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Cementless unicompartmental knee replacement achieves better ten-year clinical outcomes than cemented: a systematic review

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Abstract

Purpose The aim of this study was to report and compare the long-term revision rate, revision indications and patient reported outcome measures of cemented and cementless unicompartmental knee replacements (UKR).

Methods Databases Medline, Embase and Cochrane Central of Controlled Trials were searched to identify all UKR studies reporting the ≥ 10 year clinical outcomes. Revision rates per 100 component years [% per annum (% pa)] were calculated by fixation type and then, subgroup analyses for fixed and mobile bearing UKRs were performed. Mechanisms of failure and patient reported outcome measures are reported.

Results 25 studies were eligible for inclusion with a total of 10,736 UKRs, in which there were 8790 cemented and 1946 cementless knee replacements. The revision rate was 0.73% pa (CI 0.66–0.80) and 0.45% pa (CI 0.34–0.58) per 100 component years, respectively, with the cementless having a significantly ($p < 0.001$) lower overall revision rate. Therefore, based on these studies, the expected 10-year survival of cementless UKR would be 95.5% and cemented 92.7%. Subgroup analysis revealed this difference remained significant for the Oxford UKR (0.37% pa vs 0.77% pa, $p < 0.001$), but for non-Oxford UKRs there were no significant differences in revision rates of cemented and cementless UKRs (0.57% pa vs 0.69% pa, $p = 0.41$). Mobile bearing UKRs had significantly lower revision rates than fixed bearing UKRs in cementless ($p = 0.001$), but not cemented groups ($p = 0.13$). Overall the revision rates for aseptic loosening and disease progression were significantly lower ($p = 0.02$ and $p = 0.009$ respectively) in the cementless group compared to the cemented group (0.06 vs 0.13% pa and 0.10 vs 0.21% pa respectively).

Conclusions Cementless fixation had reduced long-term revision rates compared to cemented for the Oxford UKR. For the non-Oxford UKRs, the revision rates of cementless and cemented fixation types were equivalent. Therefore, cementless UKRs offer at least equivalent if not lower revision rates compared to cemented UKRs.

Level of evidence III.

Keywords Arthroplasty · UKA · Unicondylar

Abbreviations

AKSS-O	American Knee Society Score (Objective)
AKSS-F	American Knee Society Score (Functional)
CENTRAL	Cochrane Central of Controlled Trials
CI	Confidence interval
HSS	Hospital for Special Surgery knee score
KSS	Knee Society Score
MINOR	Methodological index for evaluation of non-randomised studies
OKS	Oxford Knee Score
pa	Per annum
PROM	Patient-reported outcome measure
PRIMSA	Preferred reporting items for systematic reviews and meta-analyses
TKR	Total knee replacement
WOMAC	Western Ontario and McMaster universities arthritis index
UKR	Unicompartmental knee replacement

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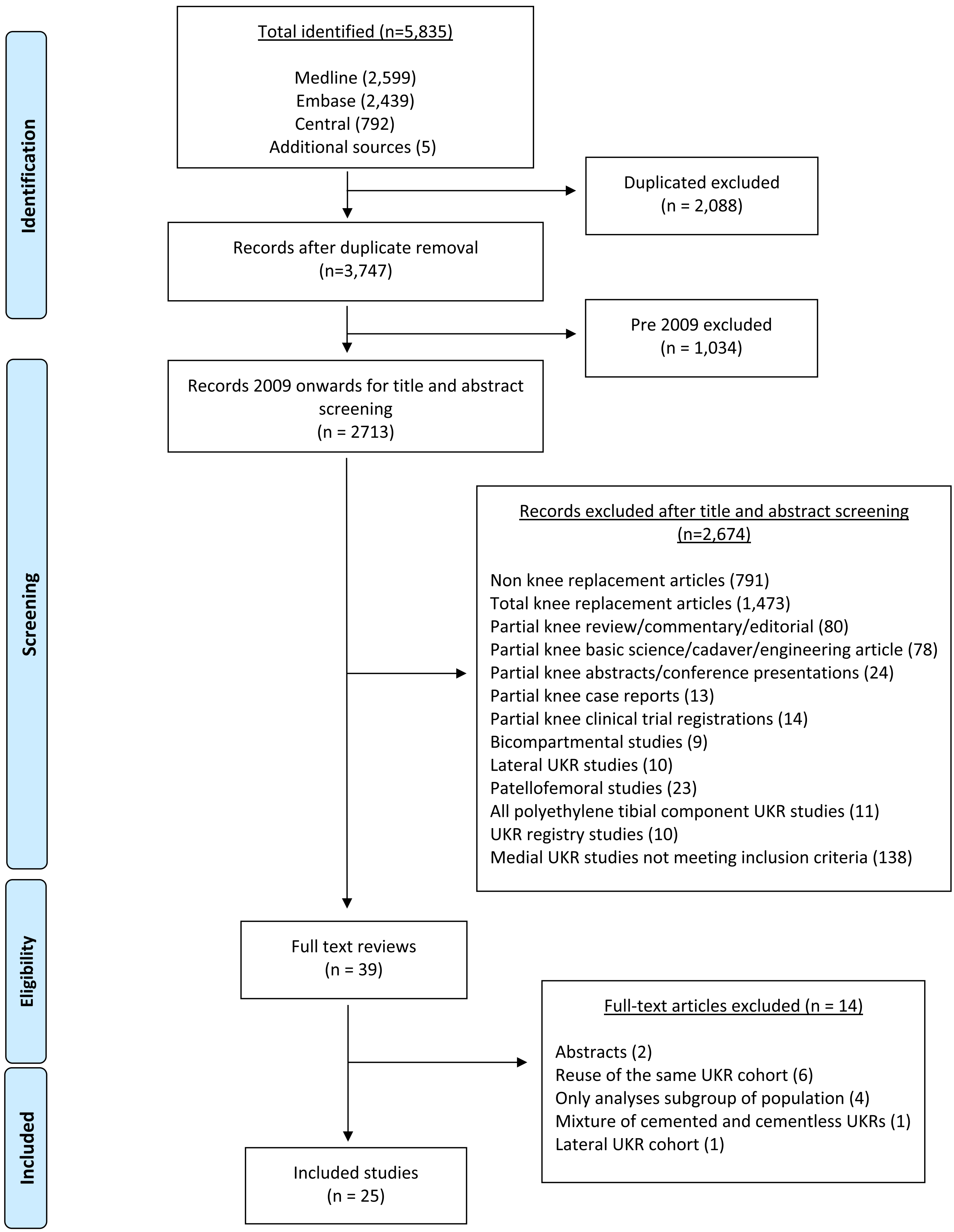

Fig. 1 PRISMA flow chart

Introduction

Unicompartmental knee replacement (UKR) is an effective well-established treatment for anteromedial knee osteoarthritis which has failed to respond to conservative management [66]. Whilst UKR offers substantial benefits over total knee replacement (TKR) [36, 44, 67], it has a higher revision rate, particularly for aseptic loosening [7, 48, 62].

The two main types of fixation used to implant components are cemented and cementless techniques. Cemented components rely on bone cement to fix the components to surrounding trabecular bone; whereas, cementless components rely on the principle of press-fit fixation and osseointegration [39, 40, 63]. The current gold standard for knee replacements is cemented fixation [7, 48, 62] given the poor results of the first cementless knee replacements [5, 10].

There has been a recent increase in interest in cementless fixation given the need for fixation to last a patient's lifetime with rising life expectancies [32]. Additionally, the merits of a more natural biological fixation, avoidance of cementation errors, a reduction in radiolucent lines and pain are certainly attractive [10, 27, 44].

There is currently no consensus on how the overall long-term clinical outcomes of cemented UKRs compare to cementless UKRs across the world and for different UKR types. Such a comparison would need to investigate not only the revision rate, but also the functional outcomes achieved from both fixation types. This systematic review addresses this question by comparing cemented and cementless UKR results published globally by comparing: revision rates, revision indications and PROMs. The null hypothesis was that there would be no difference in the revision rates of cemented and cementless UKRs.

Materials and methods

This systematic review has been registered prospectively on PROSPERO, CRD42019134315 and follows the preferred reporting items for systematic reviews (PRISMA).

Inclusion and exclusion criteria

The inclusion criteria were studies in the English language that reported the ≥ 10-year outcomes of any primary medial UKR for osteoarthritis in adult patients. Studies included were from 2009 onwards to assess the outcomes of UKRs published within the last 10 years. The most commonly used cementless UKRs were introduced after cemented versions and first widely adopted from 2009 onwards [42]. Additionally using studies before this period would include a disproportionate number of older cemented UKR studies which would not be deemed as comparable to the more recent cementless UKR studies.

Exclusion criteria included registry studies given they tend not to subdivide implants according to fixation and whether the implant is medial/lateral and to prevent duplication of patients with existing studies in the literature [7, 48]. Additionally, registries can under-report revisions [57]. Additional exclusion criteria were case reports, abstracts, hybrid UKRs and any studies in which lateral UKRs formed more than 10% of the whole cohort given our study was focusing on medial UKR outcomes. Studies of all polyethelene tibial components, bicompartmental replacements and those looking at only certain subgroups of the population were excluded given these contribute potential unnecessary confounders. Details of the number of articles actually

Table 1 List of excluded full texts and reasons

Study	Reason for exclusion
Abdulkarim et al. [1]	Abstract only
Ali et al. [2]	Same cohort as Pandit et al. [51] but earlier results
Bottomley et al. [8]	Does not report results of cemented or cementless UKRs separately
Bray et al. [9]	Abstract only
Campi et al. [12] (cementless arm)	Cementless arm only reports short- to mid-term follow-up. Cemented arm included in the review as reports long-term outcomes
Hamilton et al. [24]	Same cohort as Pandit et al. [51] and only analyses subgroup of the cohort
Hamilton et al. [23]	Same cohort as Pandit et al. [51] and only analyses subgroup of the cohort
Hamilton et al. [22]	Same cohort as Pandit et al. [51] and only analyses subgroup of the cohort
Hamilton et al. [21]	Same cohort as Pandit et al. [51] and only analyses subgroup of the cohort
Heyse et al. [26]	Only analyses patients under 60 years of age
Kennedy et al. [28]	Same cohort as Pandit et al. [51] and only analyses subgroups of the cohort
Kim et al. [30]	Only analyses patients under 60 years of age
Noaur et al. [47]	Not available in English language and also only analyses patients under 60 years of age
Parratte et al. [53]	Only analyses patients under 50 years of age
Saragaglia et al. [58]	Over 10% of cohort are lateral UKRs

Table 2 Breakdown of UKR prostheses used in included studies

	UKR prosthesis	Number of UKRs	Number of surgical centres
Cementless UKR studies			
Campi et al. [11]	Oxford	682	2
Hall et al. [20]	Unix	85	1
Lecuire et al. [34]	Alpina	101	1
Mohammad et al. [41]	Oxford	1000	1
Schlueter-Brust et al. [59] (cementless arm)	Uniglide	78	1
		Total: 1946	Total: 6
Cemented UKR studies			
Alnachoukati et al. [3]	Oxford	825	4
Aly et al. [4]	Oxford	45	1
Argenson et al. [6]	Miller-Galante	70	1
Campi et al. [12] (cemented arm)	Oxford	522	1
Chattelard et al. [13]	Allegretto, Presevation, Genesis, Hermes, HLS, Lotus, Miller-Galante, Oxford	559	13
Edmonson et al. [16]	Oxford	364	1
Emerson et al. [17]	Oxford	213	1
Faour Martin et al. [18]	Oxford	511	1
Foran et al. [19]	Miller-Galante	19	1
Kim et al. [29]	Oxford	180	1
Kristensen et al. [31]	Oxford	695	1
Lim et al. [37]	Miller Gallante/Preservation UKR	279	1
Lisowiski et al. [38]	Oxford	138	1
Pandit et al. [51]	Oxford	1000	1
Price et al. [55]	Oxford	682	1
Schlueter-Brust et al. [59] (cemented arm)	Uniglide	152	1
Song et al. [61]	Miller-Galante	68	1
Venkatesh et al. [64]	Miller-Galante	175	1
White et al. [65]	Oxford	554	2
Winnock de Grave et al. [68]	Zimmer Unicondylar Knee	460	1
Yoshida et al. [69]	Oxford	1279	2
		Total: 8790	Total: 38

excluded from the study based on the inclusion and exclusion criteria specified are summarised in Fig. 1.

Search strategy

Alongside an expert librarian, the databases Medline, Embase, Central were searched from their inceptions to 23/04/2019 and are summarised in the Appendix. Key words used in the search strategy included "knee arthroplasty" and "fixation" with all variations of these terms. In addition, reference lists of the included publications were also screened to identify any additional reports.

First, study duplicates were removed followed by a title and abstract screening based on eligibility criteria. All shortlisted papers had full texts extracted and were assessed. Where the same cohort was published more than once, the most recent publication using the full cohort was included. There was complete agreement between the independent authors (HRM, GSB) who screened the studies.

Outcomes of interest

The primary outcome of interest was revision. This was measured from; (1) revision rate and (2) 10-year survivals reported. Revision was defined as any removal/addition of any component to the knee joint as per the registries [7, 48, 62]. Secondary outcomes were (1) Revision indications and (2) PROMs.

The a priori analysis was to first compare fixation groups (cementless vs cemented), and then compare bearing-type

Table 3 Risk of bias of cemented and cementless UKR studies

Study	MINORS %	Sample size	Revisions reported	Implant survival reported	Mechanisms of failure reported	Bias risk
Cementless UKR studies						
Campi et al. [11]	75.0	A	A	A	A	Low
Hall et al. [20]	75.0	B	A	A	A	Low
Lecuire et al. [34]	75.0	A	A	A	A	Low
Mohammad et al. [41]	87.5	A	A	A	A	Low
Schlueter-Brust et al. [59]	87.5	A	A	A	A	Low
Cemented UKR studies						
Alnachoukati et al. [3]	87.5	A	A	A	A	Low
Aly et al. [4]	56.3	C	A	B	A	High
Argenson et al. [6]	87.5	A	A	A	A	Low
Campi et al. [12]	87.5	A	A	A	A	Low
Chattelard et al. [13]	62.5	A	A	B	A	Low
Edmonson et al. [16]	68.8	A	A	A	A	Low
Emerson et al. [17]	75.0	A	A	A	A	Low
Faour Martin et al. [18]	87.5	A	A	A	A	Low
Foran et al. [19]	75.0	B	A	A	A	Low
Kim et al. [29]	75.0	A	A	A	A	Low
Kristensen et al. [31]	81.3	A	A	A	A	Low
Lim et al. [37]	87.5	A	A	A	A	Low
Lisowiski et al. [38]	81.3	A	A	A	A	Low
Pandit et al. [51]	81.3	A	A	A	A	Low
Price et al. [55]	87.5	A	A	A	A	Low
Schlueter-Brust et al. [59]	87.5	A	A	A	A	Low
Song et al. [61]	87.5	B	A	A	A	Low
Venkatesh et al. [64]	81.3	A	A	A	A	Low
White et al. [65]	87.5	A	A	A	A	Low
Winnock de Grave et al. [68]	81.3	A	A	A	A	Low
Yoshida et al. [69]	81.3	A	A	A	A	Low

(mobile vs fixed bearing) results within each fixation category.

Data collection and risk of bias

Two authors (HRM and GSB) independently extracted data from all included studies. Contact attempts were made for all authors to obtain missing information. In cases where a study reported results for both cemented and cementless fixation types, only UKR arms reporting long-term outcomes were included in the review as per the specified inclusion criteria.

All studies were assessed for risk of bias using the methodological index for evaluation of non-randomised studies (MINORs) as a percentage and an additional system based on the reporting of the primary outcome (A = clearly reported, B = not reported/unclear) and the number of cases (A > 100 cases, B 51–99 and C < 50) [10, 15, 44, 60]. Studies with a MINORs score over 80% were deemed at low risk of bias and those below 70% at high risk except those with three or more As in the primary outcomes [10, 15, 44, 60].

Data synthesis and analysis

The primary outcome, the revision rate, was calculated per 100 component years which is equivalent to the annual rate [% per annum (% pa)] as per the Australian Joint Registry [7] and previous reports [10, 25, 33, 44]. This involved dividing the total number of revisions by the total observed component years multiplied by 100 [50]. 95% confidence intervals (CI) were generated using the Clopper Pearson method [14]. Each revision indication rate was also calculated using the same methodology. Revisions and their indications per 100

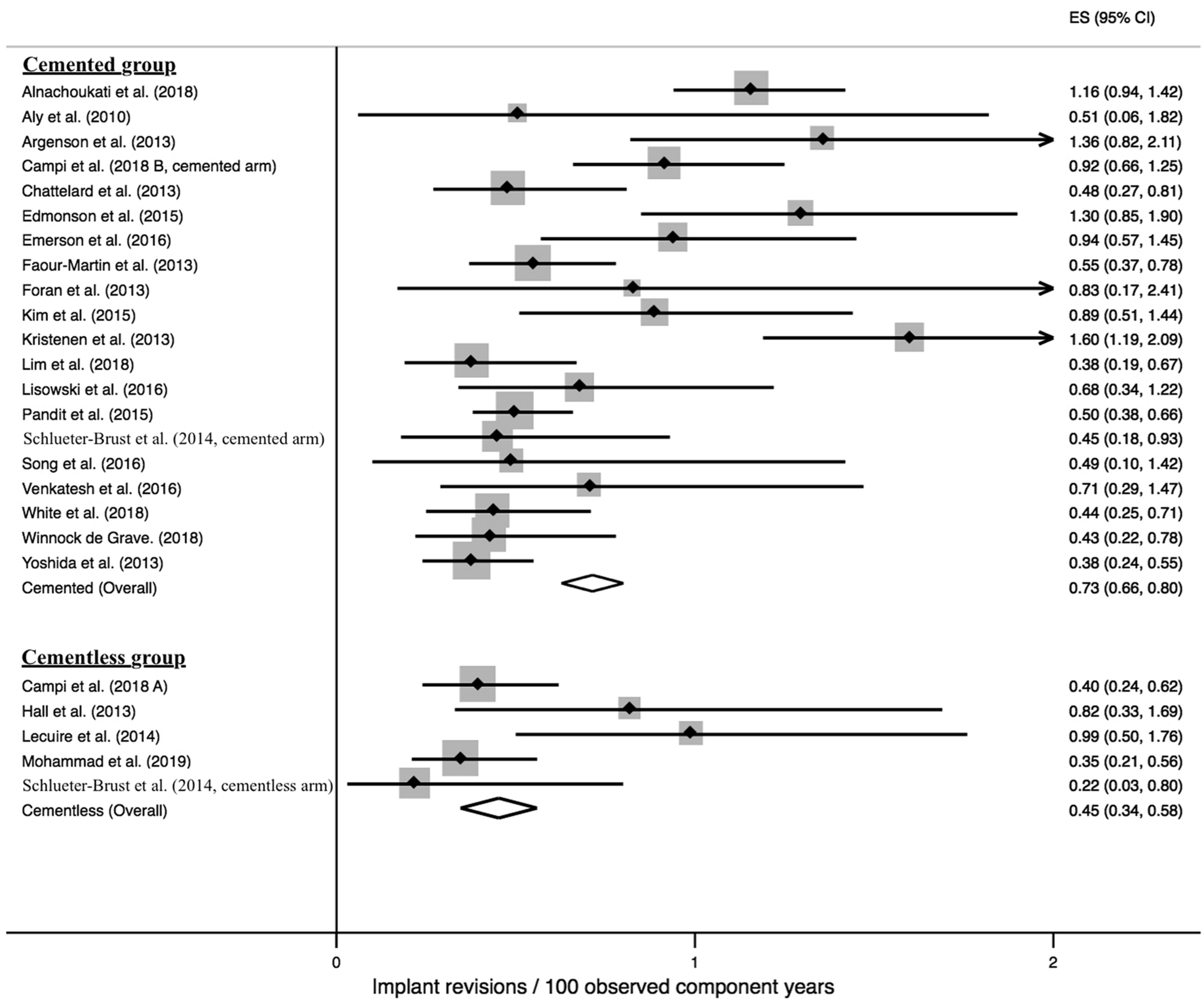

Fig. 2 Forest plot of revision rates per 100 component years of cemented and cementless UKR studies

component years were compared between groups using the chi-squared proportional test.

From the included studies, Campi et al. [11] reported the results for 1000 UKRs, but of these, 318 UKRs were also used in Mohammad et al.'s.[41] more recent study. The results of Campi et al's. [11] unique 682 UKRs were obtained to prevent duplication of UKRs in the analysis. Therefore, in this systematic review, the number of UKRs reported for Campi et al. [11] is 682. This prevented overpowering the study and used the most up to date information for the cohort.

All statistical analysis was performed using Stata version 14 (STATA Corp, Texas, United States of America). *p* values of < 0.05 were deemed statistically significant.

Results

5835 articles were identified, which after duplicates and title/abstract screening were reduced to 39. Full text analyses deemed 25 articles eligible for inclusion (Fig. 1). Details of full text articles excluded are in Table 1. There were 21 studies [3, 4, 6, 12, 13, 16–19, 29, 31, 37, 38, 51, 55, 59, 61, 64, 65, 68, 69] reporting the long-term outcomes of cemented UKRs and 5 [11, 20, 34, 41, 59] reporting the outcomes of cementless UKRs. The majority of studies (15/25) were of the Oxford UKR (Table 2). All identified studies were observational studies with no long-term comparative studies. All studies scored low risk of bias except Aly et al. [4] (Table 3).

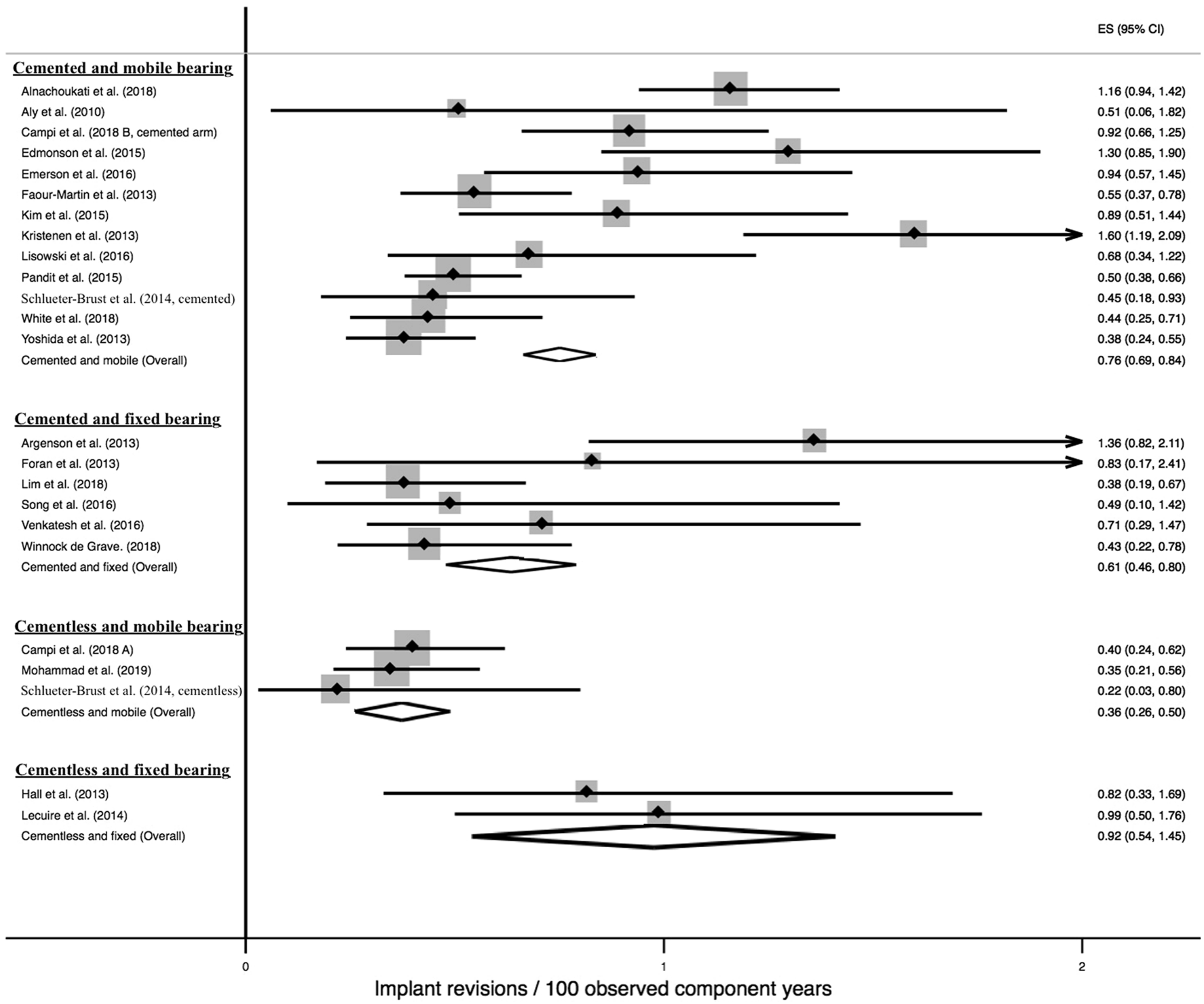

Fig. 3 Forest plot of revision rate per 100 component years by fixation and bearing type

The total number of UKRs in the cemented and cementless groups was 8790 and 1946.

Revisions by fixation type

24 out of 25 studies ($n = 10{,}054$) reported the number of revisions during the study period and the mean follow-up which allowed for quantitative analysis (Fig. 2). The only exception to this was Price et al. ($n = 682$) [55] which reported the median follow-up. Table 7 in the appendix summarises this in detail for each study.

The overall revision rate for the cemented and cementless groups was calculated separately. In the cemented group ($n = 8108$), there were 456 revisions out of 62,637 component years resulting in a revision rate of 0.73% pa (CI 0.66–0.80) (Table 7). This equates to a 10-year survival of 92.7%. In the cementless group ($n = 1946$), there were 57 revisions out of 12,740 component years resulting in a revision rate of 0.45% pa (CI 0.34–0.58) (Table 7). This equates to a 10-year implant survival of 95.5%. The differences between cementless and cemented revision rates were significant ($p < 0.001$). The revision rates are plotted in Fig. 2.

Table 4 Long-term implant survivals for the overall cohort from each of the included studies

Study	Implant survival reported (%)	Time point (years)
Cementless UKR		
Campi et al. [11]	96.6	10
Hall et al. [20]	76.0 (CI 60.0–97.0)	12
Lecuire et al. [34]	88.0 (CI 81.0–95.0)	13
Mohammad et al. [41]	97.5 (CI 95.7–98.5)	10
Schlueter-Brust et al. [59] (cementless arm)	97.4	10
Cemented UKR		
Alnachoukati et al. [3]	85.0 (CI 81.2–88.8)	10
Aly et al. [4]	n.r	10
Argenson et al. [6]	94.0 (CI 91.0–97.0)	10
Campi et al. [12] (cemented arm)	n.r	10
Chattelard et al. [13]	83.7 (CI 80.2–87.2)	10
Edmonson et al. [16]	87.9 (CI 82.5–93.3)	11
Emerson et al. [17]	88.0 (CI 82.4–93.6)	10
Faour Martin et al. [18]	96.3	10
Foran et al. [19]	93.0 (CI 83.0–98.0)	15
Kim et al. [29]	90.5 (CI 85.9–95.0)	10
Kristensen et al. [31]	85.3 (CI 78.7–90.0)	11
Lim et al. [37]	95.1 (CI 92.2–97.7)	10
Lisowiski et al. [38]	90.6 (CI 85.2–96.0)	15
Pandit et al. [51]	96.0 (CI 92.5–99.5)	10
Price et al. [55]	93.6 (CI 90.6–96.6)	10
Schlueter-Brust et al. [59] (cemented arm)	95.4	10
Song et al. [61]	95.6	10
White et al. [65]	95.2 (CI 92.3–98.4)	12
Winnock de Grave et al. [68]	94.2 (CI 86.8–97.5)	10
Venkatesh et al. [64]	96.0	11
Yoshida et al. [69]	95.4 (CI 91.2–99.7)	10

There were 13 studies of the cemented Oxford UKR ($n=6326$) and 2 studies of the cementless Oxford UKR ($n=1682$). For the cemented Oxford, there were 381 revisions out of 49,384 component years giving a revision rate of 0.77% pa (CI 0.70–0.85). The cementless Oxford studies reported 37 revisions out of 9874 component years giving a revision rate of 0.37% pa (CI 0.26–0.52). The difference between the revision rates was significant ($p<0.001$).

There were 10 studies of non-Oxford UKRs, of which 8 had cemented UKRs ($n=1782$) and 3 had cementless UKRs ($n=264$). For the cemented UKRs, there were 75 revisions out of 13,253 component years giving a revision rate of 0.57% pa (CI 0.45–0.71). For the cementless UKRs, there were 20 revisions from 2866 component years giving a revision rate of 0.69% pa (CI 0.43–1.10). There were no significant differences in the cemented and cementless non-Oxford UKR study's revision rates ($p=0.41$).

Revisions by bearing type

In the cemented group ($n=8108$), there were 6478 mobile bearing UKRs [3, 4, 12, 16–18, 29, 31, 38, 51, 59, 65, 69] and 1071 fixed bearing UKRs [6, 19, 37, 61, 64, 68] clearly indicated. Chatellard et al. [13] ($n=559$) had a mixture of mobile and fixed bearing UKRs and, hence, was not included in this analysis. There were 388 revisions out of 50,934 component years and 54 revisions out of 8813 component years for mobile and fixed bearing cemented UKRs, respectively. This resulted in revision rates of 0.76% pa (CI 0.69–0.84) and 0.61% pa (CI 0.46–0.80), respectively (Fig. 3, Table 7). The corresponding 10-year implant survival for mobile and

Table 5 Indications for revision surgery in the cemented and cementless cohorts

Indication for revision	No of cemented cases ($n=7586$)	Percentage of cemented cases (%)	Revisions per 100 component years for each indication (% pa)	No of cementless cases ($n=1946$)	Percentage of cementless cases (%)	Revisions per 100 component years for each indication (% pa)	Comparison between groups p value
Disease progression[a]	125	1.6	0.21	13	0.7	0.10	$p=0.009$
Aseptic loosening[a]	76	1.0	0.13	7	0.4	0.06	$p=0.02$
Bearing dislocation	41	0.5	0.07	15	0.8	0.12	$p=0.08$
Pain	50	0.7	0.09	5	0.3	0.04	$p=0.09$
Infection	34	0.4	0.06	3	0.2	0.02	p=0.14
Other	15	0.2	0.03	3	0.2	0.02	$p=1.0$
Unknown	16	0.2	0.03	0	0	0	$p=0.09$
Instability	17	0.2	0.03	0	0	0	$p=0.06$
Polyethelene wear/fracture[a]	12	0.2	0.02	7	0.4	0.05	$p=0.03$
Periprosthetic fracture	10	0.1	0.02	3	0.2	0.02	$p=0.72$
Haemarthrosis	6	0.1	0.01	0	0	0	$p=0.60$
Malposition	16	0.2	0.03	1	0.1	0.008	$p=0.34$

The Chi-squared proportions test was utilised to compare each revision indication per 100 component years except when the expected frequency < 5 where the fisher exact test was utilised

[a]Indicates revision indications significantly different between groups

fixed cemented UKRs were 92.4% and 93.9%. The differences in revision rates between mobile and fixed bearing cemented UKRs were not significant ($p=0.13$).

In the cementless group ($n=1946$), there were 1760 mobile bearing UKRs [11, 41, 59] and 186 fixed bearing UKRs [20, 34]. There were 39 revisions out of 10,779 component years and 18 revisions out of 1961 component years. This resulted in revision rates of 0.36% pa (CI 0.26–0.50) and 0.92% pa (CI 0.54–1.45), respectively (Fig. 3, Table 7). The 10-year survival for mobile and fixed bearing cementless UKRs were 96.4% and 90.8% with this difference being significant ($p=0.001$).

Implant survival reported

Of the 21 cemented studies, 19 studies reported the long-term survival. 15 studies reported the implant survivals at 10 years and ranged between 83.7 and 96.3% (Table 4). All 5 cementless studies reported long-term implant survivals. 3 studies reported the 10-year implant survival ranging between 96.6 and 97.5% (Table 4).

Indications for revision

All studies (23 studies, $n=9532$; 7586 cemented and 1946 cementless) except Campi et al. [12] and Price et al. [55], reported the mechanisms of failure by fixation type and mean follow-up time (Table 8). The revision rates per 100 component years for aseptic loosening and disease progression were significantly lower ($p=0.02$ and $p=0.009$, respectively) in the cementless group compared to the cemented group (0.06 vs 0.13% pa and 0.10 vs 0.21% pa, respectively). The revision rate for polyethylene wear/impingement was significantly higher ($p=0.03$) in the cementless group (0.05 vs 0.02% pa). No other revision indication was significantly different between cementless and cemented UKRs (Table 5).

Patient-reported outcome measures

13/21 cemented studies and 4/5 cementless studies reported the long-term PROMS for the overall cohort studied. Studies reporting preoperative PROMs all showed an improvement at the ≥ 10-year scores. For the cemented UKRs the 10-year

Table 6 Patient reported outcomes reported for the whole cohort at approximately 10 years

Study	Patient reported outcome measure	Time point (years)
Cementless UKR		
Campi et al. [11]	OKS 41.7 (SD 6.8)	10
Hall et al. [20]	OKS 38 (range 13–48), WOMAC 20 (range 0–72)	10
Lecuire et al. [34]	AKSS 171.4 (SD 25.3)	10
Mohammad et al. [41]	OKS 41.2 (SD 9.8), Tegner 2.8 (SD 1.3), AKSS-0 89.1 (SD 13.0), AKSS-F 80.4 (SD 14.6)	10
Schlueter-Brust et al. [59] (cementless arm)	n.r	n.r
Cemented UKR		
Alnachoukati et al. [3]	AKSS-F 77 (SD 28), AKSS-O 90 (SD 18)	10
Aly et al. [4]	HSS 177.6 (range 78–198)	10
Argenson et al. [6]	KSS clinical 91 (range 50–100) KSS functional 88 (range 45–100)	20
Campi et al. [12] (cemented arm)	n.r	n.r
Chattelard et al. [13]	n.r	n.r
Edmonson et al. [16]	AKSS-O 87, AKSS-F 73, OKS 37, HSS 84	10
Emerson et al. [17]	AKSS-O 93, AKSS-F 78	8
Faour Martin et al. [18]	AKSS-O 90.2 (SD 7.82), AKSS-F 88.6 (SD 17.8)	10
Foran et al. [19]	39 knees HSS 85–100, 6 knees HSS 70–84 and 4 knees had HSS 60–69	10
Kim et al. [29]	AKSS-O 85.4 (range 58–100), AKSS-F 80.5(range 50–100)	10
Kristensen et al. [31]	n.r	n.r
Lim et al. [37]	n.r for overall cohort	n.r
Lisowiski et al. [38]	OKS 41.9 (SD 6.4), KSS 81 (SD 20.7)	12
Pandit et al. [51]	OKS 40 (SD 9), AKSS-O 80 (SD 15), AKSS-F 76 (SD 22), Tegner 2.7 (SD 1.3)	10
Price et al. [55]	n.r	n.r
Schlueter-Brust et al. [59] (cemented arm)	n.r	n.r
Song et al. [61]	n.r for overall cohort	n.r
Venkatesh et al. [64]	KSS Clinical 91.8 (range 51–100) KSS Functional 92 (range 55–100)	Most recent follow-up
White et al. [65]	n.r	n.r
Winnock de Grave et al [68]	OKS 43.3 (range 7–48)	Most recent follow-up
Yoshida et al. [69]	OKS 38.1 (SD 6.8)	10

AKSS-O American Knee Society Score-Objective, *AKSS-F* American Knee Society Score-Functional, *HSS* Hospital for Special Surgery knee score, *KSS* Knee Society Score, *OKS* Oxford Knee Score, *WOMAC* Western Ontario and McMaster universities arthritis index

OKS reported ranged between 37 and 40 and for the cementless, it ranged from 38 to 41.7 (Table 6).

Discussion

This is the first systematic review to the best of the author's knowledge comparing the long-term outcomes of cemented and cementless UKRs. Overall cementless UKRs had a revision rate that was about one-third lower than cemented. This difference appears to be due primarily to the rates of revision for aseptic loosening more than halving.

Although historically cementless implants had a reputation of poor outcomes [10], this review suggests that they currently achieve similar if not better results than cemented implants. This review's results are in agreement with a recent registry-based propensity-matched comparison of cemented and cementless Oxford UKRs [42], which found that the revision rate of the cementless was nearly a third less than the cemented and the revision rate for aseptic loosening more than halved. There are also concerns that cementless fixation is less forgiving than cemented and that only high-volume surgeons would benefit. However, another study has found that the merits of cementless are independent of surgeon volume [43]. Therefore, all surgeons should at least consider using cementless UKR implants.

The fact that cementless UKRs had significantly lower revision rates only for the Oxford UKRs could be because of the limited numbers in the non-Oxford implant group making it more prone to type 2 error. However despite this, the revision rates of the non-Oxford UKR fixation groups were essentially equivalent. The other possibility is the design of the Oxford UKR, which is ligament preserving with a mobile bearing resulting in predominantly compressive loads with minimal shear, and is therefore ideal for cementless fixation.

Randomised studies comparing UKR fixation showed a significant reduction of radiolucencies in cementless groups indicative of improved fixation [27, 52]. This probably explains why the rates of revision for loosening reduced. The decrease in revision rate for arthritis progression with cementless fixation is more difficult to explain. Possible explanations include cement fragments causing direct damage to the lateral compartment or cementing errors causing medial overstuffing resulting in lateral overload. The cementless Oxford UKR femoral component, compared to the cemented, has an additional anterior peg to improve fixation. To accommodate this more bone has to be removed anterior to the femoral component which may decrease the risk of the bone impinging on the bearing, which is known to increase the risk of disease progression [56]. Additionally, the overall mean follow-up weighted on each studies sample size differed between fixation groups (cemented = 7.7 years, cementless = 6.5 years). Arthritis progression tends to occur late, so the longer weighted mean follow-up in the cemented group will disproportionately increase its revision rate specifically for this indication.

No obvious differences in long-term PROMs were found between the cementless and cemented groups. However, both groups had better PROM scores than those commonly reported for TKR [46].

There are two fundamentally different design concepts for UKR; mobile and fixed bearings. The debate of which is better has been a contentious issue [49]. Theoretical advantages of a mobile bearing UKR include lower linear polyethylene wear, better long-term knee kinematics, and a more even load distribution at the implant–bone interface [35]. However, fixed bearings have the advantage of not dislocating. Our study showed that mobile bearing UKRs had significantly lower revision rates than fixed bearing UKRs in the cementless but not cemented groups. Other reviews and clinical studies, which were predominantly based on cemented components also found no differences in their outcomes [35, 45, 54].

The main limitation of this review is that all included studies were observational cohorts with no comparative control arm. Although there has been a formal comparison of the overall revision rates of cemented and cementless UKR from studies using the proportional chi-squared test, this must be interpreted with caution given this is an overall comparison between studies and not from a pooled comparison within studies. Therefore, it does not account for confounding factors, or selection bias related to the selection of patients included in these cohorts with different lengths of follow-up. There is considerable heterogeneity between studies (Fig. 2) where the revision rate can be seen to vary between studies, particularly for the cemented studies. Additionally, given the cementless studies are understandably from fewer centres, this may introduce a possible expertise bias. However it is encouraging that our results mirror those published from propensity-matched registry comparisons, which address these limitations [42]. Larger UKR numbers would cause the revision rate to fall, but this would not explain the lower revision rates in the cementless group as they had far fewer UKRs than the cemented group. Finally, the study was limited given most studies were of the Oxford UKR but this reflects the current literature and highlights the need for more long-term non-Oxford UKR studies of both fixation types.

Conclusions

Cementless fixation offers lower long-term revision rates than cemented, particularly in mobile bearing UKR, with a reduction in aseptic loosening rates suggesting improved fixation. All surgeons should, therefore, at least consider using cementless UKRs in their practice.

Author contributions HRM, GSB, JAK, SJM, AJ and DM designed the study. HRM and GSB collected and analysed the data with statistical support from AJ and DM. HRM, GSB, JAK, SJM, AJ and DM helped with data interpretation. HRM wrote the initial manuscript draft which was then revised appropriately by all authors prior to submission. All authors were involved in the study design, analysis, interpretation of findings and writing of the submitted manuscript.

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Compliance with ethical standards

Conflict of interest The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other non-profit organisation with which one or more of the authors are associated. This research did not receive any specific grant from funding agencies in the

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Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Appendix

Database searches

MEDLINE search

1. Knee/ or exp Knee Joint/ or Osteoarthritis, Knee/
2. knee*.tw.
3. 1 or 2
4. Knee Prosthesis/ or Arthroplasty, Replacement, Knee/
5. (knee* and (arthroplast* or implant* or replace* or prosthe* or endoprosthe*)).tw.
6. 4 or 5
7. "Prostheses and Implants"/
8. 3 and 7
9. 6 or 8
10. Cementation/
11. Bone Cements/
12. exp Hydroxyapatites/
13. (cement* or uncement* or hydroxyapatite or durapatite or hybrid or porous* or coat* or press-fit* or fixation or implant*).tw.
14. 10 or 11 or 12 or 13
15. 9 and 14
16. 15
17. limit 16 to english language
18. Osteoarthritis, Knee/
19. osteoarthr*.tw.
20. 18 or 19
21. 17 and 20

EMBASE search

1. knee/
2. knee*.tw.
3. 1 or 2
4. exp knee arthroplasty/
5. exp knee prosthesis/
6. (knee* adj2 (arthroplast* or implant* or replace* or prosthe* or endoprosthe*)).tw.
7. 4 or 5 or 6
8. exp implantation/
9. 3 and 8
10. 7 or 9
11. cementation/
12. hydroxyapatite/
13. (cement* or uncement* or hydroxyapatite or durapatite or hybrid or porous* or coat* or press-fit* or fixation or implant*).tw.
14. 11 or 12 or 13
15. knee osteoarthritis/
16. (knee and osteoarthr*).ti,ab.
17. 15 or 16
18. 10 and 14 and 17
19. 18
20. limit 19 to english language

CENTRAL search

1. MeSH descriptor: [Knee] explode all trees
2. MeSH descriptor: [Knee Joint] explode all trees
3. knee*
4. #1 OR #2 OR #3
5. MeSH descriptor: [Arthroplasty, Replacement, Knee] explode all trees
6. MeSH descriptor: [Knee Prosthesis] explode all trees
7. (knee* and (arthroplast* or implant* or replace* or prosthe* or endoprosthe*))
8. #5 OR #6 OR #7
9. MeSH descriptor: [Prostheses and Implants] explode all trees
10. #4 AND #9
11. #8 OR #10
12. MeSH descriptor: [Cementation] explode all trees
13. MeSH descriptor: [Bone Cements] explode all trees
14. MeSH descriptor: [Durapatite] explode all trees
15. (cement* or uncement* or hydroxyapatite or durapatite or hybrid or porous* or coat* or press-fit* or fixation or implant*)
16. #12 OR #13 OR #14 OR #15
17. osteoarthr*
18. #11 AND #16 AND #17

See Tables 7 and 8.

Table 7 The calculated revision rates per 100 component years for each for the included studies

Study	No. of knees	Mean follow-up	Observed component years	No. of revisions	Revision rate per 100 component years (CI)
Cementless UKRs					
Campi et al. [11]	682	7	4774	19	0.40 (CI 0.24–0.62)
Mohammad et al. [41]	1000	5.1	5100	18	0.35 (CI 0.21–0.56)
Schlueter-Brust et al. [59] (cementless arm)	78	11.6	905	2	0.22 (CI 0.03–0.80)
Mobile bearing Cementless			10,779	39	0.36 (CI 0.26–0.50)
Hall et al. (2013) [20]	85	10	850	7	0.82 (CI 0.33–1.69)
Lecuire et al. (2014) [34]	101	11	1111	11	0.99 (CI 0.50–1.76)
Fixed bearing Cementless			1961	18	0.92 (CI 0.54–1.45)
Cementless overall			12,740	57	0.45 (CI 0.34–0.58)
Cemented UKRs					
Alnachoukati et al. [3]	825	9.7	8003	93	1.16 (CI 0.94–1.42)
Aly et al. [4]	45	8.75	394	2	0.51 (CI 0.06–1.82)
Campi et al. [12] (cemented arm)	522	8.3	4333	40	0.92 (CI 0.66–1.25)
Edmonson et al. [16]	364	5.5	2002	26	1.30 (CI 0.85–1.90)
Emerson et al. [17]	213	10	2130	20	0.94 (CI 0.57–1.45)
Faour Martin et al. [18]	511	10.38	5304	29	0.55 (CI 0.37–0.78)
Kim et al. [29]	180	10	1800	16	0.89 (CI 0.51–1.44)
Kristensen et al. [31]	695	4.6	3197	51	1.60 (CI 1.19–2.09)
Lisowiski et al. [38]	138	11.7	1615	11	0.68 (CI 0.34–1.22)
Pandit et al. [51]	1000	10.3	10,300	52	0.50 (CI 0.38–0.66)
Schlueter-Brust et al. [59] (cemented arm)	152	10.2	1550	7	0.45 (CI 0.18–0.93)
White et al. [65]	554	6.6	3656	16	0.44 (CI 0.25–0.71)
Yoshida et al. [69]	1279	5.2	6651	25	0.38 (CI 0.24–0.55)
Mobile bearing cemented			50,934	388	0.76 (CI 0.69–0.84)
Argenson et al. [6]	70	20	1400	19	1.36 (CI 0.82–2.11)
Foran et al. [19]	19	19	361	3	0.83 (CI 0.17–2.41)
Lim et al. [37]	279	10.5	2930	11	0.38 (CI 0.19–0.67)
Song et al. [61]	68	9	612	3	0.49 (CI 0.10–1.42)
Venkatesh et al. [64]	175	5.6	980	7	0.71 (CI 0.29–1.47)
Winnock de Grave et al. [68]	460	5.5	2530	11	0.43 (CI 0.22–0.78)
Fixed bearing cemented			8813	54	0.61 (CI 0.46–0.80)
Chattelard et al. [13] Mixture of mobile and fixed	559	5.17	2890	14	0.48 (CI 0.27–0.81)
Cemented overall	8108		62,637	456	0.73 (CI 0.66–0.80)

Table 8 The revision indications for the included studies in the mechanisms of failure analysis

Study	No of revisions	Details of revisions
Cementless studies		
Campi et al. [11]	19	1 Pain, 2 tibial loosening, 5 lateral disease progression, 1 patellofemoral dx, 2 tibial plateau fractures, 1 tibial overhang/impingement, 7 bearing dislocation
Hall et al. [20]	7	4 aseptic loosening, 1 sepsis, 2 OA progression
Lecuire et al. [34]	11	1 knee rheumatoid degeneration, 1 OA in lateral compartment, 1 increased pain, 1 ACL rupture, 3 polyethelene fracture, 4 bearing exchange for wear
Mohammad et al. [41]	18	7 bearing dislocation, 4 disease progression, 2 pain, 2 debridement washout and bearing exchange for infection, 1 AVN, 1 femoral comp loosening, 1 tibial plateau fracture
Schlueter-Brust et al. [59] (cementless arm)	2	1 pain, 1 bearing dislocation
Cemented studies		
Alnachoukati et al. [3]	93	19 tibial loosening, 5 tibial and femoral loosening, 6 tibial collapse, 22 arthritis progression, 2 tibial overload, 1 loose body removal, 7 femoral loosening, 13 unknown, 5 bearing dislocation, 1 tibial fracture, 1 instability, 1 car accident, 1 infection, 3 pain, 1 RA, 3 chronic haemarthrosis, 2 polywear impingement
Aly et al. [4]	2	1 fracture of medial tibial plateau, 1 aseptic loosening
Argenson et al. [6]	19	9 OA progression, 2 aseptic loosening, 3 patellafemoral prosthesis because of OA progression, 5 polyethelene wear
Chattelard et al. [13]	14	5 loosening, 5 tibial component wear, 2 lateral OA, 2 infection
Edmonson et al. [16]	26	9 Lateral compartment OA 5 Combination of lateral and patellofemoral OA 6 Aseptic loosening 4 Dislocated bearing 2 Unexplained medial pain
Emerson et al. [17]	20	3 chronic haemarthrosis 2 loose femoral components 2 loose tibial components 9 progression of OA in lateral compartment 1 bearing dislocation 1 polyethelene wear 2 unknown
Faour Martin et al. [18]	29	15 infection 2 bearing exchange for dislocation 8 persistent pain 4 aseptic loosening tibial component
Foran et al. [19]	3	2 patellofemoral and lateral OA, 1 lateral OA
Kim et al. [29]	16	7 bearing dislocations 1 bearing wear and breakage 1 MCL rupture with bearing dislocation 3 Femoral component loosening 1 Femoral and tibial component loosening 1 Component loosening with bearing dislocation 1 Tibial condylar fracture 1 Infection
Kristensen et al. [31]	51	8 aseptic loosening of tibial component 1 aseptic loosening of femoral component 2 aseptic loosening of both components 14 Progressive OA in lateral compartment 2 Progression of retropatellar OA 10 Pain without loosening 4 Deep infection 2 Periprosthetic fracture 2 Malposition 4 Instability 2 Other
Lim et al. [37]	11	2 aseptic loosening, 6 OA progression, 1 poly fracture, 1 poly wear and progressive arthritis, 1 medial condylar fracture

Table 8 (continued)

Study	No of revisions	Details of revisions
Lisowiski et al. [38]	11	4 pain 6 disease progression 1 bearing dislocation
Pandit et al. [51]	52	25 Progressive OA in lateral compartment 7 bearing dislocation 7 unexplained pain 1 unknown 6 infection 1 ACL injury 1 ANV lateral femoral condyle 1 Tibial malposition 1 aseptic loosening femur 1 aseptic loosening tibia 1 instability
Schlueter-Brust et al. [59] (cemented arm)	7	4 pain, 3 bearing dislocation
Song et al. [61]	3	1 tibial plateau fracture, 1 tibial plateau collapse, 1 pain
Venkatesh et al. [64]	7	4 unexplained pain, 2 aseptic loosening, 1 poly wear
White et al. [65]	16	6 progressive arthritis, 4 instability, 3 unexplained pain, 1 aseptic loosening of tibia, 1 infection, 1 periprosthetic fracture
Winnock de Grave et al. [68]	11	4 infection, 2 lateral pain and overload, 2 pain and patellar chondropathy, 2 lateral OA, 1 synovitis
Yoshida et al. [69]	25	1 bearing rotation, 2 periprosthetic fracture tibia, 9 bearing dislocation, 12 tibial subsidence of component, 1 progression lateral OA

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