A matched comparison of long term risks of total and unicompartmental knee replacements in different ages based on national databases

Hasan R Mohammad, A Liddle, Andrew Judge, David W Murray

Qualifications, appointments and roles of the authors

[1, 2] Mr Hasan R Mohammad - MBChB, MRCS, MRes (Dist), DPhil (Oxon).
Clinical Research Fellow in Orthopaedics.
[1, 2] Professor Andrew Judge – BSc, MSc, PhD. Professor of Translational Statistics.
[1] Professor David W Murray – MD, FRCS. Consultant Orthopaedic Surgeon and Professor of Orthopaedic Surgery.

Institutional address

1. Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences University of Oxford, Nuffield Orthopaedic Centre, Oxford, OX3 7LD, United Kingdom
2. Musculoskeletal Research Unit, Bristol Medical School, University of Bristol, Level 1 Learning and Research Building, Southmead Hospital, Westbury-on-Trym, Bristol, BS10 5NB, United Kingdom.

Corresponding author:

Name: Mr Hasan Raza Mohammad

Email: hasanmohammad@doctors.org.uk

Tel: +44 (0) 7841 873 244

Corresponding Author Address: The Botnar Research Centre, Old Road, Oxford, OX3 7LD.

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ABSTRACT

Introduction: Half the patients needing knee replacement could have either a unicompartmental or total knee replacement (TKR). We aimed to compare the long term risks of both procedures in different age groups and present the data in a way that is accessible to clinicians and patients.

Methods: The National Joint Registry collects information on knee replacements in England and Wales and was linked for multiple confounders to the National Hospital Episode Statistics database. 54,215 UKRs and 54,215 TKRs were propensity score matched and Kaplan-Meier and regression analysis were used to compare cumulative risks.

Results: UKR had higher 10yr revision rates (12% and 5% respectively, Hazard Ratio (HR) 2.31, $p<0.001$) and 10yr re-operation rates (25% and 21%, HR 1.12, $p<0.001$) than TKR. UKR had lower the 10yr mortality rates (13.6% and 15.5%, HR of 0.86, $p<0.001$). During the first 3 months after surgery UKR also had lower rates of medical ($p<0.001$) and implant related ($p<0.001$) complications and deaths (HR 0.61, $p=0.02$). If 100 patients had a UKR instead of a TKR then over 10yr, if they were <55yr old there would be 7 more re-operations and 1 less death, 55-64yr 6 more reoperations and 2 more deaths; 65-74yr 4 more re-operations and 2 less deaths, and ≥75yr 2 more re-operations and 4 less deaths.

Conclusion: UKR have higher revision and re-operation rates but lower death rates than TKR. The decision to do a UKR should, in part, be based on the balance of these risks, which are influenced by patient age. In the elderly, if UKR are used instead of TKR, the absolute decrease is death rate is higher than the increase in re-operation rate suggesting that UKR should be used whenever possible.

INTRODUCTION

Knee arthritis is a common and debilitating condition. The main treatment for end stage knee arthritis which has failed to respond to conservative management is knee replacement. Over 100,000 procedures are performed annually in the United Kingdom [1] and the number is increasing due to increasing age, obesity, actively and expectations [2, 3]. The two main types of knee replacement are total (TKR) and unicompartmental (UKR) [2]. In TKR the whole tibiofemoral articular surface is replaced with ligaments removed, whereas in UKR only the affected compartment is replaced, and the ligaments are preserved. About 50% of knees needing replacement are appropriate for UKR, yet currently only 10% are UKR [1, 4].

The National Institute of Clinical Excellence (NICE) has recently recommended that patients appropriate for UKR should be offered a choice of UKR or TKR and that the potential benefits and risks of each option should discussed [5]. Furthermore the patient members of the review panel were clear that the decision should be made by the patient and not by the surgeon [5]. The benefits of UKR, such as improved function, faster recovery and better cost effectiveness are well established [6-8]. However the risks are not so well established because they are rare events. National Registers are one of the best sources of data to assess the risks as they have data on large numbers of cases. National Registers are informed by surgeons every time a knee replacement component is implanted. If new components are implanted in a knee that has previously been replaced Registers define this as a revision and consider it to be a failure [1, 9, 10]. All National Registers conclude that the failure rate of UKR is 2 to 3 times higher than TKR and it is for this reasons that so few UKR are performed.

In assessing risk patients need more information than just the revision rate. For example they need to know the overall re-operation rate and not just the rate of re-operations in which new components are implanted and are therefore considered to be revisions. Re-operations that are not revisions have a spectrum of severity extending from amputation or internal fixation for peri-prosthetic fracture, to arthroscopy or manipulation under anaesthetic for stiffness [11]. Information about the mortality related to the knee replacement and early complications, which can be medical, such as myocardial infarction or renal failure, and implant related, such as fracture or wound dehiscence, and are also important.

Risk reduction associated with different interventions can be presented in various ways such as relative or absolute risk reduction, or numbers needed to treat [12]. Absolute risk reduction is particularly useful as it is easily understood by patients and clinicians and does not tend to exaggerate differences. If presented as frequencies it improves the understanding of risk and it is helpful to quote the difference in number of events that would be expected if 100 patients were treated in different ways [6]. The increase or decrease in risks will be affected by many factors so it is essential to match the interventions being compared. In knee replacement a factor that has a profound influence on outcome is patient age.

The aim of this study was to compare the outcomes of matched TKR and UKR using data from 3 national datasets: National Joint Registry for England Wales and Northern Ireland (NJR); Hospital Episodes Statistics Admitted Patient Care records (HES-APC) and Office of National Statistics (ONS). As well as assessing short term complications we determined ten year revision, re-operation and mortality rates. The absolute increase or decrease in these outcomes in UKR compared to TKR was assessed in different age groups.

METHODS

Data source

A retrospective observational study was performed using NJR records linked to the HES-APC database.

The NJR was established in April 2003 and is now the world's largest arthroplasty register with over 2 million joint replacements recorded [1]. HES-APC records is a database of all admission episodes for patients being admitted to an NHS hospital in England and contains detailed information for every patient (including comorbidities, deprivation indices, ethnicity), every surgical procedure (including medical complications, reoperations) [13]. Mortality data was provided from the ONS through NHS Digital.

This study was approved by the NJR Research subcommittee and had ethical approval from the South Central Oxford B Research Ethics Committee (Reference: 19/SC/0292). The linkage of the datasets was approved by the Confidentiality Advisory Group (Reference: 19/CAG/0054).

Procedures

There were significant differences in baseline characteristics between TKR and UKR groups. To address the problem of confounding by differences in baseline characteristics (Table 1) we matched patients using patient (age, sex) and surgical factors (charlson comorbidity index, ASA grade, surgical indication, thromboprophylaxis, surgeon caseload, year of surgery) using propensity scoring techniques.

Analyses were performed to compare the early (less than three months) complications and long term (10 year) rates of revision, reoperation (including revision), and mortality of TKR and UKR. Complications were divided into medical and implant related. The reasons for revision and the complexity of the revisions were also compared.

Statistical analysis

Given the potential for factors other than the type of implant to affect the revision rate we a priori matched the TKR and UKR groups for multiple known confounders using propensity scores. This a priori approach was supported by the substantial differences in patient, surgical, and implant factors between the unmatched TKR and UKR groups (Table 1).

Logistic regression was used to generate a propensity score representing the probability that a patient received a UKR and were generated from patient demographics and surgical factors (including surgeon caseload). This is a well-recognised approach for comparing implant types [14-19]. Surgical factors included surgeon caseload, defined as the average number of primary knee replacements performed per year. Every surgeon in the NJR has a specific identifier, which was used to calculate each operating surgeon's caseload for each calendar year. The mean caseload (cases per year) was then calculated for each surgeon, with the exclusion of years in which surgeons were inactive (to prevent artificial reductions for surgeons who started operating in later years or who subsequently stopped operating as described previously [15, 20]). All patient and surgical factors in Table 1 were used for matching, apart from BMI, which had a large proportion of missing data. This approach is consistent with previous studies [14, 16, 18, 19]. The algorithm used matched on the logit of the propensity score with a 0.02-SD caliper width. The matching ratio was 1:1. We used greedy matching without replacement. This approach has been shown to have superior performance for estimating treatment effects [21]. Standardized mean differences (SMDs) were examined both before and after matching to assess for any covariate imbalance between the TKR and UKR groups, with SMDs of 10% or more considered suggestive of covariate imbalance [22]. After matching, 108,430 knee replacements (54,215 TKRs and 54,215 UKRs) were included for analysis. By controlling for these covariates the use of propensity score matching would allow the true effect of implant type on outcomes to be accurately assessed.

Outcomes of interest were: (1) revision rate, (2) two stage revisions (3) indications for revision surgery, (4) reoperation rate, (5) three month HES reported complication rate and (6) mortality rate. Ages were stratified into four age groups; (1) <55 years, (2) 55-64 years, (3) 65-74 years and (4) >75 years.

Cumulative survival was determined using the Kaplan–Meier method. The endpoint for implant survival was revision surgery (any implant component removed, exchanged, or added) and reoperation surgery (any additional surgery to the knee joint including revision). The endpoint for patient survival was mortality. Implant and patient survival rates were compared between the TKR and UKR groups, using Cox regression models, with the proportional hazards assumptions assessed in all analyses. If the proportional hazards assumption was violated, we analysed survival hazards in sections, with breaks being placed at the points of divergence from proportionality. To account for clustering within the matched cohort, a robust variance estimator was tested in regression models. A multi-level frailty model sensitivity analysis was performed to control for patient clustering within surgeons, but this did not influence the results. Univariable and adjusted models were also tested. The adjusted models included covariates with residual imbalance after matching (SMD of 10% or more).

HES reported complications were divided into medical complications and implant complications. Medical complications were defined as a stroke, myocardial infarction, chest infection, deep vein thrombosis/pulmonary embolism (DVT/PE), urinary tract infection (UTI), acute renal failure or blood transfusion. Implant complications were defined as wound dehiscence, surgical site infection, fracture, prosthesis complications and neurovascular injury. Complications are reported both combined and individually. The proportional chi-square test with Yates' correction was used to compare the frequency of revisions for specific indications and three month medical complications between the TKR and UKR groups.

All statistical analyses were performed using Stata (Version 15.1; StataCorp, College Station, TX, USA) except propensity score matching, which was performed using R (Version 3.4.0; R Foundation for Statistical Computing, Vienna, Austria). P-values of < 0.05 were considered significant, with 95% confidence intervals (CI) presented.

RESULTS

Between 1st January 2004 and 31st December 2018 1,186,514 knee replacements were performed. From these 858,725 records were linked to the HES admitted patient care records. After removing patellofemoral replacements and missing implant types there were 850,383 joint replacements for analysis. From these 743,158 knee replacements (687,910 TKR, 55,248 UKRs) had complete sets of data for all patient, surgical and implant confounding factors and were included for analysis in our study. For full details of the data cleaning process refer to Figure 1.

There were significant differences in baseline characteristics between the TKR and UKR groups, many of which are known to influence outcomes (Table 1). After 1:1 propensity score matching, the matched study group consisted off 108,430 knee replacements (54,215 TKRs and 54,215 UKRs). After matching the groups were well balanced except from minor differences in year of surgery (Table 1). The mean follow-up for the TKR and UKR groups were 7 years (SD 3.7) with no differences in follow up between groups.

Revision endpoint

In the TKR group there were 1,842 revisions at mean of 3.7 years (SD 3.0) postoperatively and in the UKR group there were 4,034 revisions at a mean of 4.1 years (SD 3.2). The 10 year implant survival using revision as the endpoint for TKR and UKR was 95.1% (CI 94.8-95.4) and 87.9% (CI 87.5-88.3). The absolute difference in revision rate at ten years was 7.2%. The Hazard Ratio (HR) for revision from 0-10 years was 2.31 (CI 2.19-2.45, $p<0.001$) The HR changed with time (Figure 2) but the survival of TKR was superior at all time points. Between 0-2 years the HR was 1.99 (CI 1.82-2.18, $p<0.001$) and between 2-10 years was 2.54 (CI 2.36-2.73, $p<0.001$).

The rates of revision for aseptic loosening, osteoarthritis progression, pain, dislocation/subluxation, component dissociation, malalignment, periprosthetic fracture, lysis, wear and implant fracture and other were significantly higher following UKR compared to TKR (Table 2). The rates of infection and stiffness were twice as high for TKR compared to UKR (Table 2). There were no differences in the rates of instability revision rates.

From the 1,842 revisions in the TKR group 305 (16.7%) were two stage which was higher than the 128 (3.2%) that were two stage from the 4,043 in the UKR group. This gave 10 year survivals of 99.2% (CI 99.1-99.3) and 99.6 (CI 99.6-99.7) respectively with a HR of 0.44 (CI 0.36-0.54, p<0.001).

Reoperation endpoint

In the TKR group there were 8491 reoperations at a mean of 2.6 years (SD 2.9) postoperatively. In the UKR group there 9277 reoperations at a mean of 3.2 years (SD 3.0) postoperatively. This gave 10 year implant survivals of 79.3% (CI 78.9-79.8) and 74.6% (CI 74.1-75.1) for TKR and UKR respectively. The absolute difference in reoperation rate at ten years was 4.7%. The HR for reoperation from 0-10 years was 1.12 (CI 1.08-1.15, p<0.001) The HR for reoperation varied with time (Figure 3). In the first two years the UKR implant survival was better with a HR of 0.90 (CI 0.86-0.94, p<0.001). From 2 to 10 years the TKR implant survival was better with a HR of 1.47 (CI 1.40-1.53, p<0.001).

HES reported three month complications

Overall the risk of complications during the three months following surgery were significantly (p<0.001) lower for UKR (2.97% n=1,611) than for TKR (4.77%, n=2,587). The absolute difference in complication rate was 1.8%.

The risk of medical complications was significantly lower following UKR (3.08% vs 1.86%, p<0.001, Table 3). The rates of chest infection (0.91% vs 0.59%, p<0.001), deep vein thrombosis/pulmonary embolism (0.50% vs 0.27%, p<0.001), urinary tract infection (0.76% vs 0.47%, p<0.001), acute renal failure (0.74% vs 0.51%, p<0.001) and blood transfusion (0.37% vs 0.05%, p<0.001) were significantly lower for UKR.

The risk of implant related complications was significantly lower following UKR (1.83% vs 1.16%, p<0.001, Table 3). The rates of wound dehiscence (0.41% vs 0.29%, p=0.001), surgical site infection (0.69% vs 0.41%, p<0.001) and prosthesis complication (0.70% vs 0.39%, p<0.001) were all significantly lower for UKR. The rate of fracture was significantly higher for UKR (0.05% vs 0.09%, p=0.004).

Mortality

In the TKR group there were 5,808 deaths at a mean of 6.6 years (SD 3.5) postoperatively and in the UKR group there were 4,859 deaths at a mean of 6.7 years (SD 3.6). At all-time points postoperatively the HR was below one showing that the death rates following UKR were less than following TKR. However with time postoperatively the HR increased (Table 4). The 30 day mortality was 0.07% and 0.03% in the TKR and UKR groups respectively giving a HR of 0.38 ($p=0.002$, Figure 4). The 90 day mortality was 0.12% and 0.07% with a HR of 0.61 ($p=0.02$, Figure 4). At 1 year the mortality was 0.44% and 0.33% with a HR of 0.77 ($p=0.007$, Figure 4). The 5 year mortality rates were 4.7% and 4.0% with a HR of 0.84 ($p<0.001$). At 10 years the mortality rates were 15.5% and 13.6% with a HR of 0.86 ($p<0.001$). The 10 year patient survival following TKR was 84.5% (CI 84.1-85.0) and following UKR was 86.4% (CI 86.0-86.8) (Figure 5). The absolute difference in 10 year patient survival was 1.9%.

Effect of age on revision, reoperation, non-revision reoperation and mortality

For both TKR and UKR the 10 year implant survival with revision as the endpoint improved with increasing age. In terms of the relative performances of TKR and UKR, there was a significant interaction between age and revision risk ($p<0.02$). The numbers in each age group are summarised in Table 5. With increasing age groups the relative risk of revision surgery for UKR increased compared to TKR as evidenced by the increased HRs (Table 6). In contrast with increasing age the absolute difference in risk of revision surgery for UKR compared to TKR progressively decreased from 9.8% for <55yr to 4.6% for ≥75yr

For both TKR and UKR the implant survival with reoperation as the endpoint improved with increasing age. In terms of the relative performances of TKR and UKR, there was no significant interaction between age and revision risk ($p=0.10$) (Table 7). This suggests that age had no effect on the relative reoperation rate of TKR and UKR. However with increasing age, as the overall re-operation rate decreased, the absolute difference in risk of reoperation for UKR compared to TKR progressively decreased from 6.6% for <55yr to 2.4% for ≥75yr.

For both TKR and UKR the patient survival worsened with increasing age. In terms of the relative performances of TKR and UKR, there was a significant interaction between age and mortality risk ($p<0.001$). In all age groups the mortality risk was significantly lower

following UKR. However with increasing age groups the magnitude of this reduction decreased evidenced by the increasing HRs (Table 8). In contrast with increasing age the absolute difference in mortality for TKR compared to UKR progressively increased from 1.2% for <55yr to 3.9% for ≥75yr

The overall rate of three month HES complications increased with increasing age. For TKR it increased from 4.3% for <55yr to 7.4% for ≥75yr. For UKR it increased from 2.3% for <55yr to 5.3% for ≥75yr. In all age groups the overall complication rate was significantly lower for UKR than TKR. The absolute difference in rates in each age group were similar and ranged from 1.7% to 2.1%. The rate of medical complications was significantly lower for UKR in all age groups. The rate of implant complications was also significantly lower for UKR in all groups except the 75 years plus group where no difference was observed (Table 9). The pattern of complications in age group was similar to that found when all age groups were combined.

Figure 6 summarises the absolute difference in risks between UKR and TKR in the different age groups. The graph shows the number of events that would expected to occur if 100 patients, who were appropriate for UKR and who were due to have TKR had a UKR instead. With increasing age, over the ten year period, the absolute number of excess revisions and re-operations related to the change from TKR to UKR decreased, whereas the absolute number of lives saved increased. The decreased rate of 3 month complication associate with UKR increased slightly with increasing age.

DISCUSSION

As expected, this study shows that UKR has a significantly higher risk of revision than TKR at all time points [6]. The ten year cumulative revision rates were 12% and 5% respectively, with a Hazard Ratio of 2.31 and an absolute difference of 7%. The study also showed that at ten years the re-operation (including revision) rate of UKR (25%) was also significantly higher than that of TKR (21%). The HR was 1.12 and that the absolute difference was 5% demonstrating that the difference in re-operation rate between UKR and TKR is smaller than the difference in revision rate. Patients are probably more likely to be concerned by re-operation rates than revision rates. More importantly at ten years the death rate following UKR (13.6%) was significantly lower than that after TKR (15.5%) with a HR of 0.86 and an absolute difference of 1.9%. The overall complication rate during the first three months was also significantly lower with UKR (2.97%) than TKR (4.77%) and the absolute difference was (1.8%). The interpretation of this data is difficult as there are advantages and disadvantages of both procedures and these changes profoundly depending on the patient's age. It is therefore important to consider what happens in different age groups (Figure 6).

Most surgeons feel that in elderly the most reliable solution for severe knee arthritis is TKR as, due to the patients limited life expectancy, they will not need a revision. As a result almost all elderly patients are treated with TKR and only 4.2% of knee replacements in patients older than 75 years being a UKR [1]. The results from the study suggest that this approach may be misguided (Figure 6). In patients over 75 at 10 years although the revision rate is low (2.2%) the reoperation rate is appreciably higher (13%). However if UKR are used instead of TKR the absolute increases in re-operation rate would be small (2.4%) and would actually be lower than the absolute decrease in death rate (3.9%). Furthermore the incidence of early complications would be 2% lower. These findings suggest that in elderly patients UKR should be used whenever the indications are satisfied, and for many cases extending the indications may be justified. In this age group approximately 36% of knee replacements are appropriate for UKR [23] so approximately ten times as many UKRs could be done.

The situation is different in younger patients. As the overall death rate is so much lower in the young than the old, the decreased absolute death rate with UKR is also much smaller than in the elderly. At ten years the decreased absolute death rate with UKR is 1.2%. A difference of this magnitude would still be a great importance to the young patients. Furthermore it might

outweigh the 6.6% increased absolute risk of re-operation (Figure 6). In these young patients, whether they have had a TKR or a UKR, the chance of having a reoperation (31% or 37% respectively) or revision (9% or 20%) is high. However re-operations and particularly the revisions are likely to be more major operations after TKR than UKR. In particular most UKR revisions tend to be conversions to TKR so UKR are delaying the need for a TKR.

The factors to consider in the intermediate age groups, 55-64 and 65-74 years old, include those that are important on both the young and old groups (Figure 6). In making the decision whether to have a UKR or TKR patients need to balance the increased absolute risk at ten years of having a re-operation (5.7% or 3.6%) against the decreased absolute risk of dying (1.7% or 2.2%). Furthermore they need to put into balance the decreased absolute risk of having an early complication (1.71% to 1.79%) such as a renal failure, venous thrombo-embolism or wound dehiscence. If there is doubt about their decision then these patients, like the old and young, should also consider the well-established advantages of UKR compared to TKR such as the more rapid recovery and improved function.

The most important findings of this study relate to mortality. The death rate following TKR during the first month after the operation is 2.6 times higher than after UKR and during the first three months is 1.6 time higher. These findings are supported by previous studies [6, 24] and are to be expected given the much higher risk of early medical complications. The reason for the higher risk of medical complications and death is that TKR is a bigger operation causing greater stress to the patients: The incision is larger, there is more soft tissue damage, more bone is removed, larger intramedullary rods are used and blood loss and the need for transfusion is greater. During the first 10 years the death rate after TKR is 1.2 times higher than after UKR. The difference in death rate at 10 years is partly because of the early marked difference in death rate and partly because in subsequent time intervals there is a slight difference in death rate. The difference decreases with time and by 8 to 10 years it is no longer significant. This suggests that the operation has an effect on mortality for an extended period. It is probably partly because post-operative complications may cause permanent damage to the patients increasing their co-morbidity and thus their mortality. Another possible explanation is that as the function following UKR is better than after TKR, UKR patients do more exercise which will improve general health and decrease mortality.

Surgeons have traditionally made the decision whether to do UKR based on the relative revision rates for UKR of TKR. This practice is now reinforced by the NJR which provides surgeons with information about their revision rates. The NJR identifies outliers for all knee replacement by combining the revision rate for UKR and TKR. As the revision rate for UKR is higher than that of TKR, surgeons that do large numbers of UKR are more likely to be outliers and outliers are likely to be surgeons doing UKR. Considerable pressure is placed upon surgeon outliers to change their practice and if they are UKR users to do less. This may prevent patients who chose to have a UKR, based on the risk factors, from having one. Therefore surgeons who are outliers for all knee replacement, should not feel they need to change their UKR practice providing they are not outliers for UKR.

A further issue with revision being the primary outcome measure is that it is much easier to revise a UKR, which is usually a simple conversion to a TKR, than to revise a TKR and the outcome is expended to be better. As a result the threshold for revision of a UKR is lower. An analysis of registry data provides evidence to support this as a UKR with a bad outcome has a 63% change of being revised whereas as a TKR with a similarly bad outcome has a 12% chance of being revised [25]. Therefore the higher revision rate of a UKR may be in part a manifestation of an advantage of a UKR, which is if there is a problem it can easily be addressed. Despite these issues revision is still an important outcome measure. There is a great variability in UKR revision rates between different surgeons. However if surgeons adhere to the evidence based indications and do UKR in at least 20% of the knee replacements they are likely to have low revision rate, and their revision rates should be substantially lower than those seen in this study [26].

For most causes of revision the risk was higher with UKR than TKR. However for one of the commonest and perhaps the worst cause of revision, infection, the revision rate of UKR was less than half that of TKR. Infection is one of the most difficult problems to treat and often requires a two stage procedure. The risk of two stage revision after UKR was also less than half that following TKR. Early complications related to infection, such as surgical site infection, wound dehiscence, chest infection, and urinary tract infection, also occur significantly less often after UKR than TKR.

This is the largest study with the longest follow up comparing UKR and TKR. The strengths of this study are that it is an unselected registry sample recruited over an extended period

from 2005 to 2018, which reduces the chances of selection bias. By linking the NJR and HES-APC datasets various clinical outcomes including revision, reoperation, non-revision reoperation, medical complication rate and patient mortality were able to be comprehensively assessed with adequate power and follow up. Additionally the propensity matching allowed for a fair comparison of similar population cohorts and helps address the risks of patient, surgical and implant confounding factors. Indeed the matching process was successful with all except the year of surgery achieving an SMD < 10% suggestive of covariate balance between comparative groups.

The main study limitation of this study is that it is retrospective and is based on observational data. To address this limitation we propensity matched groups. Matching can reduce the generalizability of findings, however as we were able to match virtually all the UKR to TKR this is unlikely to be an issue. Despite matching, there is potential for residual confounding particularly as the groups were not perfectly matched given there was imbalance in the year of primary surgery. Although operating techniques improve with time, there were no differences in our findings when we adjusted the regression models for year of primary surgery. There was a substantial proportion of BMI data missing so we did not match on BMI. However there were no significant differences in BMI between the matched groups. The only way to achieve balance with respect to both known and unknown confounders is with a randomised trial. However, to compare the outcomes we assessed would require very large numbers and long follow-up, which would be impractical, and we believe propensity matching offers the next best alternative. Additionally, the reasons for revision in the NJR are those recorded at the time of surgery even if this subsequently changed due to histopathology and microbiology data. Registries can underreport revisions [27] although there is no reason to believe this would differ between the groups, and it is not possible to confirm causality in registry-based studies.

In conclusion this study highlights the importance of analysing various different outcomes. In addition to assessing 10 year revision rates, which are widely considered to be the best measure of failure, we also assessed outcomes that are more relevant to patients such as 10 year mortality, re-operation rates and early complication rates. We found that over ten years although UKR had higher overall revision rates it had lower rates of two stage revisions. It also has higher re-operation rates, except in the first two years, but lower ten year death rates. During the first three months UKR also had lower risk of medical and implant complications

and the death rate was about two thirds that of TKR. The balance of these rates varied in different age groups. To present this to patients they could consider that if 100 patients due to have a TKR had a UKR instead then, over ten years, if they were <55 years old there would be 7 more re-operations and 1 less death, 55-64 years 6 more reoperations and 2 more deaths; 65-74 years 4 more re-operations and 2 less deaths, ≥ 75 years 2 more re-operations and 4 less deaths.

LIST OF FIGURES

Figure 1. Data flowchart of dataset cleaning and merging

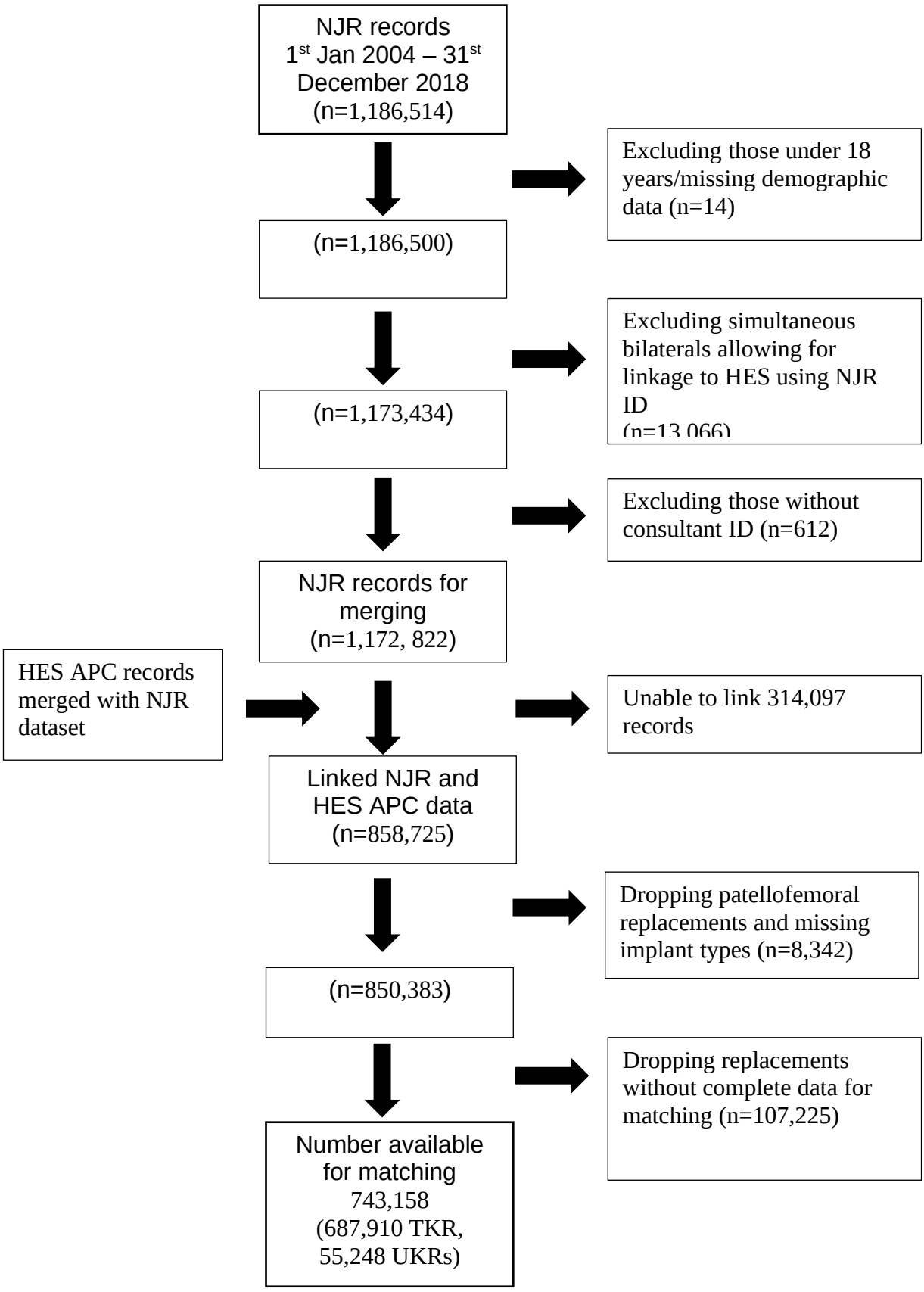


Figure 2. Kaplan Meier graph comparing implant survival (revision endpoint) of TKRs and UKRs

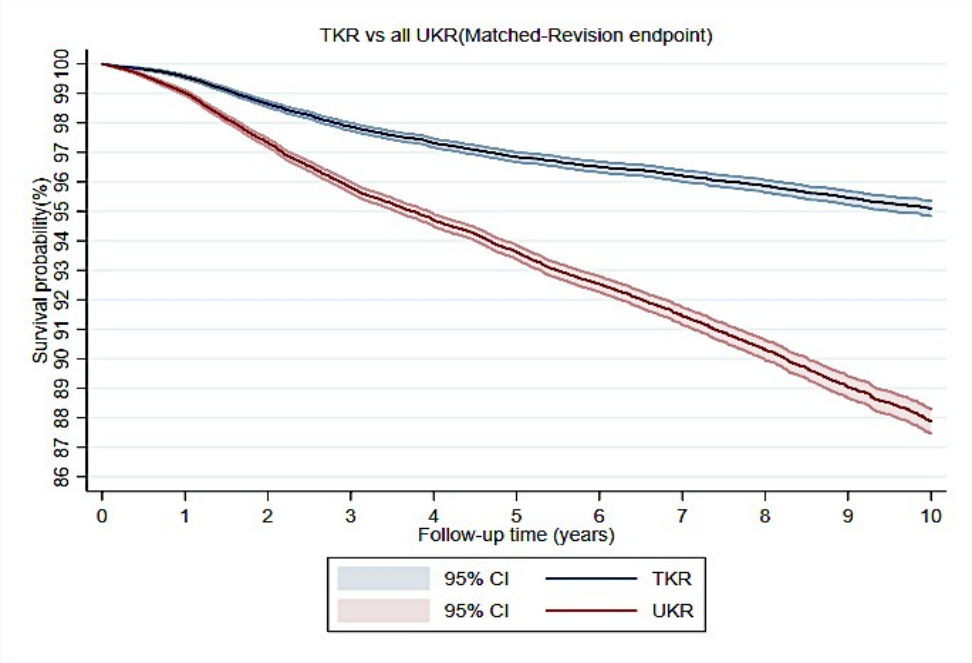


Figure 3. Kaplan Meier graph comparing implant survival (reoperation endpoint) of TKRs and UKRs

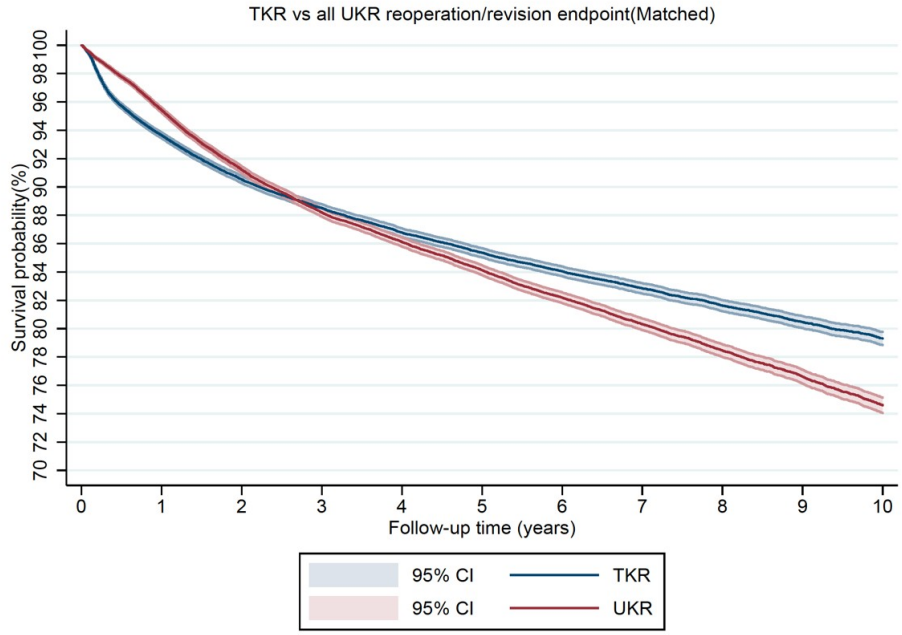


Figure 4. Kaplan Meier graph comparing patient survival of TKRs and UKRs to 1 year

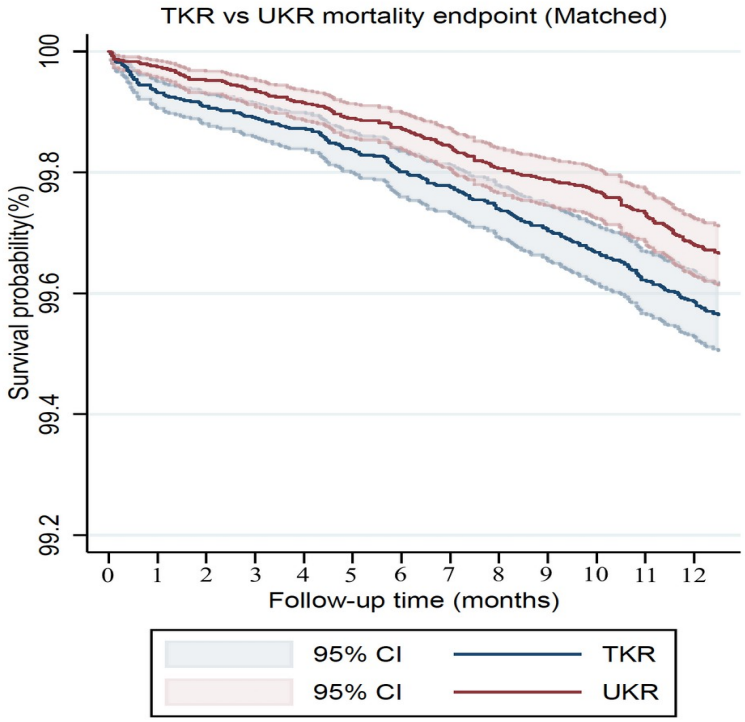


Figure 5. Kaplan Meier graph comparing patient survival of TKRs and UKR to 10 years

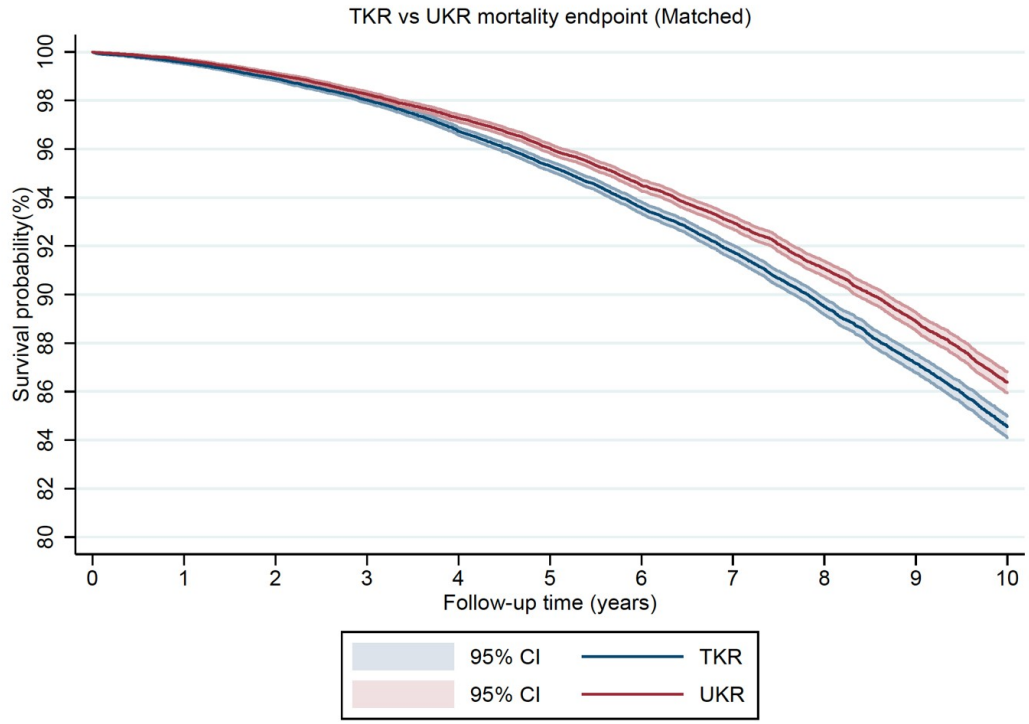
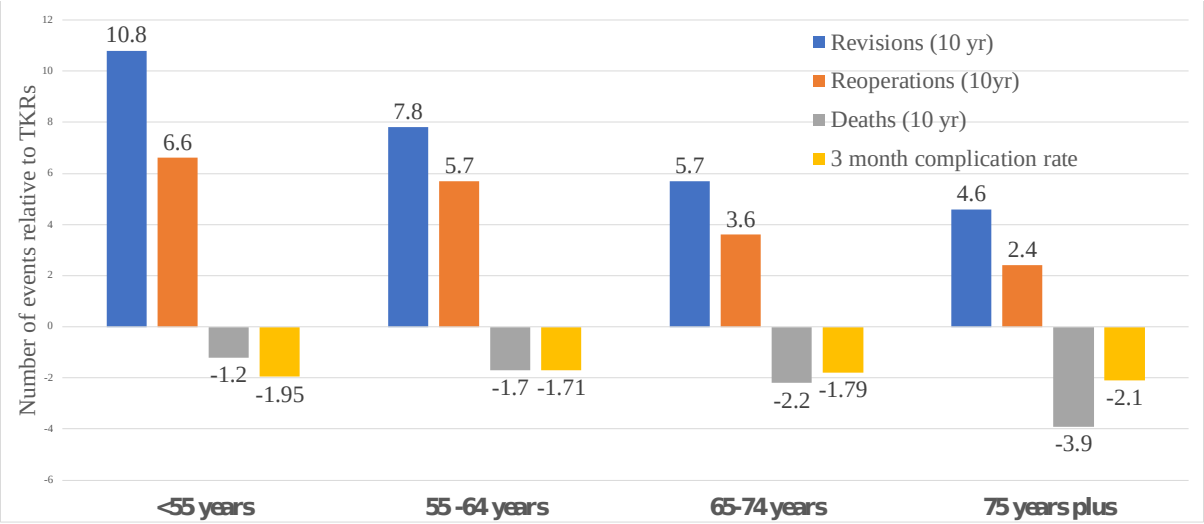


Figure 6. Bar chart showing the absolute increase or decrease in 10 year re-operations, 10 year mortality and 3 month complications if 100 patients in each age group had a UKR instead of a TKR



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Table 1. Baseline characteristics before matching TKRs and UKRs

	Unmatched cohort			Matched cohort		
Covariate	TKR (n=687,910)	UKR (n=55,248)	SMD	TKR (n=54,215)	UKR (n=54,215)	SMD
Admission type						
Elective	686,359 (99.8%)	55,179 (99.9%)	0.03	54,143 (99.9%)	54,146 (99.9%)	0.007
Emergency	1,145 (0.2%)	45 (0.1%)		40 (0.1%)	45 (0.1%)	
Other	406 (0.1%)	24 (0.0%)		32 (0.1%)	24 (0.0%)	
Gender						
Female	397,580 (57.8%)	26,328 (47.7%)	0.20	25,716 (47.4%)	25,946 (47.9%)	0.008
Male	290,330 (42.2%)	28,920 (52.4%)		28,499 (52.6%)	28,269 (52.1%)	
Age at surgery (yr)						
Mean (SD)	70.2 (SD 9.3)	64.1 (SD 9.8)	0.64	64.1 (SD 9.6)	64.3 (SD 9.8)	0.003
BMI (kg/m^2)*						
Mean (SD)	31.0 (SD 5.5, n=450,147)	30.4 (SD 5.1, n=37,943)	0.12	30.3 (SD 5, n=11,801)	30.2 (SD 4.9, n=5565)	0.02
Primary diagnosis						
Primary OA	660,579 (96.0%)	54,292 (98.3%)	0.14	53,266 (98.3%)	53,264 (98.2%)	0.004
Primary OA and Other	8032 (1.2%)	365 (0.7%)		347 (0.6%)	361 (0.7%)	
Other	19,299 (2.8%)	591 (1.1%)		602 (1.1%)	590 (1.1%)	
Charlson comorbidity index						

None	479,655 (69.7%)	41,103 (74.4%)	0.12	40,492 (74.7%)	40,289 (74.3%)	0.02
Mild	146,567 (21.3%)	10,687 (19.3%)		10,438 (19.3%)	10,513 (19.4%)	
Moderate	41,999 (6.1%)	2,467 (4.5%)		2,401 (4.4%)	2,433 (4.5%)	
Severe	19,689 (2.9%)	991 (1.8%)		884 (1.6%)	980 (1.8%)	
Ethnicity						
White	647,039 (94.1%)	53,055 (96.0%)	0.11	52,106 (96.1%)	52,049 (96.0%)	0.01
Black (Caribbean)	4,786 (0.7%)	220 (0.4%)		209 (0.4%)	219 (0.40%)	
Black (African)	2,935 (0.4%)	152 (0.3%)		142 (0.3%)	152 (0.3%)	
Black (Other)	1,217 (0.2%)	52 (0.1%)		59 (0.1%)	52 (0.1%)	
Indian	16,623 (2.4%)	771 (1.4%)		711 (1.3%)	767 (1.4%)	
Pakistani	6,132 (0.9%)	262 (0.5%)		263 (0.5%)	262 (0.5%)	
Bangladeshi	492 (0.1%)	24 (0.0%)		31 (0.1%)	24 (0.0%)	
Chinese	516 (0.1%)	22 (0.0%)		21 (0.0%)	22 (0.0%)	
Other	8,170 (1.2%)	690 (1.2%)		673 (1.2%)	668 (1.2%)	
Rural/Urban classification						
Urban	520,413 (75.7%)	38,978 (70.6%)	0.13	38,316 (70.7%)	38,405 (70.8%)	0.006
Town/Fringe	80,040 (11.6%)	6,892 (12.5%)		6,839 (12.6%)	6,729 (12.4%)	

Village/Hamlet	8,336 (1.2%)	178 (0.3%)		9,060 (16.7%)	9,081 (16.8%)	
Indices of multiple deprivation (quintiles)						
1	107,839 (15.7%)	6289 (11.4%)	0.17	6,228 (11.5%)	6,258 (11.5%)	
2	129,418 (18.8%)	9266 (16.8%)		9,133 (16.9%)	9,153 (16.9%)	
3	151,737 (22.1%)	12,268 (22.2%)		12,038 (22.2%)	12,059 (22.2%)	
4	156,380 (20.7%)	13,087 (23.7%)		12,963 (23.9%)	12,848 (23.7%)	
5	142,536 (20.7%)	14,388 (26.0%)		13,853 (25.6%)	13,897 (25.6%)	
Surgeon caseload of primary knee surgery practice (cases/yr)	76.6 (SD 47.4)	92.4 (SD 50.1)	0.33	92.1 (SD 54.5)	91.9 (SD 50.0)	0.004
Primary complexity						
Normal	684,951 (99.6%)	55,182 (99.9%)	0.06	54,149 (99.9%)	54,149 (99.9%)	<0.001
Complex	2,959 (0.4%)	66 (0.1%)		66 (0.1%)	66 (0.1%)	
ASA grade						
1	63,179 (9.2%)	10,326 (18.7%)	0.35	10,340 (19.1%)	9,837 (18.1%)	0.02
2	497,045 (72.3%)	39,480 (71.5%)		38,571 (71.1%)	38,960 (71.9%)	
3 or above	127,686 (18.6%)	5442 (9.9%)		5,304 (9.8%)	5,418 (10.0%)	

VTE – chemical						
LMWH (+/-other)	486,575 (70.7%)	36,644 (66.3%)	0.11	35,598 (65.7%)	35,851 (66.1%)	0.02
Aspirin only	47,054 (6.8%)	5138 (9.3%)		5,192 (9.6%)	5,010 (9.2%)	
Other	118,183 (17.2%)	10,528 (19.1%)		10,313 (19.0%)	10,421 (19.2%)	
None	36,098 (5.2%)	2938 (5.3%)		3,112 (5.7%)	2933 (5.4%)	
VTE – mechanical						
Any	635,845 (92.4%)	55,212 (94.5%)	0.08	50,992 (94.1%)	51,182 (94.4%)	0.02
None	52,065 (7.6%)	3,036 (5.5%)		3,223 (5.9%)	3,033 (5.6%)	
Fixation						
Cemented	661,269 (96.1%)	43,050 (77.9%)	0.56	43,311 (79.9%)	43,029 (79.4%)	0.02
Cementless	22,486 (3.3%)	10,886 (19.7%)		9,589 (17.7%)	9,922 (18.3%)	
Hybrid	4,155 (0.6%)	1,312 (2.4%)		1,315 (2.4%)	1,264 (2.3%)	
Year of surgery						
2004	11,303 (1.6%)	895 (1.6%)	0.14	825 (1.5%)	895 (1.7%)	0.12
2005	16,637 (2.4%)	1071 (1.9%)		1,228 (2.3%)	1071 (2.0%)	
2006	22,196 (3.2%)	1818 (3.3%)		1,699 (3.1%)	1807 (3.3%)	
2007	32,943 (4.8%)	2576 (4.7%)		2,580 (4.8%)	2,571 (4.7%)	
2008	39,206 (5.7%)	3060 (5.5%)		3,073 (5.7%)	3,051 (5.6%)	
2009	43,393 (6.3%)	3250 (5.9%)		3,408 (6.3%)	3220 (5.9%)	

2010	48,984 (7.1%)	3499 (6.3%)		3,970 (7.3%)	3460 (6.4%)	
2011	52,247 (7.6%)	3545 (6.4%)		4,075 (7.5%)	3,494 (6.4%)	
2012	54,113 (7.9%)	4007 (7.3%)		4,120 (7.6%)	3,952 (7.3%)	
2013	55,217 (8.0%)	3983 (7.2%)		4,720 (7.9%)	3,908 (7.2%)	
2014	60,156 (8.7%)	4578 (8.3%)		4,619 (8.5%)	4,480 (8.3%)	
2015	61,173 (8.9%)	4769 (8.6%)		4,968 (9.2%)	4,635 (8.5%)	
2016	64,241 (9.3%)	5438 (9.8%)		5,058 (9.3%)	5,263 (9.7%)	
2017	66,040 (9.6%)	6193 (11.2%)		5,380 (9.9%)	6,019 (11.1%)	
2018	60,061 (8.7%)	6566 (11.9%)		4,942 (9.1%)	6,389 (11.8%)	
Bone graft						
None	679,574 (98.8%)	55,070 (99.7%)	0.10	54,021 (99.6%)	54,038 (99.7%)	0.005
Bone graft used	8,336 (1.2%)	178 (0.3%)		194 (0.4%)	177 (0.3%)	

Table 2. Indications for revision Comparisons between the frequency of revision indications were conducted using the Chi squared test. * refers to revision indications that were statistically significantly different between groups.

Revision indication	**TKR (n=54,215)**	**Mean time to TKR revision (years)**	**UKR (n=54,215)**	**Mean time to UKR revision (years)**	**Comparison between groups (P value)**
Aseptic loosening	500 (0.92%)	4.7 (SD 3.4)	1023 (1.89%)	4.3 (SD 3.2)	<0.001
OA progression	172 (0.32%)	4.4 (SD 3.2)	1249 (2.30%)	5.6 (SD 3.4)	<0.001
Pain	255 (0.47%)	3.3 (SD 2.5)	823 (SD 1.52%)	3.1 (SD 2.2)	<0.001
Other	164 (0.30%)	3.4 (SD 2.8)	503 (0.93%)	3.6 (SD 2.8)	<0.001
Dislocation subluxation revision	42 (0.10%)	3.2 (SD 3.2)	260 (0.48%)	2.8 (SD 3.0)	<0.001
Instability	330 (0.61%)	3.7 (SD 3.0)	336 (0.62%)	4.3 (SD 3.3)	0.82
Component dissociation	25 (0.05%)	3.8 (SD 3.3)	136 (0.25%)	3.1 (SD 3.2)	<0.001
Malalignment	161 (0.30%)	3.0 (SD 2.4)	230 (0.42%)	3.4 (SD 2.9)	<0.001
	385 (0.71%)	2.7 (SD 2.5)	172 (0.32%)	2.7 (SD 2.6)	<0.001

Infection					
Periprosthetic fracture	44 (0.08%)	4.8 (SD 3.4)	92 (0.17%)	1.6 (SD 2.2)	<0.001
Lysis	112 (0.21%)	5.7 (SD 3.6)	177 (0.33%)	5.0 (SD 3.3)	<0.001
Wear	92 (0.17%)	6.9 (SD 3.9)	258 (0.48%)	6.5 (SD 3.5)	<0.001
Stiffness	167 (0.31%)	2.9 (SD 2.5)	77 (0.14%)	3.9 (SD 3.2)	<0.001
Implant fracture	8 (0.01%)	4.6 (SD 2.4)	19 (0.04%)	4.7 (SD 3.7)	0.03
Incorrect sizing	0 (0%)	0 (0%)	N/A	0 (0%)	No revisions

Table 3. Three month medical complication comparison between TKRs and UKRs. Rates were compared between groups using the Chi squared test.

Three-month medical complication (HES records)	TKR (n=54,215)	UKR (n=54,215)	Comparison of both groups (p value)
Medical complications	1,670 (3.08%)	1,010 (1.86%)	<0.001
Stroke	34 (0.06%)	31 (0.06%)	0.71
Chest infection	491 (0.91%)	318 (0.59%)	<0.001
Myocardial infarction	58 (0.11%)	50 (0.09%)	0.44
Deep vein thrombosis/ Pulmonary embolism	273 (0.50%)	149 (0.27%)	<0.001
Urinary tract infection	411 (0.76%)	255 (0.47%)	<0.001
Acute renal failure	400 (0.74%)	276 (0.51%)	<0.001
Blood transfusion	198 (0.37%)	26 (0.05%)	<0.001
Implant complications	990 (1.83%)	628 (1.16%)	<0.001

Wound dehiscence	224 (0.41%)	159 (0.29%)	0.001
Surgical site infection	376 (0.69%)	224 (0.41%)	<0.001
Fracture	25 (0.05%)	50 (0.09%)	0.004
Prosthesis complication	381 (0.70%)	209 (0.39%)	<0.001
Neurovascular injury	16 (0.03%)	13 (0.02%)	0.58

Table 4. Numbers of revisions and deaths in TKR and UKR comparative groups at various time points and their respective HRs.

Time point	TKR revisions	UKR revisions	Excess UKR revisions	Revision HR	TKR deaths	UKR deaths	Excess TKR deaths	Mortality HR
0-1 months	25	29	4	1.16 (0.68-1.98) P=0.59	39	14	25	0.38 (CI 0.20-0.70, p=0.002)
0-3 months	57	92	35	1.63 (1.16-2.24) P=0.005	63	37	26	0.61 (CI 0.40-0.91, p=0.02)
0-12 months	238	529	291	2.23 (1.92-2.60) P<0.001	238	181	57	0.77 (CI 0.63-0.93, p=0.007)
0-5 years	1403	2724	1321	2.04 (1.91-2.18) P<0.001	2138	1745	393	0.84 (CI 0.79-0.90, p<0.001)
0-10 years	1735	3773	2038	2.31 (2.19-2.45) P<0.001	4722	3911	811	0.86 (CI 0.83-0.90, p<0.001)
0-2 years	692	1347	655	1.99 (1.82-2.18) P<0.001	589	500	89	0.85 (0.76-0.96) P=0.009
2-4 years	550	1039	489	2.03 (1.83-2.25) P<0.001	994	791	203	0.83 (0.75-0.91) P<0.001
4-6 years	253	628	375	2.71 (2.35-3.15) P<0.001	1130	936	194	0.87 (0.80-0.95) P=0.002
6-8 years	140	449	309	3.60 (2.98-4.35) P<0.001	1090	862	228	0.83 (0.76-0.91) P<0.001
8-10 years	100	310	210	3.41 (2.72-4.27) P<0.001	919	822	97	0.93 (0.84-1.01) P=0.113

Table 5. Numbers in different age groups of the cohort

Age group	Overall number	TKR numbers	UKR numbers
<55 years	18,362	8,954	9,408
55-64 years	36,765	18,679	18,086
65-74 years	36,872	18,707	18,165
>75	16,431	7,875	8,556

Table 6. Implant survival (revision endpoint) in different age groups

Age group	TKR 10 year implant survival	UKR 10 year implant survival	HR at 0-10 years	Absolute difference at 10 years (%)
All ages	95.1 (CI 94.8-95.4)	87.9 (CI 87.5-88.3)	2.31 (2.19-2.45, p<0.001)	7.2%
< 55 years	91.0 (CI 90.1-91.8)	80.2 (CI 78.9-81.4)	2.14 (CI 1.93-2.38, p<0.001)	10.8%
55- 64 years	94.9 (CI 94.4-	87.1 (CI 86.3-	2.38 (CI 2.17-2.61,	7.8%

	95.3)	87.8)	p<0.001)	
65-74 years	96.4 (CI 96.0-96.7)	90.7 (CI 90.0-91.3)	2.31 (2.07-2.58, p<0.001)	5.7%
75 plus	97.8 (CI 97.3-98.2)	93.2 (CI 92.4-94.0)	2.85 (2.31-3.51, p<0.001)	4.6%

Table 7. Implant survival reoperation endpoint different age groups

Age group	TKR 10 year implant survival	UKR 10 year implant survival	HR at 0-10 years	Absolute difference at 10 years (%)
All ages	79.3 (CI 78.9-80.0)	74.6 (CI 74.1-75.1)	1.12 (CI 1.08-1.15, p<0.001)	4.7%
< 55 years	69.1 (67.8-70.3)	62.5 (61.0-63.9)	1.12 (1.06-1.19) P<0.001	6.6%
55- 64 years	77.8 (77.0-78.5)	72.1 (71.2-73.0)	1.15 (1.09-1.21) P<0.001	5.7%
65-74 years	82.9 (82.2-83.6)	79.3 (78.4-80.2)	1.06 (1.00-1.12) P=0.04	3.6%
75 plus	87.3 (86.2-88.4)	84.9 (83.7-86.0)	1.15 (1.04-1.27) P=0.008	2.4%

Table 8. Patient survival in different age groups

Age group	TKR 10 year patient survival	UKR 10 year patient survival	HR at 0-10 years	Absolute difference at 10 years (%)
All ages	84.5 (CI 84.1-85.0)	86.4 (CI 86.0-86.8)	0.86 (0.83-0.90, p<0.001)	1.9%
< 55 years	95.7 (CI 95.1-96.3)	96.9 (CI 96.3-97.4)	0.70 (0.57-0.86, p=0.001)	1.2%
55–64 years	92.1 (91.5-92.6)	93.8 (CI 93.2-94.3)	0.78 (0.70-0.86, p<0.001)	1.7%
65-74 years	83.2 (82.4-84.0)	85.4 (84.6-86.2)	0.85 (0.79-0.91, p<0.001)	2.2%
75 plus	57.2 (55.5-58.8)	61.1 (CI 59.5-62.6)	0.87 (0.82-0.93, p<0.001)	3.9%

Table 9. Three month complications in each age group

Three-month medical complication (HES records)	TKR	UKR	Absolute difference (%)	Comparison of groups (p value)
<55 years				
Medical complications	169 (1.89%)	89 (0.95%)	0.94%	<0.001
Implant complications	224 (2.5%)	131 (1.39%)	1.11%	<0.001
Any complications	383 (4.28%)	219 (2.33%)	1.95%	<0.001
55-64 years				
Medical complications	398 (2.13%)	225 (1.24%)	0.89%	<0.001
Implant complications	356 (1.91%)	187 (1.03%)	0.88%	<0.001
Any complications	737 (3.95%)	406 (2.24%)	1.71%	<0.001
65-74 years				
Medical complications	619 (3.31%)	356 (1.96%)	1.35%	<0.001
Implant complications	295 (1.58%)	187 (1.03%)	0.55%	<0.001

Any complications	887 (4.74%)	535 (2.95%)	1.79%	<0.001
75 years and over				
Medical complications	484 (6.15%)	340 (3.97%)	2.18%	<0.001
Implant complications	115 (1.46%)	123 (1.44%)	0.02%	0.9
Any complications	580 (7.37%)	451 (5.27%)	2.03%	<0.001

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