.20, 84.68]
Vendittoli et al 2013	6	109	4	100	4.8%	1.38 [0.40, 4.74]
Wang et al 2012	0	37	0	39		Not estimable
Zywiel et al 2009	0	33	0	33		Not estimable
Total (95% CI)		**2520**		**2556**	**100.0%**	**1.65 [1.28, 2.13]**
Total events	142		86			

Heterogeneity: $Chi^2 = 19.94$, df = 19 (P = 0.40); $I^2 = 5\%$

Test for overall effect: Z = 3.86 (P = 0.0001)

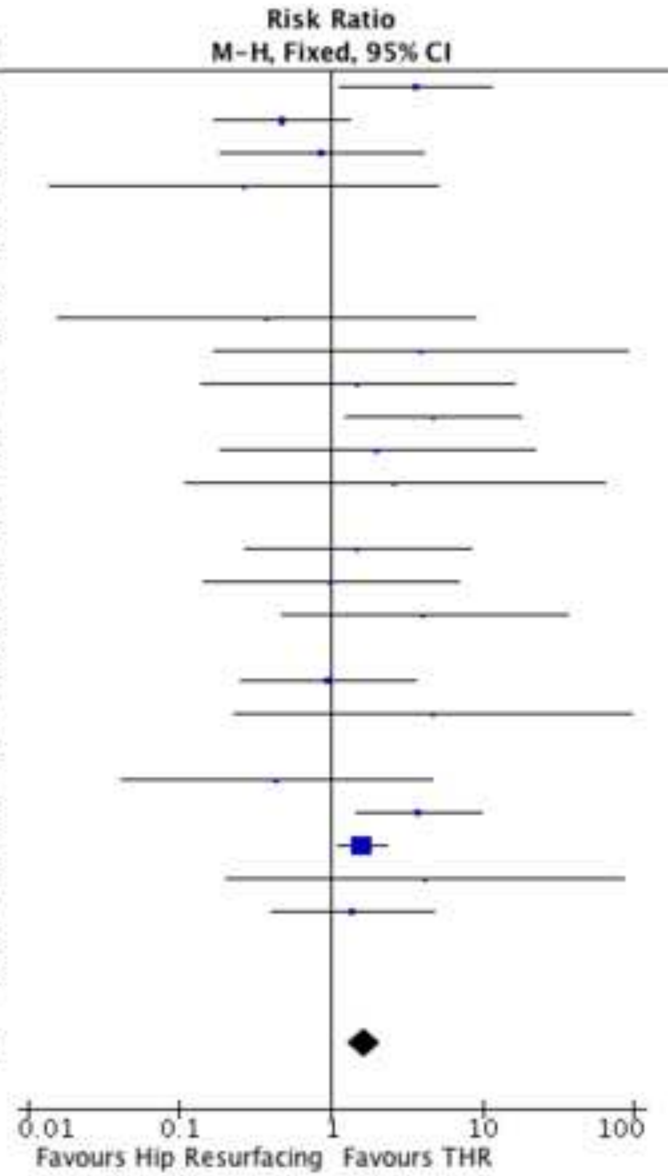

Figure 4

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Study or Subgroup	Hip resurfacing Events	Hip resurfacing Total	Total Hip Replacement Events	Total Hip Replacement Total	Weight	Risk Ratio M-H, Random, 95% CI
Ardnt et al 2013	8	55	4	100	6.4%	3.64 [1.15, 11.53]
Baker et al 2011	5	63	9	54	7.9%	0.48 [0.17, 1.34]
Bisseling et al 2015	3	38	3	33	3.8%	0.87 [0.19, 4.01]
Costa CR et al 2011	0	73	3	137	1.0%	0.27 [0.01, 5.09]
Costa ML et al 2012	0	60	0	66		Not estimable
Fink Barnes et al 2014	0	89	0	47		Not estimable
Garbuz et al 2010	0	48	0	56		Not estimable
Girard et al 2006	0	49	1	55	0.9%	0.37 [0.02, 8.96]
Gustafson et al 2014	1	19	0	25	0.9%	3.90 [0.17, 90.74]
Hall et al 2009	1	33	2	99	1.6%	1.50 [0.14, 16.01]
Howie et al 2005	8	11	2	13	5.0%	4.73 [1.26, 17.79]
Issa et al 2013	2	120	1	120	1.6%	2.00 [0.18, 21.76]
Lavigne et al 2008	1	81	0	71	0.9%	2.63 [0.11, 63.65]
Lavigne et al 2010	0	24	0	24		Not estimable
Mont et al 2001	3	30	2	30	3.0%	1.50 [0.27, 8.34]
Mont et al 2009	2	54	2	54	2.4%	1.00 [0.15, 6.84]
Parry et al 2015	4	87	1	89	1.9%	4.09 [0.47, 35.88]
Patel et al 2009	0	12	0	12		Not estimable
Pollard et al 2006	4	54	4	51	4.9%	0.94 [0.25, 3.58]
Rama et al 2009	2	103	0	97	1.0%	4.71 [0.23, 96.91]
Sandiford et al 2010	0	141	0	141		Not estimable
Smolders et al 2013	1	38	2	33	1.6%	0.43 [0.04, 4.57]
Stulberg et al 2009	24	337	5	266	9.2%	3.79 [1.47, 9.80]
TAAG data	65	658	41	658	39.3%	1.59 [1.09, 2.31]
Vendittoli et al 2010	2	64	0	53	1.0%	4.15 [0.20, 84.68]
Vendittoli et al 2013	6	109	4	100	5.7%	1.38 [0.40, 4.74]
Wang et al 2012	0	37	0	39		Not estimable
Zywiel et al 2009	0	33	0	33		Not estimable
Total (95% CI)		**2520**		**2556**	**100.0%**	**1.63 [1.20, 2.20]**
Total events	142		86			

Heterogeneity: $Tau^2 = 0.02$; $Chi^2 = 19.94$, $df = 19$ ($P = 0.40$); $I^2 = 5\%$

Test for overall effect: $Z = 3.15$ ($P = 0.002$)

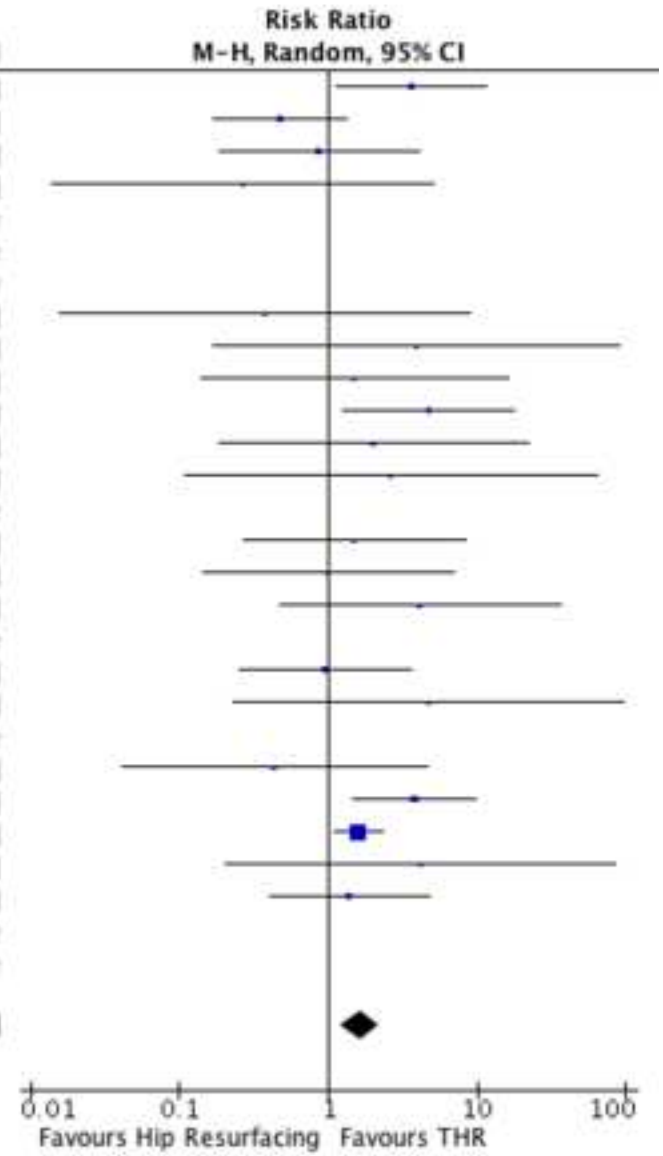

Figure 5

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Study or Subgroup	Hip resurfacing Events	Hip resurfacing Total	Total Hip Replacement Events	Total Hip Replacement Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Ardnt et al 2013	8	55	10	100	2.2%	1.45 [0.61, 3.47]
Baker et al 2011	3	63	9	54	3.0%	0.29 [0.08, 1.00]
Bisseling et al 2015	1	38	3	33	1.0%	0.29 [0.03, 2.65]
Costa CR et al 2011	1	73	3	137	0.6%	0.63 [0.07, 5.91]
Costa ML et al 2012	11	60	18	66	5.2%	0.67 [0.35, 1.31]
Fink Barnes et al 2014	6	89	2	47	0.8%	1.58 [0.33, 7.55]
Garbuz et al 2010	0	48	0	56		Not estimable
Girard et al 2006	0	49	0	55		Not estimable
Gustafson et al 2014	1	19	0	25	0.1%	3.90 [0.17, 90.74]
Hall et al 2009	0	33	1	99	0.2%	0.98 [0.04, 23.50]
Howie et al 2005	8	11	3	13	0.8%	3.15 [1.10, 9.06]
Issa et al 2013	1	120	1	120	0.3%	1.00 [0.06, 15.80]
Lavigne et al 2008	0	81	0	71		Not estimable
Lavigne et al 2010	2	24	3	24	0.9%	0.67 [0.12, 3.64]
Mont et al 2001	0	30	1	30	0.5%	0.33 [0.01, 7.87]
Mont et al 2009	1	54	1	54	0.3%	1.00 [0.06, 15.58]
Parry et al 2015	4	87	2	89	0.6%	2.05 [0.38, 10.88]
Patel et al 2009	0	12	0	12		Not estimable
Pollard et al 2006	7	54	5	51	1.6%	1.32 [0.45, 3.90]
Rama et al 2009	0	103	3	97	1.1%	0.13 [0.01, 2.57]
Sandiford et al 2010	5	141	4	141	1.2%	1.25 [0.34, 4.56]
Smolders et al 2013	1	38	2	33	0.7%	0.43 [0.04, 4.57]
Stulberg et al 2009	115	337	102	266	34.9%	0.89 [0.72, 1.10]
TAAG data	86	658	112	658	34.3%	0.77 [0.59, 1.00]
Vendittoli et al 2010	2	64	0	53	0.2%	4.15 [0.20, 84.68]
Vendittoli et al 2013	20	109	29	100	9.3%	0.63 [0.38, 1.04]
Wang et al 2012	1	37	1	39	0.3%	1.05 [0.07, 16.24]
Zywiel et al 2009	0	33	0	33		Not estimable
Total (95% CI)		**2520**		**2556**	**100.0%**	**0.84 [0.73, 0.96]**
Total events	284		315			

Heterogeneity: $Chi^2 = 20.76$, df = 22 (P = 0.54); $I^2 = 0\%$

Test for overall effect: Z = 2.47 (P = 0.01)

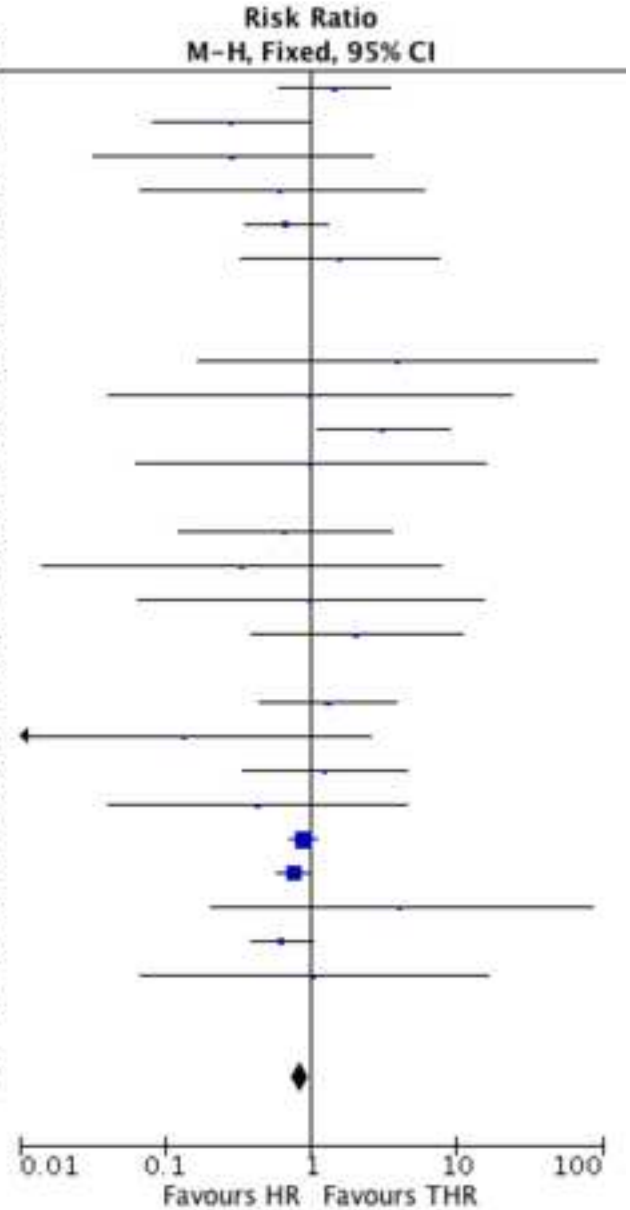

Figure 6
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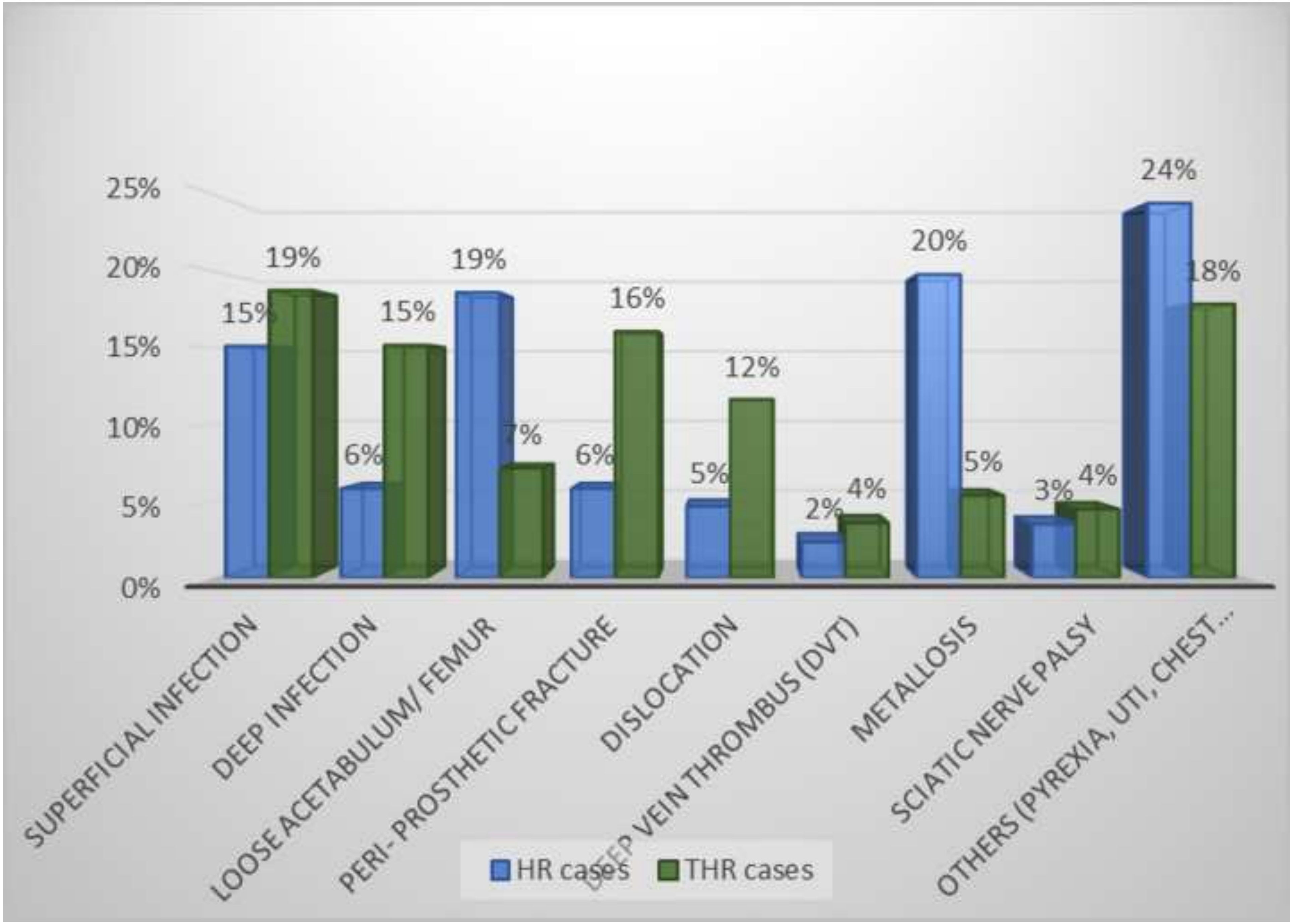

Figure 7
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