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Long-term outcomes of over 8,000 medial Oxford Phase 3 Unicompartmental Knees—a systematic review

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Background and purpose — There is debate as to the relative merits of unicompartmental and total knee arthroplasty (UKA, TKA). Although the designer surgeons have achieved good results with the Oxford UKA there is concern over the reproducibility of these outcomes. Therefore, we evaluated published long-term outcomes of the Oxford Phase 3 UKA.

Patients and methods — We searched databases to identify studies reporting ≥ 10 year outcomes of the medial Oxford Phase 3 UKA. Revision, non-revision, and re-operation rates were calculated per 100 component years (% pa).

Results — 15 studies with 8,658 knees were included. The annual revision rate was 0.74% pa (95% CI 0.67–0.81, n = 8,406) corresponding to a 10-year survival of 93% and 15-year survival of 89%. The non-revision re-operation rate was 0.19% pa (95% CI 0.13–0.25, n = 3,482). The re-operation rate was 0.89% pa (95% CI 0.77–1.02, n = 3,482). The most common causes of revision were lateral disease progression (1.42%), aseptic loosening (1.25%), bearing dislocation (0.58%), and pain (0.57%) (n = 8,658). Average OKS scores were 40 at 10 years (n = 3,417). The incidence of medical complications was 0.83% (n = 1,443).

Interpretation — Very good outcomes were achieved by both designer and non-designer surgeons. The PROMs, medical complication rate, and non-revision re-operation rate were better than those found in meta-analyses and publications for TKA but the revision rate was higher. However, if failure is considered to be all re-operations and not just revisions, then the failure rate of UKA was less than that of TKA.

Abbreviations

AMOA – anteromedial osteoarthritis
AKSS-O – American Knee Society Score (objective)
AKSS-F – American Knee Society Score (functional)
DVT – Deep vein thrombosis
HSS – Hospital for Special and Surgery Knee Score
OKS – Oxford Knee Score
pa – Per annum
PE – Pulmonary embolism
PROM – Patient-reported outcome measure
SONK – Spontaneous osteonecrosis of the knee
TKA – Total knee arthroplasty
UKA – Unicompartmental knee arthroplasty

Over 100,000 primary knee arthroplasties are conducted annually in the United Kingdom and demand is predicted to increase 6-fold by 2030 (UK National Joint Registry 2014). The 2 main treatments for severe knee osteoarthritis that has failed non-operative management are total knee arthroplasty (TKA) and unicompartmental knee arthroplasty (UKA). UKA in appropriate patients has significant benefits over TKA including faster recovery, better patient-reported outcome measures (PROMs), and reduced risk of major complications, but has also been reported to have a higher revision rate (Liddle et al. 2014). There is therefore debate as to which is the most clinically effective.

The most commonly used UKA prosthesis in the United Kingdom is the Oxford Knee (Biomet, Swindon, UK) (UK National Joint Registry 2011). The primary indication for the Oxford Knee is anteromedial osteoarthritis (AMOA) with spontaneous osteonecrosis of the knee (SONK) being another rarer indication. In AMOA the patient should have bone-on-bone arthritis in the medial compartment, full -thickness lateral compartment cartilage, functionally normal medial collateral and anterior cruciate ligament, and a patellofemoral joint without lateral bone loss and grooving (Goodfellow et al. 1988, Beard et al. 2007). Other factors such as site of the pain, age, weight, activity, and chondrocalcinosis have been

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shown not to have any adverse effect on outcomes and are therefore not considered to be contraindications (Pandit et al. 2006, 2011, Kendrick et al. 2010, Berend et al. 2014). Given these indications, about half of patients needing knee replacements are suitable for UKA (Willis-Owen et al. 2009).

Good long-term survival rates have been published by the designer surgeons. Labek et al. (2011) have raised concerns about the validity of these results as they were better than registry data and other published results of the Oxford Knee including short-term publications relating to the Phase 3. There has not been a systematic review of the long-term survival (≥ 10 year) of the Oxford Phase 3 UKA and its functional outcomes. This review assesses the long-term outcomes (≥ 10 year) of the medial Oxford Phase 3 implant in an effort to bring some consensus to the implant's long-term outcomes.

Methods

This systematic review has been registered prospectively on PROSPERO with CRD42017058005 and follows the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidance (Appendix 1, see Supplementary data).

Inclusion and exclusion criteria

Our inclusion criteria were all studies in the English language reporting the ≥ 10-year survival or outcomes of the Oxford Phase 3 medial UKA in patients over the age of 18 years. Although no registry reports were identified by our search, we did not intend to include these given their limitations due to data pooling and to prevent duplication of patients. Furthermore, studies provided more details about the patients, indications, and the implant type (medial/lateral/cemented/cementless), allowing us to determine whether they should be included or not. We excluded case reports from our review.

Search strategy

With the assistance of an expert information analyst, the databases Medline, Embase, and Cochrane Central Register of Controlled Trials (CENTRAL) were searched from January 1, 2008 to December 1, 2016, as the Oxford Phase 3 UKA was first introduced in 1998, meaning 10-year outcomes could only be reported from 2008 onwards.

Key words used in the search strategy included "knee arthroplasty", "partial", "unicompartmental", "unicondylar", and all synonyms, abbreviations, and variations in spellings of these terms. The full search strategies employed are in Appendix 2 (see Supplementary data). Additionally 5 abstracts from papers that have been presented but not yet published were included (Alnachoukati et al. 2016, Kendall 2016, Kornilov et al. 2016, White et al. 2016, Campi et al. 2017).

Search results from the databases had abstracts assessed for shortlisting-based eligibility criteria. All shortlisted papers had full papers obtained where possible and assessed to confirm eligibility. In cases in which more than 1 paper had been published on the same cohort of patients, the most recent paper using the full cohort was used and the others discarded to prevent overpowering our analysis by duplication of patients. There was complete agreement between 2 independent authors (HRM and LS) regarding the inclusion and exclusion of papers for our review.

Outcomes of interest

Our primary outcomes for this review were: (1) Annual revision rate; (2) Annual non-revision re-operation rates; (3) Annual re-operation rate; (4) Survival at ≥ 10 years. Secondary outcomes of interest were: (1) Cause of revision; (2) Long-term patient-reported outcomes (PROMs); and (3) Overall medical complication incidence.

Revision was defined as the removal or addition of any implant component. Re-operation was defined as revisions or any other sort of surgical intervention. Non-revision re-operation was defined as a re-operation that did not classify as a revision. Medical complication was defined as any medical adverse event postoperatively including pulmonary embolism, stroke, myocardial infarction, and deep vein thrombosis.

Data collection and risk of bias

2 authors (HRM, LS) independently extracted data from all included studies. Authors were contacted for missing information as required.

All studies were assessed for risk of bias using the methodological index for evaluation of non-randomized studies (MINORS) and an additional scoring system based on the presence of primary outcome reporting (A = clearly reported, B = non-reported/unclear) and the number of cases in the studies (A > 100, B = 51–99, C = < 50) (Slim et al. 2003, Campi et al. 2016). This modified method of assessing bias has previously been reported by Campi et al. (2016) and de Vos-Kerkhof et al. (2016). Studies with a MINORS score over 80% were considered at low risk of bias and those below 70% at high risk except those with 3 or more "As" in outcome reporting and study size (Campi et al. 2016). These are summarized in Table 1.

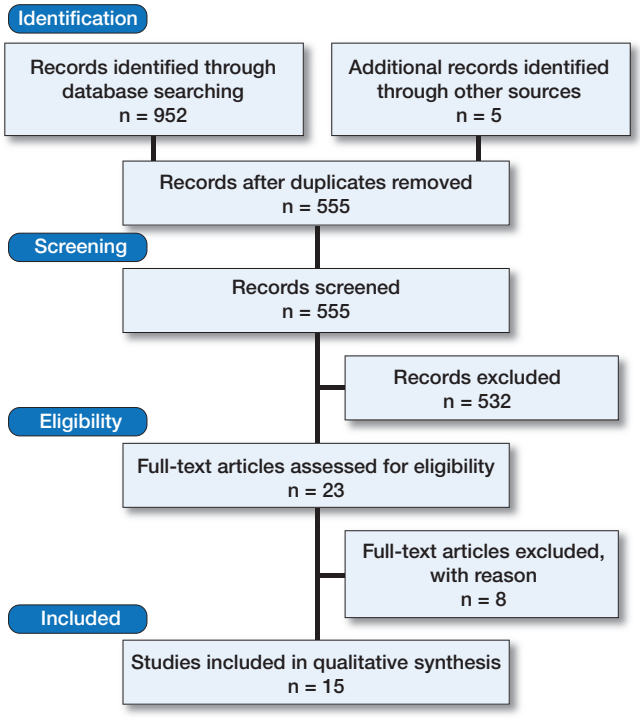
Data synthesis and analysis

The unit of analysis used is the number of knees. The outcomes revision, non-revision re-operation, and re-operation were calculated per 100 observed component years which is the equivalent of the annual rate (% pa) which is a well-established methodology of the Australian Joint Registry (Labek et al. 2011, Campi et al. 2016).

First the total observed component years were calculated by multiplying the number of cases by the mean follow-up for each study. Then the total number of revisions, non-revision

Table 1. Risk of bias of studies included in systematic review

Study	Minors	Sample size	Survival outcome	Revision outcome	Re-operation outcome	Bias risk
Alnachoukati et al. (2016)	10/16	A	A	A	B	Low
Aly et al. (2010)	9/16	B	B	A	B	High
Bottomley et al. (2016)	13/16	A	A	A	A	Low
Campi et al. (2017)	13/16	A	A	A	A	Low
Edmonson et al. (2015)	11/16	A	A	A	A	Low
Emerson et al. (2016)	12/16	A	A	A	B	Low
Faour-Martin et al. (2013)	14/16	A	A	A	A	Low
Kendall et al. (2016)	13/16	A	A	A	A	Low
Kim et al. (2015)	12/16	A	A	A	B	Low
Kornilov et al. (2016)	9/16	A	B	A	A	Low
Kristensen et al. (2013)	13/16	A	A	A	B	Low
Lisowski et al. (2016)	13/16	A	A	A	B	Low
Pandit et al. (2015)	13/16	A	A	A	B	Low
White et al. (2016)	11/16	A	A	A	B	Low
Yoshida et al. (2013)	13/16	A	A	A	B	Low



PRISMA flow diagram.

re-operations, or re-operations were respectively divided by the total observed component years and multiplied by 100 (Campi et al. 2016). 95% confidence intervals (CI) were calculated using the Clopper Pearson (1934) exact method.

The revision rate per 100 component years was then transformed into 10-year survival by multiplying this value by 10 and subtracting from 100. To calculate the 15-year survival this revision rate per 100 observed component years was multiplied by 15 and subtracted from 100.

Results

Our literature search identified a total of 958 papers which after duplicates were removed were narrowed to 555 papers. After all the titles and abstracts were assessed by 2 independent reviewers this was narrowed to 23 papers. Full texts of these papers were analyzed by 2 independent reviewers of which 15 were included in the final systematic review (Studies are reported in Table 1). The total number (n) of knees in the 15 papers was 8,658. All 15 papers included were observational cohort studies. Details of excluded papers from full text review (8 papers) can be found in Table 2, see Supplementary data. The PRISMA chart is summarized in the Figure.

Revisions

All 15 studies reported the number revisions during their study period. The summary of their findings is in Table 3, see Supplementary data. The total number of revisions was 460 (5.3%). Of these 15 studies 14 reported the mean follow-up used to calculate the annual revision rate (Table 4). From these 14 studies (n = 8,406) there were 441 revisions and 59,656 component years. The overall revision rate was 0.74% pa (CI 0.67–0.81), which corresponds to a 10-year survival of 93% (CI 91.9–93.3) and 15-year survival of 89% (CI 87.9–90) (Table 4). The only study which did not report the mean follow-up was Kornilov et al. (2016), who reported 19 revisions out of 252 cases.

Analysis of the causes of revision was possible on all 15 papers giving a total of 8,658 cases. From these cases the most common reasons for revision were lateral disease progression (123 cases, 1.4% incidence), aseptic loosening (108 cases, 1.25% incidence), bearing dislocation (50 cases, 0.58% incidence), and pain (49 cases, 0.57% incidence). For more details see Table 5 (see Supplementary data).

Non-revision re-operations

6 out of 15 studies (Faour-Martin et al. 2013, Edmondson et al. 2015, Bottomley et al. 2016, Kendall 2016, Kornilov et al. 2016, Campi et al. 2017) (n = 3,734) reported 43 non-revision re-operations (1.2%). From these 6 studies 5 reported mean follow-up time used to calculate the non-revision re-operation rate pa. From these 5 studies (n = 3,482) there were 41 non-revision re-operations and 21,988 component years, giving an annual non-revision re-operation rate of 0.19% (CI 0.13–0.25) (Table 6, see Supplementary data). Kornilov et al. (2016) did not report mean follow-up time but report 2 non-revision re-operations from 252 cases.

Table 4. Studies reporting the number of revisions and mean follow-up period

Study	No. of knees	Revisions	Mean follow-up years	Observed component years	Annual revision rate (95% CI)
Alnachoukati et al. (2016)	825	93	9.7	8,003.5	1.16 (0.94–1.42)
Aly et al. (2010)	45	2	8.8	393.8	0.51 (0.06–1.82)
Bottomley et al. (2016)	1,084	46	5.2	5,636.8	0.82 (0.60–1.09)
Campi et al. (2017)	1000	25	7	7,000	0.36 (0.23–0.53)
Edmonson et al. (2015)	364	26	5.5	2,002	1.30 (0.85–1.90)
Emerson et al. (2016)	213	20	10	2,130	0.94 (0.57–1.45)
Faour-Martin et al. (2013)	511	29	10.4	5,304.2	0.55 (0.37–0.78)
Kim et al. (2015)	166	16	10	1,660	0.96 (0.55–1.56)
Kristensen et al. (2013)	695	51	4.6	3,197	1.60 (1.19–2.09)
Lisowski et al. (2016)	138	11	11.7	1,614.6	0.68 (0.34–1.22)
Pandit et al. (2015)	1000	52	10.3	10,300	0.50 (0.38–0.66)
White et al. (2016)	563	16	6.6	3,715.8	0.43 (0.25–0.70)
Kendall (2016)	523	29	3.9	2,048.4	1.42 (0.95–2.03)
Yoshida et al. (2013)	1,279	25	5.2	6,650.8	0.38 (0.24–0.55)
Total/overall:	8,406	441		59,656	0.74 (0.67–0.81)

These studies were used to calculate the total number of revisions and observed component years, which were subsequently used to calculate the overall revisions per 100 observed component years.

Re-operations

6 out of 15 studies (Faour-Martin et al. 2013, Edmondson et al. 2015, Bottomley et al. 2016, Kendall 2016, Kornilov et al. 2016, Campi et al. 2017) (n = 3,734) reported 217 re-operations (5.8%). From these 6 studies, 5 reported mean follow-up time used to calculate re-operation rate pa. From these 5 studies (n = 3,482) there were 196 re-operations and 21,988 component years, giving an annual re-operation rate of 0.89% (CI 0.77–1.02) (Table 6, see Supplementary data). Only Kornilov et al. (2016), who reported 21 re-operations from 252 cases, did not report mean follow-up time.

Survival

13 of 15 studies (n = 8,361, see Table 7, Supplementary data) reported the 10-year or 15-year survival. 11 out of 15 studies (n = 7,700, Table 7, see Supplementary data) reported the overall 10-year or 15-year survival of the implant using revision as the endpoint as between 85% and 97%. 4 studies reported survival rates below 90%, 2 above 90% but below 95%, and 5 above 95% at 10 years. 3 out of 15 studies (n = 1,661) reported the overall 15-year survival rates as 96%, 91%, and 91%. It is important to note that the survival percentages reported by individual studies use different revision definitions from each other and some vary from our definitions.

Medical complications

4 out of 15 studies (Aly et al. 2010, Faour-Martin et al. 2013, Edmondson et al. 2015, Kendall 2016) reported the number of medical complications in their studies. The total number of cases from these 4 studies was 1,443 with 12 medical complications corresponding to a long-term medical complication incidence of 0.83%. All medical complications were either deep vein thrombosis (DVT) or pulmonary embolism (PE). No cases of myocardial infarction, stroke, or mortality were reported.

PROMs

9 out of 15 studies (n = 5,177, See Table 8, Supplementary data) reported the PROMs of patients in their cohorts. All papers reported PROMs of either the Oxford Knee Score (OKS) or American Knee Sociaty Score (AKSS) except Aly et al. (2010) who reported only the Hospital for Special Surgery Knee Score (HSS). All studies reported improvements in PROMs at final follow-up as compared with preoperatively (Table 8, see Supplementary data). The 4 studies (n = 3,417) reporting 10-year OKS had average scores of 42, 42, 40, and 38, giving a weighted average of 40. The 5 studies (n = 2,715) reporting 10-year AKSS-O all reported average scores of 90, 93, 90, 85, and 80, giving a weighted average of 86.

Discussion

Our systematic review has for the first time brought together all existing evidence of the long-term outcomes of the Oxford Phase 3 implant. Assessing over 8,000 UKA we found the 10-year survival to be 93%, 15-year survival 89%, non-revision re-operation rate 0.19% pa, mean Oxford Knee Score (OKS) 40, and a medical complication incidence of 0.8%.

To put these results in context they can be compared with the outcomes of TKA. A meta-analysis of the long-term outcomes of TKA identifies 911 revisions from 20,873 cases over a mean follow-up of 11 years, corresponding to a revision rate of 4.4% (Lutzner et al. 2011). Our predicted revision rate at same follow-up (11 years) is 8.1% based on our revision rate of 0.74% pa. Therefore, our 11-year survival (92%) is lower than that reported for TKA (96%) (Lutzner et al. 2011). However, in general UKA revisions are more straightforward than TKA revisions, with most being simple conversions to TKA or bearing replacements and the outcomes tend to be better.

Non-revision re-operation and re-operation rates are poorly reported for TKA. However, Zmistowski et al. (2011) reported the non-revision re-operation rate on 10,188 TKAs to be 3.8% at median 4-year follow-up. This is much higher than our predicted non-revision re-operation rate of 0.78% over the same period based on a non-revision re-operation rate of 0.19% pa.

The KAT trial reported data on revision and re-operation number for 1,715 patients in TKA followed up to a median of

10 years (Murray et al. 2014). At 10 years the revision rate was 5.8%, the non-revision re-operation rate was 7.5%, and the overall re-operation rate 13.3%. In our study the 10-year revision rate was 7.8%, the 10-year non-revision re-operation rate was 1.9%, and the overall re-operation rate was 8.9% (based on annual rates). The data from KAT (Murray et al. 2014), and the TKA meta-analysis (Lutzner et al. 2011, Zmistowski et al. 2011) are similar and taken together show that compared with TKA, the Oxford Knee has a higher revision rate, a much lower non-revision re-operation rate, and a lower overall re-operation rate.

The most common causes of revision in our study are similar to a systematic review of early-midterm studies of the Oxford Knee (Kim et al. 2014). Both our and the previous reviews identified aseptic loosening, bearing dislocation, and pain as the commonest causes for revision. However, we found lateral disease progression was the commonest cause unlike their[AQ1] review, presumably due to the longer follow-up. In both studies revision for patellofemoral problems and polyethylene wear is rare or non-existent. In TKA the most common reported causes of revision in the long term include aseptic loosening, infection, and polyethylene wear (Roberts et al. 2007, Argenson et al. 2013).

The overall incidence of medical complications in our study was 0.83% and complications reported were either DVTs or PEs. A systematic review by Gandhi et al. (2009) reported DVT incidence in cemented and cementless TKA as 8% and 7.7% respectively, which is nearly an order of magnitude higher. This higher rate of thromboembolism is in concordance with a propensity-matched comparison of UKA and TKA based on joint registry data (Liddle et al. 2014). The reported rates of stroke and myocardial infarction following TKA are 0.2% and 2.2% respectively, whereas in our study they were none (Lu et al. 2015, Mortazavi et al. 2010).

Studies in our review, reporting the 10-year OKS, ranged from 38 to 42 with a weighted mean of 40. The KAT trial reported an average OKS as 34 at 10-year follow up (Murray et al. 2014). Other reports of long-term trends in OKS following TKA are worse, at an average 30 at 10 years (Williams et al. 2013). This suggests the PROM scores are better in UKA than in TKA in the long term. However, without preoperative OKS this comparison may be unreliable.

In 2004 the cementless Phase 3 Oxford UKA was introduced (Goodfellow et al. 2016). There is a theoretical concern that cementless fixation may be worse than cemented, potentially increasing the risk of loosening. From the long-term papers included in our review only Campi et al. (2017) exclusively reported cementless UKA (n = 1,000). They demonstrated excellent long-term survival and 10-year OKS. These results suggest that cementless UKA is at least as good as cemented UKA.

Our review found only 1 paper based solely on the data from the designer-surgeons. In this study of cemented components, reported by Pandit et al. (2015), the annual revision rate was 0.50% pa, corresponding to a 10-year survival of 95%. In the non-designer studies, the revision rates ranged from 0.38 to 1.6% pa with most 10-year survival rates above 90%. Campi et al. (2017) reported a multicentre cementless series from both designer and non-designer surgeons with no difference between the surgeons in any outcome measure. These comparisons suggest that non-designer surgeons can achieve as good results as the designers, presumably because they are using similar indications and techniques.

There are some limitations to our systematic review. Some papers did not report all our outcomes of interest. Regardless of this, however, our numbers of knees for analysis for our revision rates were 8,406 cases. Several papers lacked clear definitions of outcomes measured. In most cases a formal definition of revision was given, but this was more poorly reported for re-operation and complications. It was, however, usually possible to work out the number of re-operations and medical complications using our a priori definitions.

The overall rate of revisions per 100 observed component years (% pa) and its subsequent survival calculation is based on an assumption that revision rate is constant and does not take into account that revision rates may be higher earlier, which tends to overestimate revision rate in studies with a shorter mean follow-up. This method does offer the advantage of being able to compare studies with different lengths of follow-up (Pabinger et al. 2013). However, calculations of overall survival could not include studies not reporting the mean follow-up. although in our review this only excluded 1 study (Kornilov et al. 2016).

In summary this systematic review of 15 studies reporting the 10-year outcomes of over 8,000 Oxford Phase 3 UKA shows that very good survival and PROMs with a low complication rate are routinely achieved and are not exclusive to the designer surgeons. The PROMs, medical complication rate, and non-revision re-operation rate were better than those found in publications for TKA but the failure rate is higher if failure is defined as revision. However, if failure is defined as all re-operations, not just revisions, then the failure rate of UKA is lower than that of TKA.

Supplementary data

Tables 2, 3, 5–8 and Appendices 1–2 are available as supplementary data in the online version of this article, http://dx.doi.org/ 10.1080/17453674.2017.1367577

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