SYSTEMATIC REVIEW

Complications Rate and Hip Function After Revision of Infected Hip Arthroplasty with Bone Defects using Bone Allografts: A Systematic Review and Meta-Analysis

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Abstract

Objectives: We performed a systematic review and meta-analysis to evaluate complication rates and hip function following the revision of infected hip arthroplasty with bone defects using bone allografts.

Methods: A comprehensive search of the PubMed, Web of Science, Embase, and Cochrane Library databases was conducted up to January 2024 to identify pre-post clinical trials. The primary outcomes assessed were the risk of reinfection, a critical concern for surgeons, and hip functional scores. The methodological quality of the included studies was also evaluated. A weighted mean difference (WMD) with a 95% confidence interval (CI) was used as the pooled estimate for clinical outcomes through random-effects meta-analysis, accounting for heterogeneity across studies.

Results: Of the 2,189 records retrieved, 12 pre-post clinical trials (with fair to good quality) were included in the meta-analysis, involving a total of 342 participants. The pooled mean difference in Harris Hip Score (HHS) was 36.86 (95% CI: 29.58 to 44.13) post-surgery. In a subgroup analysis of studies employing structural grafts, the HHS increased by 36.99 (95% CI: 29.56 to 44.42). The overall reinfection rate was 6%. Subgroup analysis revealed that in studies utilizing morselized and structural allografts, the reinfection rates were 6% and 3%, respectively. The overall mean rate of aseptic loosening was 5%. Subgroup analysis showed that in studies using morselized grafts, the rate of aseptic loosening was 4%. The incidence of dislocation was 2% in the morselized group and 5% in the structural group.

Conclusion: Revision of infected hip arthroplasty with bone defects using bone allografts may improve hip function. Interestingly, morselized allografts are often associated with higher rates of reinfection. Additionally, our findings suggest that structural allografts are associated with increased dislocation rates compared to morselized allografts. This difference may be attributed to the larger and more complex defects that necessitated the use of structural allografts rather than morselized grafts.

Level of evidence: III

Keywords: Bone allograft, Infection, Meta-analysis, Total hip arthroplasty

Introduction

Periprosthetic joint infection (PJI) represents a highly complex challenge in the field of revision total hip arthroplasty (rTHA). Moreover, when this complication is accompanied by significant bone loss, the complexity of the situation is further compounded.[1,2] Effectively managing this issue requires not only infection control but also the reconstruction of the deficient bone. Several strategies have been proposed to address acetabular bone deficiencies, including bone grafts (bulk or morselized), metal mesh, various cage designs,[1] and tantalum metal augments.[3] Historically, bone loss due to infection was considered a contraindication for re-implantation,[4] primarily due to concerns about the risk of reinfection when using bone allografts. However,

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contemporary surgical approaches have become more cautious regarding the use of bone allografts in cases with a history of prior infection.

Adequate bone stock is the most crucial factor in long-term fixation,[5] and the use of bone allografts to compensate for bone loss has yielded variable results. Acceptable outcomes have been reported in the mid-term when impacted allografts are used for rTHA in non-infected cases.[6,7] While there have been proposals to use bone allografts in cases of infection.[8–11] this practice remains controversial due to concerns about the increased risk of reinfection.[8,12] To enable evidence-based decision-making, there is a clear need for a systematic review of the available evidence to provide further insight into the safety of bone allografts in these cases.

This systematic review and meta-analysis aims to search for and evaluate studies reporting outcomes related to the use of bone allografts in revision THA for infected hip joints with acetabular or proximal femur defects. Specifically, we aim to determine: 1) the complication rate, particularly reinfection, and 2) the hip function as measured by the Harris Hip Score (HHS).

Materials and Methods

This review was conducted in accordance with the guidelines and checklist of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[13] This systematic review and meta-analysis were registered with the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42023474113, https://www.crd.york.ac.uk/PROSPERO/).

Study Eligibility (Inclusion and Exclusion Criteria)

Studies were considered acceptable for inclusion in the systematic review if they met the following PICOD criteria: Population (P): rTHA following a previous infected THA with bone defects; Intervention (I): Bone allograft for bone defects (acetabular or proximal femur); Comparison (C): Not applicable; Outcome (O): Complications such as reinfection and hip functional scores; Design (D): Single-group before-after clinical trials. The following criteria were used for the exclusion of studies: animal studies, in vitro studies, letters to the editor, case reports, review articles, studies lacking data on the outcomes of interest, non-English language abstracts, and articles with insufficient data [Figure 1].

Literature Search

All authors established the research protocol for this review before the commencement of the literature searches. We conducted a comprehensive search for all pre-post clinical trials that evaluated the surgical outcomes or complication rates following the use of bone allografts in primary or revision THA for infected hip joints with bone (acetabular or femoral) defects. We searched the Cochrane Central Register of Controlled Trials, MEDLINE, Web of Science, and EMBASE for relevant controlled clinical trials from their inception to January 2024. The search strategy included the following MeSH terms and text keywords: ("Total hip arthroplasty" OR "Hip arthroplasty" OR "Hip replacement" OR "THA" OR "Total hip replacement") AND ("Bone defect" OR "Acetabular defect") AND ("Infection" OR "Reinfection" OR "PJI" OR "infected revision" OR "septic arthritis"). The reference lists of the included studies were also reviewed to identify relevant controlled clinical trials [Figure 1].

Study Selection and Data Abstraction

Two reviewers (M.S. and M.D.) independently extracted the following data: first author, year of publication, country, sample size, initial diagnosis, patient characteristics (age and sex), follow-up duration, HSS, pathogens isolated, complication rates (e.g., reinfection), type of reconstruction, antibiotic agents, type of bone allograft, duration of oral antibiotics, duration of intravenous antibiotics, and the time between excision arthroplasty and reconstruction THA for each study. A third reviewer (O.S.) resolved any disagreements between the two primary reviewers.

Risk of Bias Assessment

Along with the non-randomized before-and-after clinical trial study design of the included studies, we utilized the National Heart, Lung, and Blood Institute (NHLBI) Study Quality Assessment Tool for pre-post studies. This tool consists of 12 questions that assess the study's aim, sampling and sample size, description of the intervention and outcomes, blinding, follow-up, and statistical methods. The possible answers to these questions include: yes, no, cannot be determined (CD), not reported (NR), and not applicable (NA). The overall score is categorized as Good (score greater than 8), Fair (score between 5 and 8), or Poor (score less than 5). Two reviewers, MS and the first author, assessed the risk of bias in the studies, and the third reviewer, MD, verified their findings.

Data Analysis

The primary outcomes of our meta-analysis were reinfection rate, HHS, aseptic loosening rate, and dislocation rate. Forest plots were used to assess heterogeneity and calculate pooled weighted mean differences (WMD) and prevalence with corresponding 95% confidence intervals (95% CI). To account for heterogeneity in study populations, we conducted a random-effects meta-analysis. Heterogeneity across studies was assessed using I^2 statistics, where $I^2 = 0\%$ indicated no observed heterogeneity and $I^2 \geq 50\%$ showed substantial heterogeneity. Cochran's Q statistic was used to analyze the statistical significance of heterogeneity. A sensitivity analysis was performed to evaluate the impact of individual studies on heterogeneity and to assess the robustness of pooled estimates. Additionally, we conducted a meta-regression to determine the effect of participant age and follow-up duration on heterogeneity. Publication bias was not assessed using Egger's regression asymmetry test and Begg's adjusted rank correlation test due to the small number of studies included in the meta-analysis of HHS. All statistical tests were two-tailed, and a significance level of less than 0.05 was set for all analyses, except for the heterogeneity test. Statistical analyses were conducted using Stata version 17.0 (Stata Corp., College Station, TX, USA).

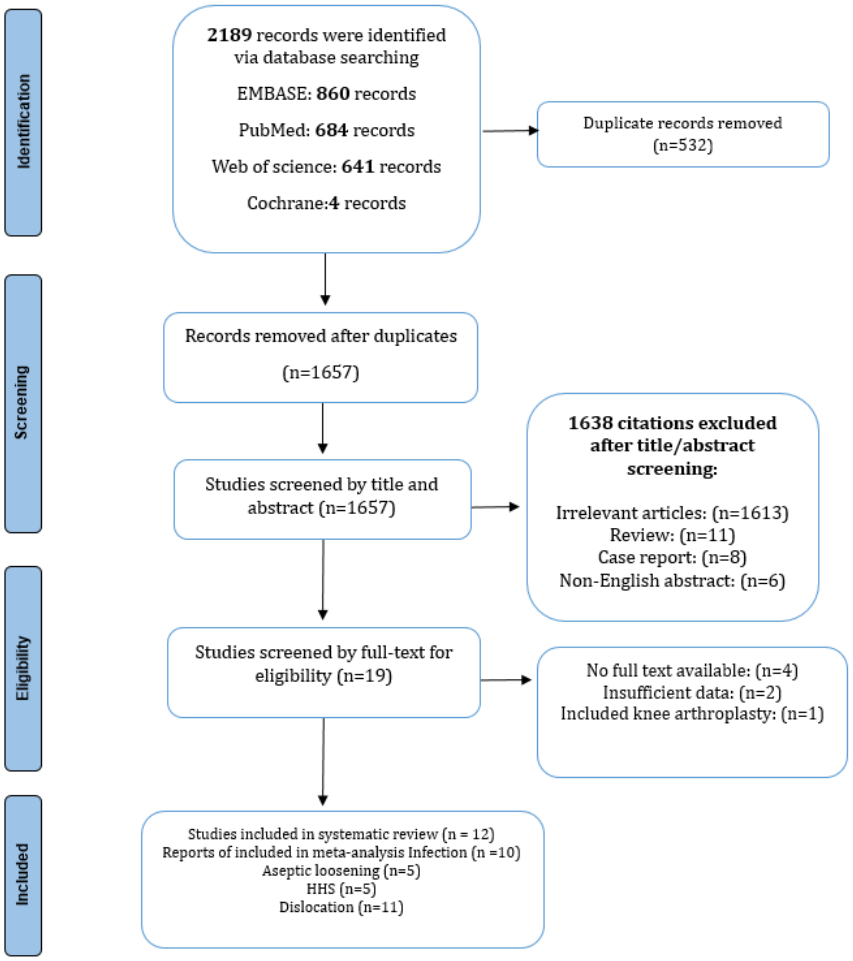

Figure 1. Flowchart of study selection

Results

Literature Search

A total of 2,189 potentially relevant citations were retrieved from the four electronic databases. After reviewing their titles and abstracts, 532 duplicates and 1,613 irrelevant citations were excluded, leaving 19 full-text articles for review. Ultimately, twelve studies published between 1997 and 2022 met the inclusion criteria and were included in the systematic review and meta-analysis. The detailed study selection process is shown in [Figure 1].

Study Selection and Data Abstraction

A total of 12 pre-post clinical trials involving 342 participants met the inclusion criteria, with 218 patients in the morselized graft group and 91 patients in the structural graft group. The excision-to-reconstruction interval ranged from 0 to 316 weeks. The mean age of the patients ranged from 28 to 86 years, and the maximum follow-up period was 211 months. The study characteristics for each study are presented in [Tables 1 and 2].

Ten studies [9,10,14-21] involving a total of 321 patients have reported the reinfection rate. Five studies [10,15,21-23] involving a total of 167 patients have stated the aseptic loosening rate. Eleven studies,[5, 9,10, 15-17, 19-23] involving a total of 324 participants, have evaluated the dislocation rate [Table 3]. Five studies [14,17,18,22,23] involving a total of 84 patients were included in the meta-analysis of HHS [Table 3].

Table 1. Demographic data of the included studies

N	Author, Year (Ref)	Country	Study design	Population	Sample size patient (hip)	Age (year) mean (range)	Gender (F/M)	Follow up (month)/ mean (range)
1	Buttaro, 2003(9)	Argentina	RSC	Osteoarthritis/ fracture of the hip/ hip dysplasia/ osteonecrosis/ rheumatoid arthritis/ low grade chondrosarcoma	29 (30)	59 (32-78)	18/11	32.4 (24-60)
2	English, 2001[10]	England	RSC	Infected primary hip arthroplasty/ infected revision arthroplasty	53	69 (44-83)	27/26	53 (24 to 122)
3	Unfried, 2022 (14)	Brazil	RSC	-	18	(60.09-79.61)	12/6	45.29-82.39
4	Ammon, 2003 [15]	UK	RSC	Osteoarthritis/ hip dysplasia/ Trauma/ Rheumatoid arthritis/ Perthes' disease/ Septic arthritis/ Avascular necrosis/ Ankylosing spondylitis/ Tumour/ Slipped upper femoral epiphysis	57	62 (28-82)	28/29	54 (24-126)
5	Winkler, 2008 [16]	Austria	Prospective Cohort-Pre-post	-	37	68.5 (42-83)	20/17	52.8 (24-96)
6	Nusem, 2006 [17]	Australia	Prospective Cohort-Pre-post	Primary osteoarthrosis/ traumatic osteoarthrosis/ ankylosing spondylitis	18	66 (45–86)	6/12	108 (60–168)
7	Lee, 2011 [18]	Canada	RSC	Osteoarthritis followed by infection , developmental hip dysplasia, fracture , avascular necrosis, Perthes disease, and slipped upper femoral epiphysis	27	62 (28–83)	-	98.4 (13.2–201.6)
8	Wang, 1996 [19]	China	Prospective Cohort-Pre-post	Osteonecrosis/ fracture/ osteoarthritis	22	48 (28-75)	4/18	48 (24- 84)
9	Hsieh, 2004 [20]	Taiwan	RSC	-	24	59 (34-69)	7/17	50.4 (24-84)
10	Elbers, 2014 [21]	Netherlands	Historical-prospective	-	36	61 (28-85)	20/16	118 (44-211).
11	Ilyas, 2001 [22]	Australia	RSC	Osteoarthritis/ traumatic arthritis/ ankylosing spondylitis	10	61.3 (42–79)	4/6	65 (36–120)
12	Alexeeff, 1995 [23]	Canada	RSC	Osteoarthritis/ rheumatoid arthritis/ Perthes' disease/ congenital dislocation of the hip/ Trauma	11	66.5 (44 - 83)	5/6	47.8 (24 - 72)

Table 2. Surgical method details of the included studies'

N	Author, Year	Reconstruction stage	Prosthesis type	Defect type	Excision to reconstruction interval (week) mean (range)	Prosthesis antibacterial coating	Bone defect severity		Bone allograft type	Duration of oral antibiotics days (Post-op)	Duration of intravenous antibiotics days (Post-op)
							Femur type (n)	Acetabular type (n)			
1	Ammon, 2003	Two	Cemented (Palacos R)	A & F	median: 24 (4 - 316)	Vancomycin or gentamicin	-	-	Morselized (45) Structural (12)	-	Cefuroxime (750 mg tds) 2
2	Winkler, 2008	One	Cementless	A & F	NA	Vancomycin or tobramycin		< 2 (Paprosky)	Morselized	-	-
3	Nusem, 2006	Two	Cemented (Palacos R)	A & F	20 (4–32)	Gentamicin	Type I (6) Type III (4) (AAOS)	Type I (2) Type II (2) Type III (5) (AAOS)	Structural	-	-
4	Lee, 2011	Two	Cemented (spacer)	A & F	22 (7.6–56)	-			Structural	-	5
5	Wang, 1996	Two	Both	A & F	26.4 (6-96)	Gentamicin-vancomycin-tobromycin-cefazolin-clindamycin			Both	46 (14-84) (n=15)	16 (7-42) (n=18)
6	English, 2001	Two	Cemented	F	32 (4-240)	Vancomycin, gentamicin, or flucloxacillin			Morselized	-	79
7	Buttaro, 2003	Two	Both	A & F	14.7 (5 to 96)	Vancomycin	Type II(20); Type III (5); Type IV (5); (Endoklinik)	Type I (8); Type II (10); Type III(12); (AAOS)	Morsellised	42 (28 -112) (n=11)	43.4 (35- 56)
8	Hsieh, 2004	Two	Cemented	A & F	13.6 (11 to 17)	Vancomycin + piperacillin, Vancomycin +aztreonam, Vancomycin, Teicoplanin, Aztreonam	Type III (6); Type I (3); (AAOS)	Type III (12); Type IV (4); (AAOS)	Structural	-	7
9	Unfried, 2022	One	Both	A & F	NA	Vancomycin and cefepime		Type II (2); Type III (4); Type I (1) (AAOS)	Morsellised	140	30
10	Elbers, 2014	Two	Both	A & F	14 (0 to 124)	-			Morsellised	Yes	Yes
11	Ilyas, 2001	Two	Cemented (Palacos R)	F	13.6 (6–32)	Gentamicin	Type III (7); Type I (2); (AAOS)	Type III (1); (AAOS)	Structural	-	-
12	Alexeef, 1995	Two	cemented	A & F					Both	84	5

Table 3. Complications rate and hip functional score of the included studies

N	Author, Year	HHS mean (SD)		Dislocation N (%)	Fractures N (%)	Re-infection N (%)	Aseptic loosening N (%)	Nerve palsy N (%)	Others N (%)	Failure N (%)
		Pre	Post							
1	Ammon, 2003	-	-	6 (10.5)	-	7 (15.5) 1 (8.3)	3 (5.2)	1 (1.75)	Symptomatic trochanteric nonunion 3 (5.2)/Pulmonary embolus 1 (1.75) / Substantial haematoma 1(1.75)/ Broken stem of femoral implant 1 (1.75)	-
2	Winkler, 2008	-	-	0 (0)	-	3 (8.10)	-	-	-	-
3	Nusem, 2006	34 (19–57)	71 (46–97)	2 (11.1)	1 (5.5)	1 (5.5)	-	-	-	-
4	Lee, 2011	39.2 (25–60)	1 year: 67.3 (40–91); Last follow: 70.3 (46–81)	1 (3.7)	-	1 (3.70)	-	1 (3.7)	unrelated deaths 2 (7.4)	
5	Wang, 1996	-	-	2 (9.09)	-	2 (9.09)	-	-	-	-
6	English, 2001	-	-	1 (1.88)	3 (5.6)	4 (7.5)	3 (5.6)	1 (1.88)	Cerebrovascular accident 1(1.88)/ Pulmonary embolism 1(1.88)/ Removal of trochanteric Cablegrip 1(1.88)	-
7	Buttaro, 2003	-	-	2 (6.89)	1 (3.44)	1(3.3)	-	-	Displacements of the greater trochanter 4(13.3)	-
8	Hsieh, 2004	-	-	1 (4.16)	2 (8.33)	0 (0)	-	-	-	-
9	Unfried, 2022	(38.55-73.83)	82.55±11.49	-	-	0 (0)	-	-	Pruritus and redness of the skin 1(5.5)/Acute renal failure 2(11.1)/Deep vein thrombosis 1(5.5)	-
10	Elbers, 2014	-	-	2(5.5)	1 (2.7)	4 (11.1)	1(2.7)	-	Persistence of pain 1(2.7)	-
11	Ilyas, 2001	27.4 (9–58)	73.5 (53–92)	1 (10)	1 (10)	-	1(10)	-	Non-union 1(10)/Haematoma 1(10)	-
12	Alexeeff, 1995	27.0 (10 - 52)	72.1 (63 - 80)	1 (9.09)	-	-	1 (9.09)	1 (9.09)	Acetabulum revised 2 (18.8)	-

Risk of Bias Assessment

Of the 12 studies, six (50%) were of good quality, and six (50%) were of fair quality. Nine studies (75%) had insufficient sample sizes. Three studies (25%) considered blinding. Most of these studies had concerns regarding statistical methods and sample size. The majority of studies received good ratings for the clarity of study objectives, specifying selection criteria, participant enrollment, defining and measuring the intervention, and assessing outcomes and loss to follow-up. The detailed results of this appraisal are presented in [Table 4].

Table 4. Methodological assessment of pre-post clinical trial studies with the NHLBI Study Quality Assessment Tool

ID	Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Quality rating
1	Ammon,2003	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	NA	No	NA	Good
2	Nusem,2005	Yes	No	CD	Yes	No	Yes	Yes	No	Yes	NA	No	NA	Fair
3	Lee 2011	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	NA	Good
4	Winkler,2008	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Na	No	NA	Good
5	Ilyas,2001	Yes	Yes	CD	Yes	No	Yes	No	No	Yes	No	No	NA	Fair
6	Buttaro,2004	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No	No	NA	Fair

Table 4. Continued

7	Elbers, 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	NA	Good
8	English, 2002	Yes	No	CD	No	Yes	Yes	Yes	No	Yes	NR	NR	NA	Fair
9	Hsieh, 2004	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NR	NR	NA	Good
10	Unfried, 2022	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	NA	Good
11	Wang, 1997	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	NA	Fair
12	ALEXEEFF, 1995	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	No	No	NA	Fair

The Questions include 1: Objective clear, 2: Eligibility specified, 3: Participant's representative, 4: All eligible enrolled, 5: Sample size, 6: Intervention, 7: Outcome measures, 8: Blinded assessors, 9: Follow up rate, 10: Statistical analysis, 11: Multiple outcome measures, 12: Individual level data to determine group effect.

Data analysis

HHS

Analyzing five studies, the mean difference in HHS was 36.85 points (range, 29.67 to 44.04) after rTHA [Figure 2]. The I^2 statistic showed moderate heterogeneity among the reported data for HHS (I^2: 66.5%, P = 0.018). To determine which study (if any) had the most impact on heterogeneity and to assess the robustness of the summary findings, a sensitivity analysis was performed by successively removing one study at a time. In this sensitivity analysis, excluding one study at a time consistently resulted in a significantly improved HHS (range of summary WMDs, 34.49 to 38.41). Analyzing three studies, the mean HHS was 37.02 points (range, 29.46 to 44.55) among the studies using structural bone allografts [Figure 2]. The I^2 statistic showed low heterogeneity among the reported data for HHS (I^2: 46.7%, P = 0.15).

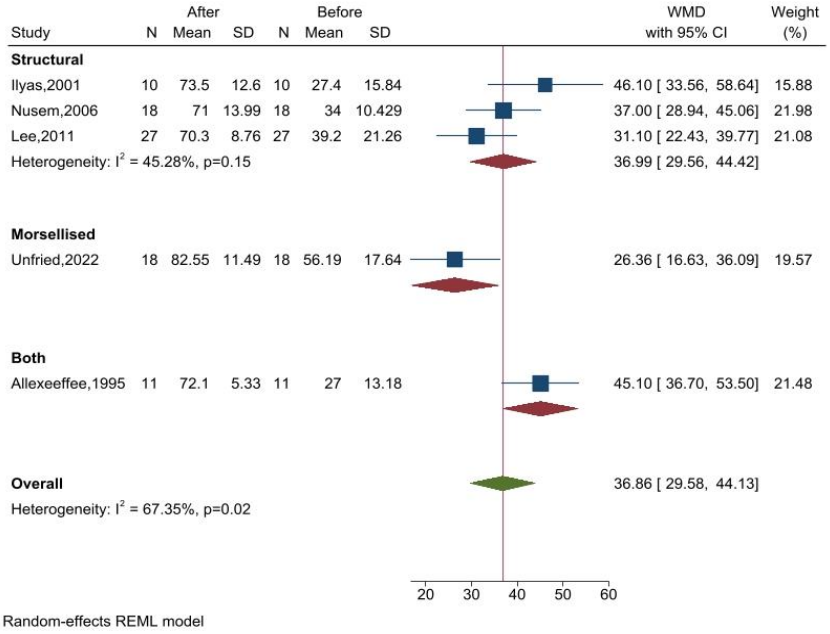

Figure 2. Meta-analysis of Harris Hip Score (HHS) for the effect of bone structural allograft for joint arthroplasty after infected hip. Diamond represents the summary weighted mean difference (pooled WMD) estimate and its width shows corresponding 95% CI with random effects estimate. I-square test and Cochran's Q statistic were used to assess the statistical heterogeneity (P =0.15) across studies

Aseptic loosening

Meta-analysis of five studies showed that the aseptic loosening rate was 0.04 (range, 0.01 to 0.09) after rTHA [Figure 3]. The I^2 statistic indicated low heterogeneity among the reported data for aseptic loosening (I^2: 0.00%, P = 0.82). To determine which study (if any) had the most impact on heterogeneity and to assess the robustness of the summary findings, a sensitivity analysis was performed by successively

removing individual studies. In this sensitivity analysis, excluding one study at a time consistently resulted in findings that remained broadly similar (range of summary prevalence: 0.043, 0.058). In the analysis of two studies using bone morselized allografts, the pooled aseptic loosening rate was 0.04 (range, 0.01 to 0.10) [Figure 3]. Similarly, in two studies using both structural and morselized allografts, the pooled aseptic loosening rate was 0.05 (range, 0.00 to 0.12) [Figure 3].

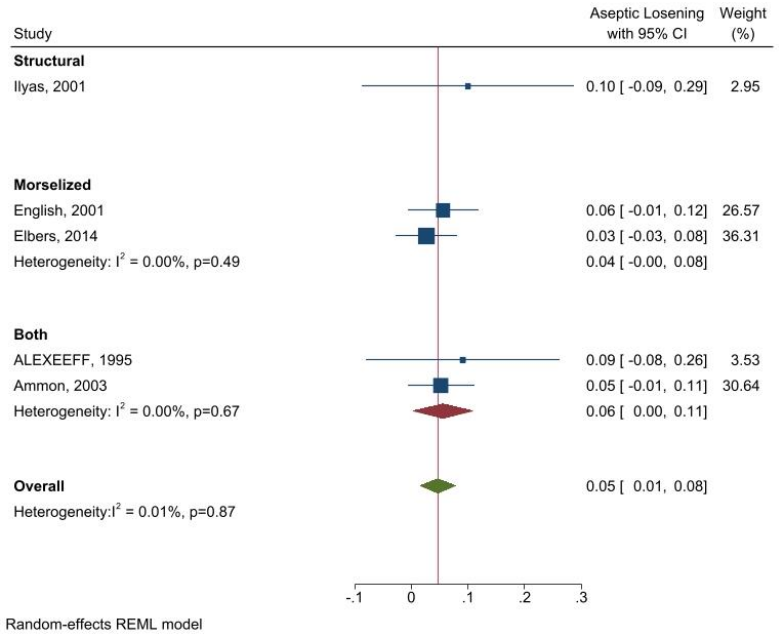

Figure 3. Subgroup meta-analysis of prevalence of aseptic loosening for the effect of bone allograft for joint arthroplasty after infected hip based on the type of allograft

Reinfection

Meta-analysis of ten studies showed that the reinfection rate was 0.06 (range, 0.04 to 0.10) after rTHA [Figure 4]. The I^2 statistic indicated low heterogeneity among the reported data for reinfection (I^2: 9.54%, P = 0.35). To determine which study (if any) had the most impact on heterogeneity and to assess the robustness of the summary findings, a sensitivity analysis was performed by successively removing individual studies. In this sensitivity analysis, excluding one study at a time consistently resulted in findings that remained largely similar (range of summary prevalence: 0.06, 0.08). In the analysis of five studies using bone morselized allografts, the reinfection rate was 0.06 (range, 0.03 to 0.11) [Figure 4]. The I^2 statistic showed low heterogeneity among the reported data for reinfection (I^2: 0.00%, P = 0.50). In three studies using bone structural allografts, the mean reinfection rate was 0.02 (range, 0.00 to 0.08) [Figure 4].

Dislocation

Meta-analysis of 11 studies showed that the dislocation rate was 0.05 (range, 0.02 to 0.08) after rTHA [Figure 5]. The I^2 statistic indicated moderate heterogeneity among the reported data for dislocation rate (I^2: 7.38%, P = 0.37). To determine which study (if any) had the most impact on heterogeneity and to assess the robustness of the summary findings, a sensitivity analysis was performed by successively removing individual studies. In this sensitivity analysis, excluding one study at a time consistently resulted in findings that remained largely similar (range of summary prevalence: 0.04, 0.06). In the analysis of four studies using bone morselized allografts, the dislocation rate was 0.03 (range, 0.00 to 0.07) [Figure 5]. The I^2 statistic showed low heterogeneity among the reported data for dislocation (I^2: 22.35%, P = 0.28). In the analysis of four studies using bone structural allografts, the dislocation rate was 0.06 (range, 0.01 to 0.13) [Figure 5]. The I^2 statistic showed low heterogeneity among the reported data for dislocation rate (I^2: 0.00%, P = 0.72).

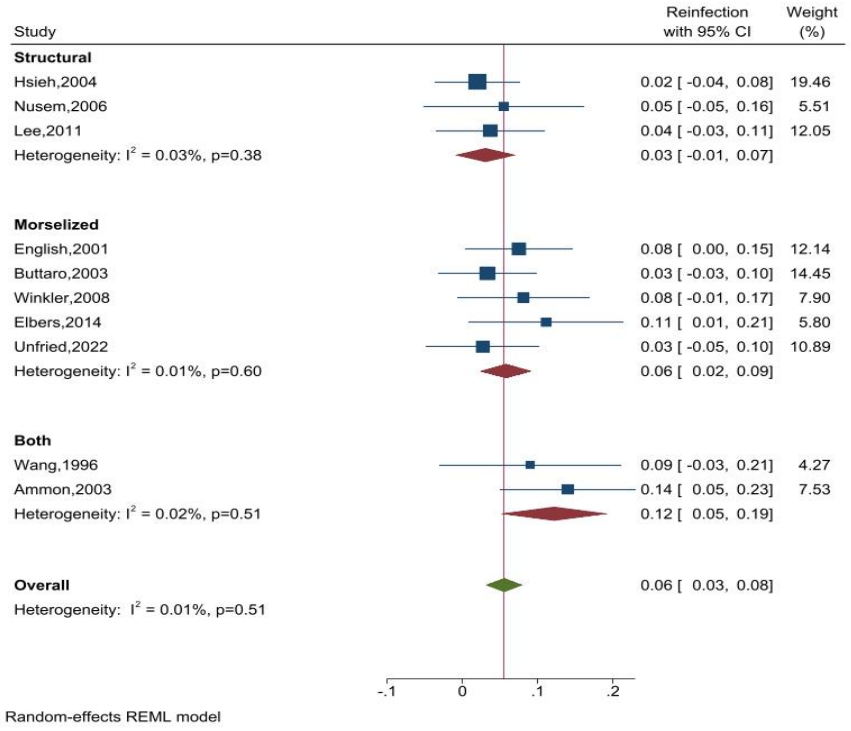

Figure 4. Subgroup meta-analysis of prevalence of Reinfection for the effect of bone allograft for joint arthroplasty after infected hip based on the type of allograft. The pooled prevalence of reinfection in Structural, Morselized, and both types of allograft is 3,6 and 12%, respectively

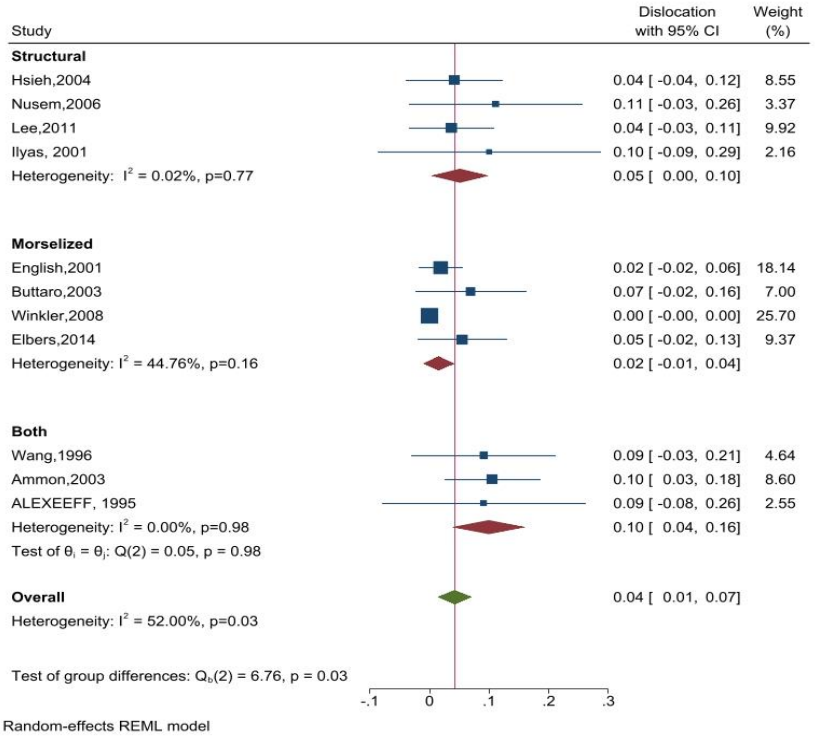

Figure 5. Subgroup meta-analysis of prevalence of dislocation for the effect of bone allograft for joint arthroplasty after infected hip based on the type of allograft.The prevalence of dislocation in Structural, Morselized, and both types of allograft is 5,2 and 10%, respectively

Discussion

The outcomes of bone allografts in addressing acetabular or femoral bone defects resulting from infection during revision THA remain uncertain. To address this gap in knowledge, we conducted a systematic review and meta-analysis of studies involving patients with hip prosthesis infection and subsequent bone defects who underwent rTHA with bone allograft. Our objective was to evaluate the incidence of complications, particularly reinfection, and assess hip functional scores following this treatment.

Findings from ten studies revealed a pooled reinfection rate of 6%. The primary complications reported included reinfection (6%), aseptic loosening (5%), and dislocation (4%). Reinfection occurred in five studies using morselized allografts (combined estimate: 6%),[9,10,14,16,21] three studies utilizing structural allografts (combined estimate: 3%),[17,18,20] and two studies employing both structural and morselized allografts (combined estimate: 12%).[15,19] The rate of reinfections following aseptic revisions (without prior infection) is slightly higher at 8.13%,[24] indicating that revision procedures inherently carry a notable infection risk, regardless of prior infection status or graft usage. While previous literature suggests that the appropriate type of acetabular bone graft is typically selected based on the classification of the bone stock deficit — with cavitary defects often restored using cancellous morselized auto- or allografts, and larger segmental bone stock defects generally addressed with structural (or bulk) cortico-cancellous auto- or allografts [25]— a recent meta-analysis by Strahl et al. indicates that both graft types were equally utilized across all AAOS and Paprosky classifications for significant bone loss[26] Concerns persist regarding the heightened risk of reinfection associated with large allografts, potentially due to impediments to antibiotic delivery and the host immune response. Despite various techniques being employed, a consensus on the optimal treatment approach remains elusive.

The choice between one-stage and two-stage procedures for treating PJIs after multiple unsuccessful surgeries remains a topic of significant debate. Some studies suggest that two-stage procedures may offer advantages in reducing the risk of infection recurrence, primarily due to the opportunity for two separate debridement and cleaning interventions[27] However, the evidence remains inconclusive regarding the superiority of either approach. For instance, Winkler et al.[16] and Unfried et al.[14] both studied one-stage procedures using morselized allografts, reporting reinfection rates of 8% and 3%, respectively. On the other hand, two-stage revisions have shown varied outcomes. Ammon et al.[15] reported a 14% reinfection rate, while Wang and Chen[19] noted a 9% reinfection rate. These studies involved mixed patient cohorts treated with either morselized or structural allografts, with follow-up periods ranging from 24 to 126 months. Given the variability in reinfection rates across studies and techniques, it remains challenging to definitively conclude whether one-stage or two-stage revisions are more effective in minimizing reinfection rates. Further research is required to provide more robust comparative data.

Revision THA presents specific challenges when managing PJIs. In addition to addressing bone loss, two additional obstacles must be overcome. First, eradicating infection is difficult due to biofilm formation, especially when dealing with "difficult-to-treat" pathogens.[28] Second, patients often present with various systemic diseases, rendering them immunocompromised.[29,30] This complicates the recovery process and can negatively impact overall outcomes for this patient population. Performing acetabular bone grafting requires a high level of technical skill and should be considered only when other reconstruction methods are unlikely to yield a lasting result. Surgeries for acetabular or femoral bone defects caused by infection during revision THA should be performed only at specialized referral centers.[31]

Additionally, it is essential to consider the potential protective role of antibacterial coatings in reducing the risk of infection recurrence. The effectiveness of silver-coated medical implants has been highlighted in oncology patients to the extent that it has become the standard approach for this particular patient subgroup[32] However, a limitation of silver coatings is their ability to cover only the outer surface of medical implants. To address this limitation, a rapidly absorbable hydrogel coating known as DAC®, composed of hyaluronan and poly-D, L-lactide covalently linked, has been developed. This coating aims to prevent bacterial colonization in the immediate post-surgery period, offering short-term localized antibiotic release while minimizing potential adverse effects and the development of antibiotic resistance.[33,34] Studies by Ammon et al. and Białecki et al., which reported the highest reinfection rates, used a single agent (vancomycin or gentamicin) for the antibacterial coating.

The weighted mean difference for HHS in the structural allograft group was notably high at 36.86, indicating an improvement in hip function post-surgery. Aseptic loosening occurred in two studies using morselized allografts (pooled estimate: 4%),[10,21] one study using structural allografts[22], and two studies using both structural and morselized allografts (pooled estimate: 6%).[15,23] Since radiographic evidence, such as radiolucent lines and cup migration, could not be consistently included in the success criteria, the rate of aseptic loosening is likely higher. Regarding dislocation, structural allografts demonstrated a pooled prevalence of 5%, morselized allografts 2%, and procedures involving both types of allografts yielded a pooled prevalence of 10%. The dislocation rate after aseptic revision THA is comparable to that of structural allografts (5%) after one year.[24]

Despite literature documenting favorable clinical and radiological outcomes in the short- to long-term, along with survival rates, for acetabular and femoral revisions employing allografts,[35,36] the precise factors contributing to successful allograft integration remain not fully understood. It is likely that factors such as defect size, surgical approach, allograft type, use of bone cement, and patient-related variables all contribute to graft incorporation.

To our knowledge, this is the first systematic review analyzing the reinfection rate of rTHA involving bone

allograft utilization in both acetabular and femoral defects. Our study has several limitations. The included studies varied in terms of the severity of acetabular or femoral bone defects. Complications across all studies were aggregated without categorization based on Paprosky's bone loss types. Nonetheless, this diversity allowed us to assess the effectiveness of bone allograft techniques across a wide range of bone defects encountered in surgical practice. Another limitation is the lack of detailed procedural data, such as prosthesis features, in some of the included studies. Notably, all included studies were retrospective follow-up studies without control groups. Variations in surgical approaches, postoperative care protocols, age at primary revision, patient demographics, primary disease, number of cases (ranging from 20 to 304), and time to follow-up (ranging from 2 to 22 years) resulted in limited comparability. However, the calculated I^2 statistics for heterogeneity were low or moderate across all conducted meta-analyses.

Conclusion

The reinfection rate after revision hip arthroplasty for infection using bone allografts ranges from 2% to 12% across the included studies. Morselized allografts, in particular, tend to have higher reinfection rates. Moreover, our analysis indicates that structural allografts are associated with a higher risk of dislocation compared to morselized allografts. Nevertheless, the evidence suggests that using allografts in patients whose infections have been fully resolved is safe and does not increase the risk of reinfection when compared to resections performed without allografts.

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