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Survivorship of Fixed Vs Mobile Bearing Unicompartmental Knee Replacement: A Systematic Review and Meta-analysis of Sixty-Four Studies and National Joint Registries

Authorship: Abu Al-Rub, Z[2*], Lamb, JN[1,2*], West RM[3], Yang X[4], Hu Y[4], Pandit HG[1,2].

Institution in which work was performed: Leeds Institute of Rheumatic and Musculoskeletal Medicine (LIRMM), School of medicine, University of Leeds, Chapel Allerton Hospital, Leeds, LS7 4SA, UK

Affiliations of authors:

[1] Leeds Institute of Rheumatic and Musculoskeletal Medicine (LIRMM), School of medicine, University of Leeds, Chapel Allerton Hospital, Leeds, LS7 4SA, UK;

[2] Leeds Teaching Hospitals NHS Trust, Beckett Street, Leeds, LS9 7TF, UK,

[3]Leeds Institute of Health Sciences, School of Medicine, University of Leeds, Leeds, LS2 9NL, UK.

[4]Xiangya Hospital, No 87, Xiangya Road, Kaifu District, Changsha, Hunan Province, China.

*Indicates equal contribution to and joint first authorship of the work contained in this manuscript.

Corresponding author: J N Lamb j.n.lamb@leeds.ac.uk

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Abstract

Background: Unicompartmental knee replacement (UKR) prostheses can use fixed (FB) or mobile bearing (MB) constructs. We compared survivorship and failure modes of both designs.

Methods: The inclusion criteria were studies published between 2005-2020 with minimum average follow-up of 5 years reporting the survival and/or number of revisions of specific designs in medial and lateral UKR. Pooled rate of revision per 100 patient years (PTIR) was estimated using a random effects model.

Results: 70 cohorts of 17 405 UKRs with weighted mean follow-up of 7.3 years (0.1-29.4 years) were included. A total of 170 923 UKRs were identified in registry reports at a weighted mean implant survival time of 15.4 years. PTIR in MB UKR versus FB UKR was similar [1.45 Vs 1.40, (p = 0.8)].

In cohort studies, the overall PTIR for MB was also similar to FB [1.03 Vs 0.78, (p= 0.1)]. For medial UKR, the PTIR for MB was marginally greater but not significantly different to FB [0.96 Vs 0.81, (p= 0.3)], whilst for lateral UKR, the PTIR for MB was significantly worse than for FB [(2.20 Vs 0.72, ($p<0.01$)]. Polyethylene wear is more common in FB implants, whilst MB implants are revised more often for bearing dislocation.

Conclusion: Overall implant survival in mid- to long-term studies is similar for MB versus FB medial UKR. MB have a four-fold higher risk of revision in comparison to FB when used for lateral UKR.

Keywords: Unicompartmental knee; Revision; Survivorship; Mobile; Fixed; Arthroplasty

1. Introduction

Unicompartmental knee replacement (UKR) is deemed to be appropriate for about one in four osteoarthritic knees needing replacement [1]. UKR is associated with faster recovery, better function and lower morbidity and mortality [2–4]. However, the UKR usage has not exceeded 5 to 10% [5]. Many surgeons are reluctant to perform UKR where indications allow because of higher revision rates than total knee replacement [5].

A UKR can be performed with either a mobile bearing (MB) or a fixed (FB). Proponents of the MB construct claim a reduction in polyethylene wear in comparison to FB constructs. MB UKR can be more technically challenging with suboptimal outcomes, and higher rate of complications like bearing dislocation [6]. Implants which reduce the technical demands on surgeons may reduce poor outcomes and encourage surgeons to implant UKRs when appropriate. FB UKR utilisation has increased from 30% in 2010, to 49% in 2018 [5]. Adoption of FB designs may be due to a perceived reduction in technical difficulty, reduced bearing dislocation and improved wear of modern polyethylene [7].

Outcomes and survivorship of both FB and MB constructs are excellent but there are significant differences in the revision rates between cohort studies and in registry data [5,8–10]. Over the past decade, systematic reviews and meta-analyses attempted to address the debate of superiority between the two constructs. Three reviews included RCTs and non-randomised comparative studies analysed 5,10, and 15 studies, respectively [11–13]. Other reviews focused on either medial or lateral only UKRs with limited study inclusion potentially limiting the usefulness of their findings [14–19]. Therefore, the aim of this study was to address the issue of limited inclusion of studies and registries in previous reviews and complement their findings through a comprehensive systematic review and meta-analysis of the implant survival in mobile versus fixed bearing UKR for medial as well as lateral constructs, using all available cohort studies with long-term follow up and registry data with minimal restriction from the past 15 years.

2. Material and methods

2.1 Data sources

This analysis was performed in two parts. Firstly, a systematic review and meta-analysis of cohort studies reporting revisions for any cause for MB or FB UKR in either the medial of lateral tibiofemoral joint, over an average follow up of at least five years was performed. Secondly, a meta-analysis of registry data was performed for UKRs where survival was reported separately for either FB or MB UKRs at or beyond least five years.

2.2 Systematic review and meta-analysis of cohort studies

The study methodology was peer reviewed and registered on the PROSPERO (id: CRD42020167444). The literature search was conducted using the online databases Medline and EMBASE. Articles were identified using a combination of keyword searches describing unicompartmental knee replacement, survival and revision. Results were combined with searches for Mesh terms (Appendix 1). Citation searching was performed for all full text manuscripts to identify manuscripts which were not found in initial searches.

Inclusion criteria for cohort studies included: Articles written in English language, available in full text, published between 2005 and 2020, human studies, with greater or equal to 5 years of average follow-up and reporting the survival and/or number of joints revised of specific UKR (mobile or fixed for either medial or lateral unicompartmental replacement). Revision was defined as revision of any part of the UKR construct. We excluded conference abstracts, manuscripts which reported on the same cohort twice, systematic reviews and registry studies to prevent duplication of observation.
Abstracts and the full texts were screened by two authors (JL and ZA) independently and disagreements at each stage were settled by consensus. Risk of bias/quality of studies was assessed using criteria developed by Wylde et al. independently by two authors (JL and ZA) [20]. Where available extracted data included: Title, authors, year of publication, prostheses used (brand and model), reconstructed tibiofemoral joint (medial or lateral), number of female patients, average age of cohort, indication for UKR (osteoarthritis (OA), spontaneous osteonecrosis of the knee (SONK), post traumatic osteoarthritis and other), number of UKRs, number of revisions, survival of cohort (with confidence intervals), revision indications and loss to follow up. Data was extracted by one author (ZA) and a random selection of 10% of screened records were double checked by a second reviewer (JL).

2.3 Mata-analysis of registry reported data

Registry data was obtained through manual searching of all publicly accessible arthroplasty registers. Survival rates for MB and FB UKR were separately reported by four arthroplasty registries and data collected included:

Date of report, country of report, prostheses used (brand and model), number of female patients, average age of cohort, number of UKRs, number of revisions, estimated proportion of cohort surviving and time point of survival estimate.

2.4 Statistical analysis

The primary exposure was the UKR construct, and the primary outcome measure was all-cause revision of any part of the construct. Study and patient level statistics were estimated using mean values weighted by number of cases. Patient time (PT) was approximated using the product of number of cases in follow-up and average follow-up time in centuries. Patient time incidence rate of revision per 100 years (PTIR) was estimated by dividing the patient time by the number of revisions. For registry reported data, PTIR was derived from the Kaplan-Meier estimates of survival for mobile and fixed bearing UKRs separately. PT was estimated using the product of number of UKRs and the survival time in centuries. PTIR was estimated by dividing PT by the product of the number of UKRs and the proportion revised. PTIR estimates were pooled using a random effects model with a comparison of subgroups based on bearing fixation (FB versus MB UKRs). The random effects method used an inverse-variance method, DerSimonian-Laird estimator for tau^2, Jackson method for confidence interval of tau^2 and tau and the results are given on a log transformed scale. All data analysis was completed using R (version 3.6.2, Vienna Austria, 2019).

3. Results

3.1 Cohort studies:

Our search resulted in 213 references from database and citation searches. After title and abstract screening, 99 records were excluded and 114 manuscripts underwent full text review (figure 1).

Full text review identified 70 cohorts (61 medial UKR and nine lateral UKR) in 64 studies which were included in further analysis. The cohorts included a total of 17 405 cases, which were comprised of 16 619 medial compartment UKR and 786 lateral compartment UKR. Weighted mean follow-up was 7.3 years and ranged from 0.1 to 29.4 years after implantation (table 1). Patient level characteristics derived from reported data are displayed in table 1.

Meta-analysis of PTIR revealed an overall rate of revision per 100 patient years (95% CI) was 0.8 (0.6 to 1) for FB UKR and 1.0 (0.8 to 1.3) for MB UKR (test for sub-group differences, p= 0.1). When analysing by subgroup of constructs on the medial and lateral condyles the rate of revision per 100 patient years (95% CI) was 1 (0.8 to 1.1) for medial UKR and 1.3 (0.8 to 2.1) for lateral UKR (test for sub-group differences, p = 0.2).

For medial UKR the PTIR for MBs UKR was higher than that for FB UKR but the difference did not reach significance (0.96 [0.8 to 1.2] versus 0.8 [0.6 to 1.1], p= 0.3, figure 2).

For lateral UKR the PTIR for MBs was significantly greater than for FBs (2.2 [1.3 to 3.6] versus 0.7 [0.4 to 1.2] p<0.01, figure 3).

Revision indications were reported in 60 of 61 medial UKR cohorts and 6 of 9 lateral UKR cohorts (table 2). The quality of cohort studies was generally low with a majority of studies reporting only from a single centre without any form of adjustment for confounding factors (figure 4).

3.2 Registry data

Our search of public reports from national and international registries yielded results for 176 412 UKRs, comprising of 75 625 FB UKRs and 100 787 MB UKRs. Weighted mean time point for survival estimates was 15.3 years.

Pooled PTIR derived from survival estimates reported by registries demonstrated a marginally increased PTIR (95% CI) for revision in MB UKR versus FB UKR, (1.44 [1.2 to 1.7] versus 1.37 [1.1 to 1.7] respectively, p = 0.75, Figure 5). The registry data does not differentiate between medial and lateral UKR and therefore sub-group analysis could not be performed.

Indications for revision in all UKRs combined were reported in all registries but subgroup analysis according to the mobility of bearing surface was only provided in the National Joint Registry of England, Wales, Northern Ireland and the Isle of Man, 16th report (table 3)[5] .

4. Discussion

This comprehensive review of fixed versus mobile bearings used in medial or lateral UKRs has shown a marginally better implant survival for FB UKR over MB UKR in cohort as well as registry data. These differences are more apparent in the lateral UKR (nearly four-fold worse for mobile UKR). Progression of arthritis is the commonest cause of revision of a UKR. This study is the first to integrate large amounts of cohort and registry data to evaluate the survivorship of the two available bearing designs for UKRs in both the medial and lateral compartments.

Results extracted from manuscripts and registry reports did not demonstrate a statistically significant difference between FB and MB UKR overall, which is similar to results reported from other reviews [11,12,21]. Overall, there was a small increased risk of revision associated with MB implants as compared to FB implants, although the difference is too small to make a meaningful statistical difference. Given that the numbers of lateral UKR are far less than medial UKR, the results are heavily skewed by medial UKR outcomes. It is up to the surgeon to choose a mode of bearing fixation for both medial and lateral UKR with which they can safely rebalance the reconstructed knee.

There was no significant difference in the rate of revision between FB and MB for medial UKR. Cohort studies demonstrated that bearing dislocation and bearing breakage as a failure mechanism are unique in the MB group whilst bearing wear is more common in the FB group. The higher bearing wear seen in FBs is compatible with previously published literature showing a higher mean penetrative wear rate 0.15 vs 0.04 mm/year in fixed versus mobile bearing UKRs [22,23]. In anteromedial OA of the knee, patients typically bear more weight through the medial tibio-femoral joint which has greater constraint in normal walking than the lateral tibio-femoral joint. This can increase the loading of the reconstructed medial UKR and increase the likelihood of bearing wear. Therefore, any potential benefit of bearing stability might be offset by the increased risk of wear with medial FB UKR, particularly where older high wear polyethylene bearings are used [24].

For lateral UKR, there was an approximately four-fold risk of revision associated with the use of MB UKR versus FB UKR, which is agreement with a previous review [14]. The lateral condylar joint is less constrained which increases the underlying risk of bearing dislocation for MB UKR. Lateral UKR performed for valgus knee OA may bear a larger proportion of body weight through the lateral versus medial condylar joint. However, there were no reported cases of revision of lateral UKR (fixed or mobile) due to bearing wear [25,26]. It appears that the FB construct maintains the benefits of a stable bearing without any reciprocal increase in wear.

Analysis of revision indications provide further insight into the potential mechanism of failure for fixed or mobile constructs. By definition, bearing dislocation is only confined to mobile constructs and therefore not possible to compare the risk, whilst bearing breakage is significantly higher in the mobile cohort and may be related to the bearing thickness. In comparison, FB wear is significantly higher than MB potentially representing the price paid by the FB constructs in exchange for reduced risk of bearing dislocation and bearing breakage.

Progression of arthritis is a dominant indication for revision for both FB and MB UKRs, an effect seen in the reported revision indications in cohort studies and in results reported by the NJR (National Joint Registry for England, Wales, Northern Ireland and the Isle of Man). The ability of the surgeon to correctly balance the knee and prevent overloading of the contralateral compartment is likely to be a key factor. Therefore, this skill becomes more challenging in the MB UKR when the surgeon must also carefully cut and select the appropriate bearing size for the reconstructed condyle to reduce the risk of dislocation, particularly following lateral MB UKR. As such, reduction of bearing instability and surgical complexity without excessive bearing wear may potentially be achieved by using a FB UKR construct, particularly when used in the lateral compartment or when low wear polyethylene bearings are used.

There is a noticeable difference in the reported indications for revision between the registry reports and the results of this meta-analysis. For example, bearing dislocation as an indication for revision was less than half the frequency reported in cohort studies, whilst the incidence of aseptic loosening and lysis was significantly higher for registry reported UKRs. This can possibly be explained by the fact that bearing dislocation treated with bearing exchange may not be recorded consistently in registry data collection methods. Furthermore, it is more likely that revisions involving removal or exchange of tibial or femoral component, in a planned setting where data collection techniques are readily used, will be more accurately recorded. Those differences are likely to reflect the constraints of the literature and registries to accurately report the true indication for revisions and may account for those findings.

There is also a prominent difference in the revision rates between different designs and different registry datasets. Those differences are likely to be multi-factorial and may be related to patient, surgical, implant and registry factors. Patient factors may include differing levels of activity, comorbidity, weight, height and baseline grade of arthritis [27–29] . Surgical factors include surgeon's annual caseload, patient selection, misinterpretation of radiographs and threshold for revision [27–32]. Implant factors include variation in implant design along with variation described in bearing mobility [33]. Registry factors may include reporting method, definition of revision procedures and data completeness.

4.1 Study Limitations

Our meta-analysis is based on observational data subject to a majority of low study quality, large statistical heterogeneity because of their inherent biases, and design differences that meta-analysis cannot overcome. Four studies reported results from multi-centre patients, whilst the rest of studies included in this analysis were single-centre and/or single surgeon cohorts [10,27–29]. Two randomised prospective studies were identified but didn't meet our inclusion criteria due to either short-term follow up and/or not reporting on survival of implant construct specifically [30,31]. Our inclusion criteria were set to reduce the bias of shorter follow up studies which may report early complication such as bearing dislocation. Those criteria may unintentionally reduce the number of cases from studies reporting survival of the most recently produced implants and approaches. Estimated PTIR in the study assumes that the revision rate is relatively constant over different periods of patient time, which may not accurately reflect the true risk of revision for any particular patient. PTIR estimates derived from average follow up is a useful method but may have limited precision, particularly with abnormal distributions of follow up time in the reported studies. Lateral UKR is an uncommon indication for UKR which reduced the number of cohorts available limiting our sample sizes in the pooled analysis. This is reflected in the confidence limits of our estimates. Implants used in this analysis may have used polyethylene with higher wear rates, suboptimal fixation methods, and outdated technology which is no longer commonly used. No adjustment for those limitations is possible due to the lack of detail given in the studies. As such, the results in this study may not accurately represent the benefits provided by recent or future technological advancements. Further insights into the performance of modern implants may be better understood using robust analysis of registry data or well-designed prospective trials. Joint registry data has the advantages of large sample size, usage by multiple surgeons in different settings and may be more generalisable in comparison to cohort study data. However, it does not differentiate between medial and lateral UKRs and does not take into consideration the learning curve and/or indication for primary surgery or revision surgery.

5. Conclusions

This up to date and comprehensive study demonstrates a comparable incidence of all cause revision between fixed and mobile bearing UKR. Subgroup analysis demonstrated a four-fold increase in risk of all cause revision associated with mobile UKR when used for lateral condylar reconstruction in comparison to fixed bearing UKRs. Failure of prosthesis is multifactorial and may be determined by factors other than bearing stability and risk of bearing dislocation. Future well-designed randomised controlled trial with standardised patient selection criteria to assess the long-term survival of fixed versus mobile bearing would be the ideal way to verify the results of the current available literature regarding the two constructs.

6. Contribution of Authors:

1- ZA: Data retrieval, manuscript preparation and editing.

2- JL: Study design, Literature search, statistical analysis, manuscript preparation and editing.

3- RMW: Statistical methods and analysis

4- XY: Manuscript editing

5- YH: Manuscript editing

6- HGP: Study design, manuscript editing.

7. Declaration

7.1 Conflict of Interest: JL is supported by the NIHR Biomedical Research Centre at the Leeds Teaching Hospitals NHS Trust and the University of Leeds.

HGP is a paid consultant for Bristol Myers Squibb, Depuy Synthes, JRI Orthopaedics, Kennedys Law, Medacta Int, Meril Life, Smith & Nephew and Zimmer Biomet. He has received institutional research grants from Charnley Trust, Depuy Synthes, Glaxo Smith Kline, NIHR, Versus Arthritis and Zimmer Biomet.

7.2 Acknowledgment: *Professor Pandit is a National Institute for Health Research (NIHR) Senior Investigator. The views expressed in this article are those of the author(s) and not necessarily those of the NIHR, or the Department of Health and Social Care.*

7.3 Funding: The study is funded by departmental funds held at the University of Leeds, England and Smith and Nephew.

Figure 1. PRISMA flow chart summarising data collection for cohorts reported in peer reviewed manuscripts.

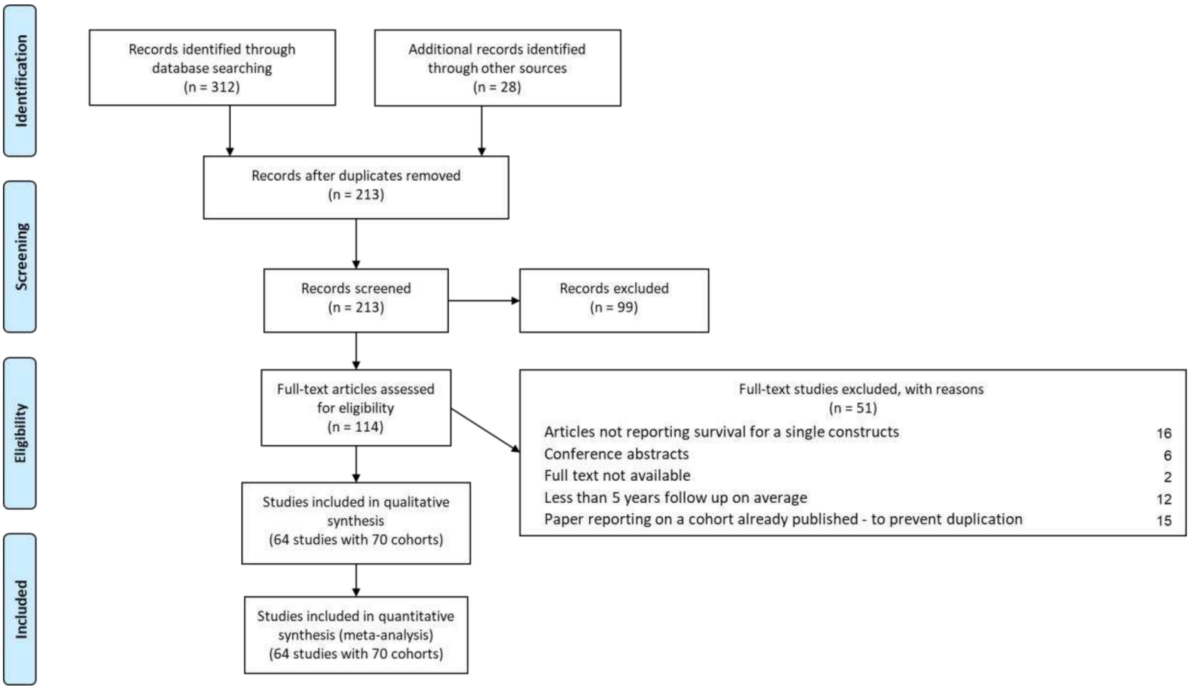

Figure 2. Forest plot demonstrating pooled patient-time incidence rates of revision per 100 years (PTIR) using a random effects model for all medial UKR cohorts. Incidence rates for fixed and mobile bearing constructs are reported separately. Note: PT indicates Patient time in centuries, CI indicates confidence interval.

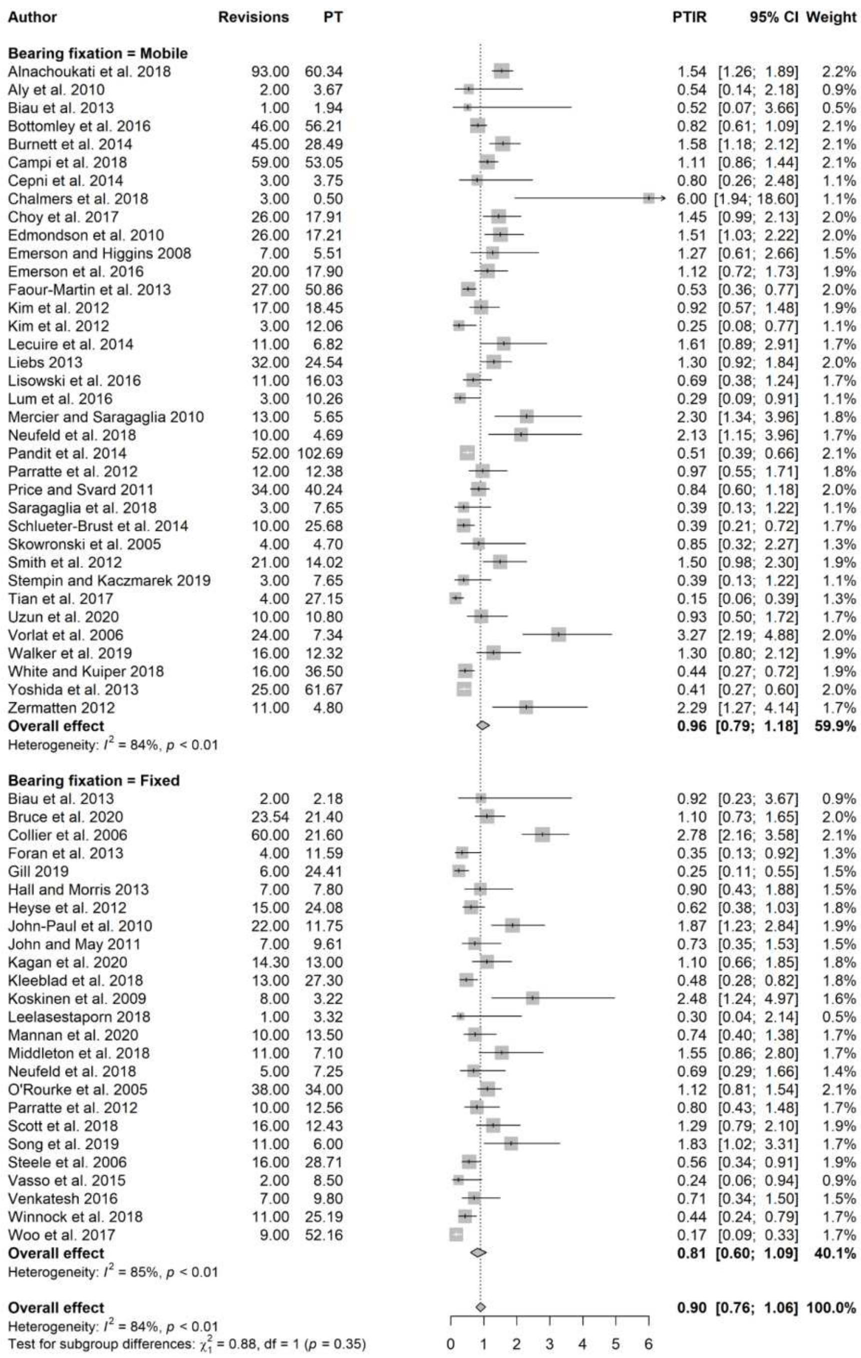

Figure 3. Forest plot demonstrating pooled patient-time incidence rates of revision per 100 years (PTIR) using a random effects model for all lateral UKR cohorts. Incidence rates for fixed and mobile bearing constructs are reported separately. Note: PT indicates Patient time in centuries, CI indicates confidence interval.

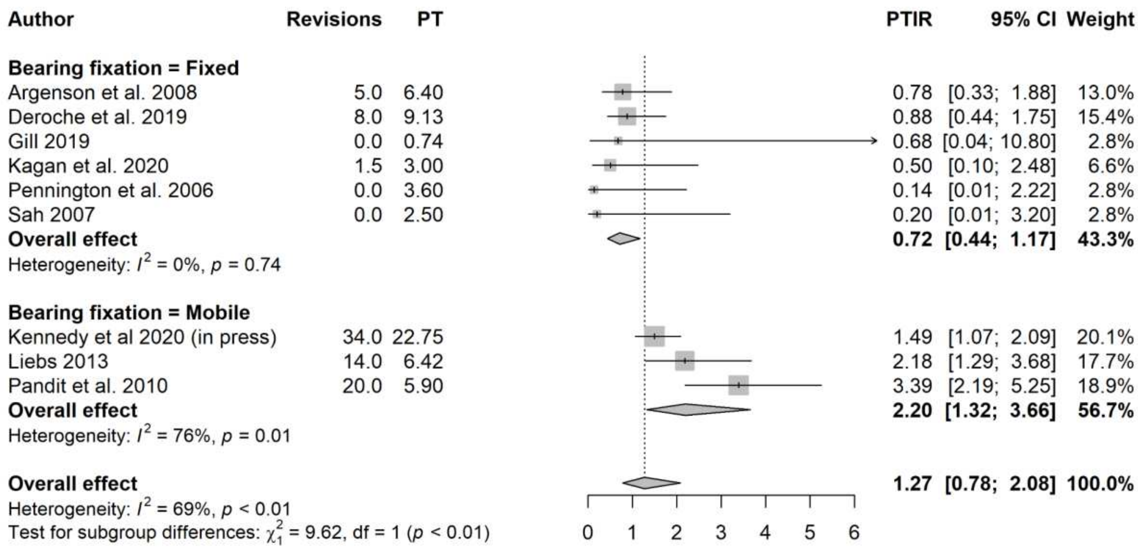

Figure 4. Plot demonstrating the quality assessment of included studies.

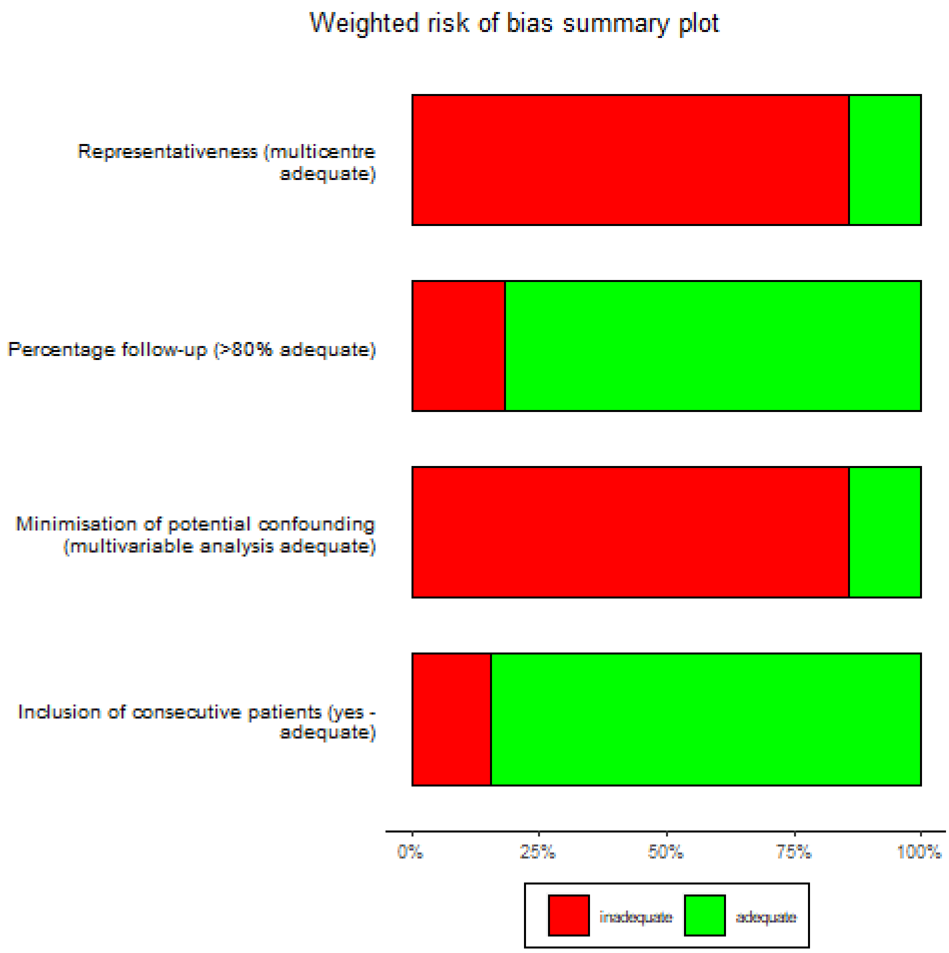

Figure 5. Forest plot demonstrating pooled patient-time incidence rates for revision per 100 years (PTIR) using a random effects model for all registry reported UKR cohorts. Incidence rates for fixed and mobile bearing constructs are reported separately.

PT: Patient time in centuries, CI: confidence interval, NJR: National Joint Registry for England, Wales, North of Ireland and Isle of Man, FJR: Finnish Joint Registry, AJR: Australian Orthopaedic Association National Joint Replacement Registry, NZJR: New Zealand Joint Registry.

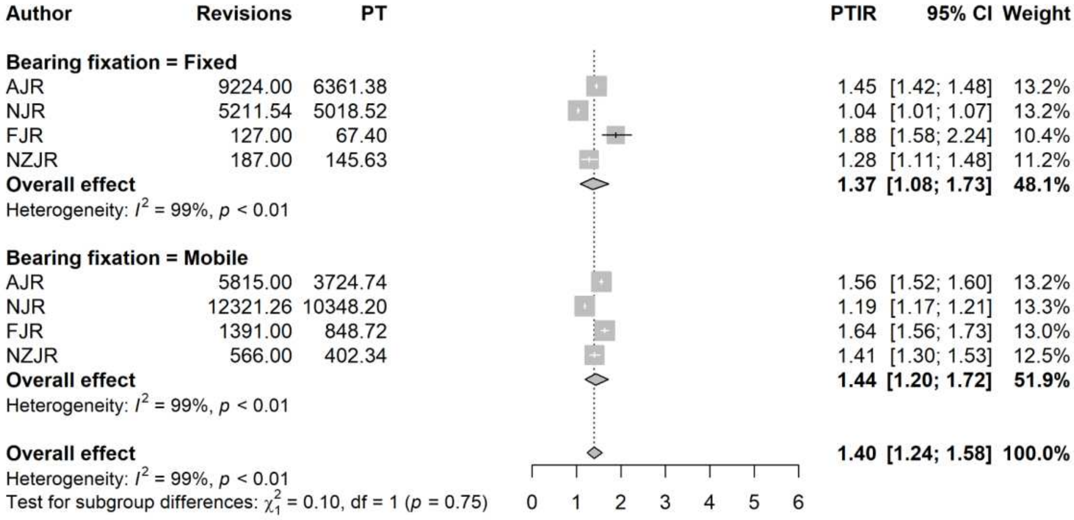

Table 1. Summary of study and patient characteristics

	Lateral UKR		Medial UKR	
	Fixed bearing	Mobile bearing	Fixed bearing	Mobile bearing
Number of UKR	215	571	4982	11637
Year of publication	2006-2020	2010-2013	2005-2020	2005-2020
Patient characteristics				
Mean age (years)	64.0	65.8	64.9	67.1
Female patients (%)	67.7	64.8	47.3	54.7
Indications				
Osteoarthritis (%)	81.4	98.8	91.8	95.1
SONK (%)	2.6	1.1	3.1	2.1
Post-Traumatic OA (%)	16.0	0.0	0.9	0.3
Other (%)	0.0	0.0	4.3	2.2
Mean follow up	11.6	6.4	7.6	7.1
Follow up range	1.5-24.0	2.1-9.8	1-29.4	0.1-22.0

Note: Means weighted by number in study, where reported. UKR indicates unicompartmental knee replacement, SONK spontaneous osteonecrosis of the knee and OA osteoarthritis

Table 2. Summary of cases revised for each unicompartmental knee replacement construct

	Lateral UKR		**Medial UKR**	
	fixed	*mobile*	*fixed*	*mobile*
Revision indication	n (%)	n (%)	n (%)	n (%)
Arthrofibrosis	0 (0)	1 (1.5)	1 (0.3)	4 (0.6)
Bearing breakage	0 (0)	0 (0)	1 (0.3)	10 (1.5)
Bearing dislocation	0 (0)	23 (33.8)	0 (0)	121 (17.6)
Bearing wear	0 (0)	0 (0)	73 (22.1)	7 (1)
Both or unspecified components loosening	0 (0)	6 (8.8)	39 (11.8)	37 (5.4)
Component malposition	0 (0)	0 (0)	3 (0.9)	3 (0.4)
Femoral component loosening	0 (0)	1 (1.5)	8 (2.4)	42 (6.1)
Peri-prosthetic Fracture	0 (0)	4 (5.9)	5 (1.5)	16 (2.3)
Haemarthrosis	0 (0)	3 (4.4)	0 (0)	8 (1.2)
Impingement	0 (0)	2 (2.9)	0 (0)	6 (0.9)
Infection	0 (0)	7 (10.3)	18 (5.4)	45 (6.6)
Instability	0 (0)	0 (0)	4 (1.2)	12 (1.7)
Pain	0 (0)	1 (1.5)	36 (10.9)	45 (6.6)
Progression of OA	12 (80)	18 (26.5)	92 (27.8)	210 (30.6)
Synovitis	0 (0)	1 (1.5)	1 (0.3)	3 (0.4)
Tibial component loosening	1 (6.7)	1 (1.5)	41 (12.4)	86 (12.5)
Unknown	2 (13.3)	0 (0)	9 (2.7)	31 (4.5)

Note: Counts are displayed with percentage of all extracted reasons for revision in each column in parentheses. UKR indicates unicompartmental knee replacement, OA osteoarthritis

Table 3. Patient time incidence rate estimates (per 100 years) of revision indications for unicompartmental knee replacement constructs in the National Joint Registry of England, Wales, Northern Ireland and the Isle of Man, 16th report

	All unicompartmental		**Fixed bearing**		**Mobile bearing**	
	PTIR	%	PTIR	%	PTIR	%
Pain	0.24	**15.8**	0.25	**16.1**	0.24	**15.6**
Dislocation / subluxation	0.08	**4.9**	0.01	**0.8**	0.10	**6.7**
Infection	0.05	**3.4**	0.06	**3.8**	0.05	**3.2**
Aseptic loosening / lysis	0.33	**21.5**	0.31	**20.0**	0.34	**22.2**
Peri-prosthetic fracture	0.03	**1.8**	0.02	**1.5**	0.03	**1.8**
Implant wear	0.11	**7.3**	0.10	**6.5**	0.12	**7.7**
Instability	0.10	**6.4**	0.07	**4.7**	0.11	**7.1**
Malalignment	0.06	**4.2**	0.06	**3.6**	0.07	**4.3**
Other indication	0.17	**11.1**	0.12	**7.8**	0.19	**12.5**
Stiffness	0.02	**1.4**	0.03	**1.6**	0.02	**1.2**
Progress	0.34	**22.2**	0.32	**20.9**	0.35	**22.8**

Note: PTIR indicates Patient time incidence rate (per 100 patient years). Estimates are derived from different periods of patient time exposure and multiple indications may exist for a single revision.

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