■ KNEE

Risk of revision for medial unicompartmental knee arthroplasty according to fixation and bearing type

SHORT- TO MID-TERM RESULTS FROM THE DUTCH ARTHROPLASTY REGISTER

J. A. Burger,
H. A. Zuiderbaan,
I. N. Sierevelt,
L. van Steenbergen,
P. A. Nolte,
A. D. Pearle,
G. M. M. J. Kerkhoffs

From Hospital for Special Surgery, Weill Medical College of Cornell University, New York, New York, USA

Aims
Uncemented mobile bearing designs in medial unicompartmental knee arthroplasty (UKA) have seen an increase over the last decade. However, there are a lack of large-scale studies comparing survivorship of these specific designs to commonly used cemented mobile and fixed bearing designs. The aim of this study was to evaluate the survivorship of these designs.

Methods
A total of 21,610 medial UKAs from 2007 to 2018 were selected from the Dutch Arthroplasty Register. Multivariate Cox regression analyses were used to compare uncemented mobile bearings with cemented mobile and fixed bearings. Adjustments were made for patient and surgical factors, with their interactions being considered. Reasons and type of revision in the first two years after surgery were assessed.

Results
In hospitals performing less than 100 cases per year, cemented mobile bearings reported comparable adjusted risks of revision as uncemented mobile bearings. However, in hospitals performing more than 100 cases per year, the adjusted risk of revision was higher for cemented mobile bearings compared to uncemented mobile bearings (hazard ratio 1.78 (95% confidence interval 1.34 to 2.35)). The adjusted risk of revision between cemented fixed bearing and uncemented mobile bearing was comparable, independent of annual hospital volume. In addition, 12.3% of uncemented mobile bearing, 20.3% of cemented mobile bearing, and 41.5% of uncemented fixed bearing revisions were for tibial component loosening. The figures for instability were 23.6%, 14.5% and 11.7%, respectively, and for periprosthetic fractures were 10.0%, 2.8%, and 3.5%. Bearing exchange was the type of revision in 40% of uncemented mobile bearing, 24.3% of cemented mobile bearing, and 5.3% cemented fixed bearing revisions.

Conclusion
The findings of this study demonstrated improved survival with use of uncemented compared to cemented mobile bearings in medial UKA, only in those hospitals performing more than 100 cases per year. Cemented fixed bearings reported comparable survival results as uncemented mobile bearings, regardless of the annual hospital volume. The high rates of instability, periprosthetic fractures, and bearing exchange in uncemented mobile bearings emphasize the need for further research.

Cite this article: ***Bone Joint J*** **2021;103-B(7):1261–1269.**

Correspondence should be sent to J. A. Burger; email: yoostburger@gmail.com

doi:10.1302/0301-620X.103B7.BJJ-2020-1224.R3 $2.00

Bone Joint J
2021;103-B(7):1261–1269.

Introduction
Unicompartmental knee arthroplasty (UKA) is an established surgical treatment for isolated knee osteoarthritis (OA). Several advantages are reported for UKA over TKA, such as improved patient-reported outcomes, improved range of motion, faster recovery, less mortality and morbidity, bone preservation, and lower costs.[1-5] However, national arthroplasty registries have reported higher revision rates after UKA compared

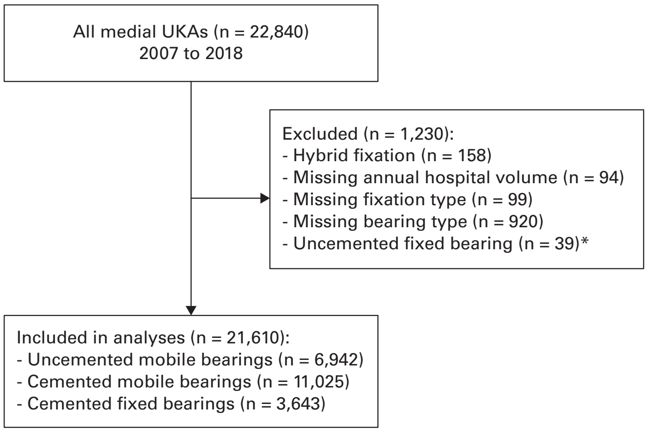

Fig. 1

Flowchart of exclusion process. UKA, uncompartmental knee arthropalsty. *Possibly incorrect data.

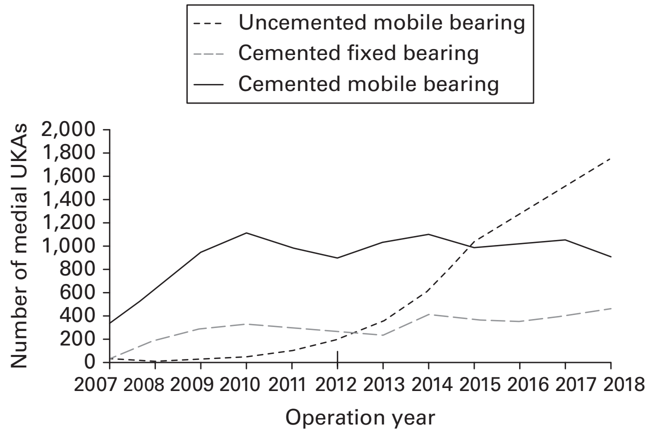

Fig. 2

Trend in usage per year of mobile bearing cemented, mobile bearing uncemented, and fixed bearing cemented unicompartmental knee arthroplasty (UKA) in the period 2007 to 2018. Coverage of all hospitals (100%) was reached in 2012.

to TKA,[6-8] with aseptic loosening as the most reported reason for revision after UKA. [6-8] These registry findings exhibit the widespread popularity of UKA with cemented fixation that has persisted until recently.

The increased revision rate reported in registries for UKA compared to TKA relates to multiple factors; UKA patients are often younger and more active,[1] a potentially lower threshold for UKA revision,[9,10] and higher incidence of complications among low-volume surgeons.[11] A proportion of authors have advocated the use of uncemented UKA designs emphasizing the potential benefits of fewer revisions due to aseptic loosening, reduction of radiolucencies under the tibial component, reduced surgical time,[12–14] the potential of an easier revision, and avoidance of cementation errors. However, uncertainty still remains due to the variable results of earlier uncemented designs for knee arthroplasty.[15,16] Authors have proposed that, compared to cemented UKA, uncemented UKAs require better bone quality for primary stability and more precise bone preparation for good bone-implant interface fixation.[17,18] Moreover, studies have reported higher rates of periprosthetic fractures, a serious complication, after uncemented medial UKA.[19,20]

Despite these concerns, the popularity of uncemented UKAs with mobile bearing surfaces has been increasing over the last decade,[6-8] but there is a lack of large-scale analyses comparing survivorship of various used UKA designs. The aim of this study was to evaluate short- to mid-term survivorship of uncemented mobile bearings and compare this to cemented mobile and fixed bearing UKAs. From the promising results of uncemented mobile bearing UKA designs,[21–23] we hypothesize that fixation type could influence survivorship.

Methods

Data from the Dutch nationwide-population-based arthroplasty register (LROI) was used for this study. The LROI has a coverage of all hospitals (100%) in the Netherlands since 2012, resulting in a complete data collection on 99% in 2018 for primary and revision knee arthroplasties.[24] The registry uses an opt-out system to require informed consent of patients and is linked to the Dutch national insurance database to identify deaths. Revisions are reported to the LROI, including information about the patient, date of revision, reason for revision, and type of revision. Revision is defined as a new operation in a previously knee arthroplasty during which one or more of the components are exchanged, removed, or added. At time of revision, one or more predefined reasons for revision and one predefined type of revision are reported by the surgeon. After submitting the revision information to the LROI, this data is linked to the primary procedure through an identification number.

For this study, all patients undergoing a primary medial UKA from 2007 to 2018 were selected from the register. For each procedure, the following data were extracted: revision information, sex, age, previous surgeries to the same knee, American Society of Anesthesiologists (ASA) grade,[24] diagnosis, surgical approach, fixation type, anonymized hospital identification number, BMI, smoking status, and the Charnley score.[24] Previous surgeries to the same knee were defined as procedures, such as meniscectomy, osteotomy, ACL reconstruction, osteosyntheses, synovectomy, arthroscopy, and patellar realignment. The Charnley score divides patients into four categories: 1) only one affected knee joint; 2a) both knee joints affected; or 2b) a knee prosthesis in the contralateral knee joint; and 3) multiple joints affected. The anonymized hospital identification numbers were used to calculate the annual hospital volume for each procedure. The registration of implant names and article numbers per procedure allow identification of bearing type used.

Statistical analysis. Median with interquartile range (IQR), means with standard deviations (SDs), or frequencies with proportions were used to describe the groups identified by fixation and bearing type. Estimated five-year revision rate with revision surgery as the endpoint was obtained by applying the Kaplan-Meier method. Competing risk analysis was used to consider death as competing event.[25] Crude as well as multivariate Cox proportional hazard models were used to compare risk of revision of the different medial UKA types. Hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated and adjustment for age, sex, ASA grade, previous surgeries to the same

Table I. Demographic details and clinical characteristics of included population with medial unicompartmental knee arthroplasty.

Variable	Uncemented mobile bearing UKA (n = 6,942)	Cemented mobile bearing UKA (n = 11,025)	Cemented fixed bearing UKA (n = 3,643)
Median follow-up, yrs (IQR)	2.03 (0.90 to 3.51)	4.78 (2.22 to 7.72)	4.05 (1.74 to 7.18)
Sex, n (%)			
Male	3,050 (44.0)	4,596 (41.7)	1,583 (43.5)
Female	3,886 (56.0)	6,421 (58.3)	2,056 (56.5)
Mean age, yrs (SD)	63.7 (8.8)	63.0 (8.7)	61.6 (8.3)
Mean BMI, kg/m^2 (SD)*	29.4 (4.7)	29.4 (4.5)	28.6 (4.1)
Previous knee surgery, n (%)†	1,844 (27.2)	3,908 (36.8)	1,517 (42.7)
ASA grade, n (%)			
I	1,587 (23.0)	3,382 (31.4)	1,386 (38.4)
II	4,543 (65.8)	6,503 (60.3)	2,021 (56.0)
III to IV	777 (11.2)	902 (8.4)	204 (5.6)
Diagnosis, n (%)			
Osteoarthritis	6,854 (99.1)	10,810 (98.6)	3,543 (98.1)
Osteonecrosis	36 (0.5)	83 (0.8)	37 (1.0)
Post-traumatic	24 (0.3)	48 (0.4)	28 (0.8)
Rheumatoid arthritis	5 (0.1)	18 (0.2)	2 (0.1)
Charnley classification, n (%)‡§			
A	3,248 (53.5)	2,840 (57.1)	1,240 (63.0)
B1	1,742 (28.7)	1,341 (27.0)	426 (21.7)
B2	975 (16.1)	730 (14.7)	251 (12.8)
C	88 (1.4)	49 (1.0)	39 (2.0)
N/A, no OA	19 (0.3)	14 (0.3)	11 (0.6)
Surgical approach, n (%)			
Medial parapatellar	6,539 (94.7)	10,531 (96.6)	3,227 (89.2)
Vastus (mid/sub)	339 (4.9)	295 (2.7)	378 (10.4)
Lateral parapatellar	14 (0.2)	53 (0.5)	12 (0.3)
Other	10 (0.1)	18 (0.2)	1 (0.0)
Smoking, n (%)‡			
Yes	646 (11.1)	491 (10.3)	234 (12.5)
No	5,149 (88.9)	4,259 (89.7)	1,645 (87.5)
Annual hospital volume, n (%)			
1 to 25 (P_0 to P_{25})	808 (11.6)	2,914 (26.4)	1,752 (48.1)
26 to 43 (P_{25} to P_{50})	899 (13.0)	3,658 (33.2)	721 (19.8)
44 to 100 (P_{50} to P_{75})	1,864 (26.9)	2,979 (27.0)	636 (17.5)
101 to 620 (P_{75} to P_{100})	3,371 (48.6)	1,474 (13.4)	534 (16.9)

Numbers do not add up to total due to missing data.
*Not registered before 2014, 615 (9%) uncemented mobile bearing, 5,478 (50%) cemented mobile bearing, and 1,533 (42%) cemented fixed bearing not eligible for this variable.
†Previous surgeries to the same knee were defined as any surgical procedure (e.g. meniscectomy, osteotomy, ACL reconstruction, osteosyntheses, synovectomy, arthroscopy, and patellar realignment).
‡Not registered before 2014, 781 (11%) uncemented mobile bearing, 5,943 (54%) cemented mobile bearing, and 1,647 (45%) cemented fixed bearing not eligible for this variable.
§The Charnley score divide patients into four categories: (A) only one affected knee joint, (B1) both knee joints affected, (B2) a knee prosthesis in the contralateral knee joint, and (C) multiple joints affected.
ASA, American Society of Anesthesiologists; IQR, interquartile range; N/A, not applicable; OA, osteoarthritis; SD, standard deviation; UKA, unicompartmental knee arthroplasty.

knee, surgical approach, and annual hospital volume was performed. Annual hospital volume was converted in a categorial variable by creating four equally sized groups using quartiles (one to 25 cases/year; 26 to 43 cases/year; 44 to 100 cases/year; and 101 to 620 cases/year). Interactions between annual hospital volume and UKA groups were assessed. Proportional hazards assumptions were checked by use of log-minus-log plots. Since BMI, smoking status, and Charnley score are registered since 2014, a sensitivity analysis was performed to assess the confounding effect of these variables. Baseline characteristics showing considerable imbalances between UKA groups were further analyzed by stratification and log-rank tests to consider the effect on five-year revision rate. Distributions of reasons for revision and type of revision were analyzed in patients with a follow-up within two years to equalize the median follow-up between UKA groups. A p-value < 0.05 was considered significant for all statistical analyses.

Results

Of the 22,840 procedures identified, 1,230 were excluded from the current analysis (Figure 1). A total of 21,610 were available for analysis, including 6,942 (32.1%) uncemented mobile bearings, 11,025 (51.0%) cemented mobile bearings, and 3,643 (16.9%) cemented fixed bearings. The median follow-up of

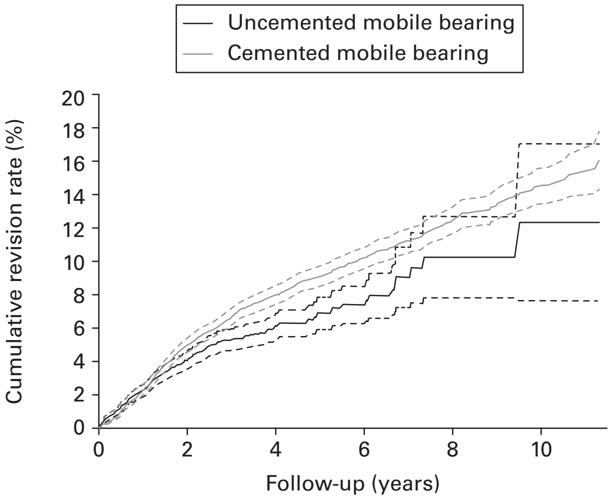

Fig. 3

The crude cumulative revision rates (with 95% confidence interval) for uncemented and cemented mobile bearing unicompartmental knee arthroplasty.

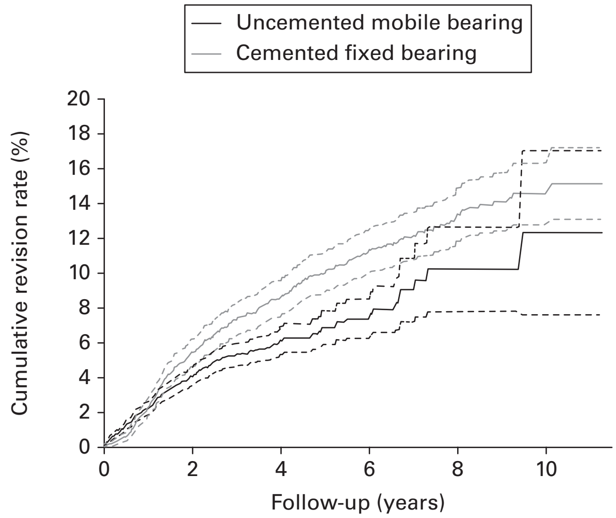

Fig. 4

The crude cumulative revision rates (with 95% confidence interval) for uncemented mobile bearing and cemented fixed bearing unicompartmental knee arthroplasty.

these groups was 2.0 years (IQR 0.9 to 3.5), 4.8 years (IQR 2.2 to 7.7) and 4.1 years (IQR 1.7 to 7.1), respectively. Each implant group had a total range from 0 to 12 years. Included UKA implants were primarily the uncemented Oxford Partial Knee (Zimmer Biomet, UK), cemented Oxford Partial Knee (Zimmer Biomet, UK), and cemented Physica Zimmer Unicompartmental High Flex Knee (LIMA, Italy).

The yearly number of uncemented mobile bearings showed a marked increase, from 198 in 2012 to 1,753 in 2018. During that same period, the incidence of cemented mobile bearings remained stable between 898 and 1,057 per year, while the cemented fixed bearings showed a slight increase from 268 in 2012 to 463 in 2018 (Figure 2). The percentage of uncemented mobile bearing, cemented mobile bearing, and cemented fixed bearing medial UKAs in 2012 was 14.0%, 65.8%, and 19.6% compared to 56.0%, 29.2%, and 14.8% in 2018, respectively.

The baseline characteristics of the uncemented mobile bearings, cemented mobile bearings, and cemented fixed bearings are summarized in Table I. Sex, age, BMI, diagnosis, Charnley classification, surgical approach, and smoking status were considered to be balanced among UKA groups, although a imbalance was reported for previous surgeries to the same knee, ASA grade, and annual hospital volume. The proportion of patients that reported previous surgeries to the same knee was 27.2% (1,844/6,779) for uncemented mobile bearings, 36.8% (3,908/10,619) for cemented mobile bearings, and 42.7% (1,517/3,552) for cemented fixed bearings. ASA grade II to IV was reported in 77.0% (5,320/6,909) of patients receiving uncemented mobile bearings, 68.7% (7,405/10,779) of patients receiving cemented mobile bearings, and 61.6% (2,225/3,612) of patients receiving cemented fixed bearings. A trend of increasing hospital volume with increasing implant usage was reported for uncemented mobile bearings (one to 25 cases/year: 11.6% (808/6,966); 26 to 43 cases/year: 13.0% (899/6,915); 44 to 100 cases/year: 26.9% (1,864/6,929); and 101 to 620 cases/year: 48.6% (3,371/6,936)), while the proportion of cemented mobile bearings was more equally distributed among the annual hospital volume groups (one to 25 cases/year: 26.4% (2,914/11,037); 26 to 43 cases/year: 33.2% (3,658/11,018); 44 to 100 cases/year: 27.0% (2,979/11,033); and 101 to 620 cases/year: 13.4% (1,474/11,000)). A trend of increasing hospital volume with decreasing implant usage was reported for cemented fixed bearings (one to 25 cases/year: 48.1% (1,752/3,642); 26 to 43 cases/year: 19.8% (721/3,641); 44 to 100 cases/year: 17.5% (636/3,6349); and 101 to 620 cases/year: 16.9% (534/3,160)).

The Kaplan-Meier analysis revealed a crude five-year cumulative revision rate of 6.9% (95% CI 5.9 to 7.9) for uncemented mobile bearings, 9.1% (95% CI 8.5 to 9.7) for cemented mobile bearings, and 10.0% (95% CI 8.8 to 11.2) for cemented fixed bearings (Figures 3 and 4). When including death as a competing risk, crude five-year cumulative revision incidences were 6.8% (95% CI 5.9 to 7.8), 8.9% (95% CI 8.3 to 9.5), and 9.8% (95% CI 8.7 to 11.0), respectively. Due to interaction between annual hospital volume and UKA group, HRs of the entire follow-up period were stratified by annual hospital volume and adjusted for age, sex, ASA grade, previous surgeries to the same knee, and surgical approach (Table II). In hospitals performing one to 25, 26 to 43, and 44 to 100 cases/year, the adjusted risk of revision for cemented mobile and fixed bearings were comparable to uncemented mobile bearings. In hospitals performing > 100 cases/year, the adjusted risk of revision was significantly higher for cemented mobile bearings compared to uncemented mobile bearings (HR 1.78 (95% CI 1.34 to 2.35)), while no difference was found for cemented fixed bearings compared to uncemented mobile bearings (HR 1.33 (95% CI 0.81 to 2.18)). Sensitivity analysis showed the risk of revision and degree of significance remained similar when adding the covariates BMI, smoking status, and Charnley score to the model.

Table III provides the stratified survival analysis for baseline characteristics showing a considerable imbalance among UKA

Table II. Crude and adjusted hazard ratio of the entire follow-up period of cemented mobile bearing, cemented mobile bearing, uncemented mobile bearing, and cemented fixed bearing medial unicompartmental knee arthroplasty (UKA), stratified by annual hospital volume.

Hospital volume	UKA group*	Crude HR (CI 95%)	p-value‡	Adjusted HR (CI 95%)†	p-value§
1 to 25 (P_0 to P_{25})	Uncemented mobile bearing	Reference		Reference	
	Cemented mobile bearing	0.79 (0.59 to 1.06)	0.122	0.82 (0.60 to 1.12)	0.205
	Cemented fixed bearing	0.88 (0.65 to 1.19)	0.397	0.90 (0.65 to 1.24)	0.502
26 to 43 (P_{25} to P_{50})	Uncemented mobile bearing	Reference		Reference	
	Cemented mobile bearing	0.93 (0.70 to 1.23)	0.611	0.94 (0.69 to 1.27)	0.675
	Cemented fixed bearing	0.99 (0.70 to 1.41)	0.953	0.94 (0.65 to 1.37)	0.761
44 to 100 (P_{50} to P_{75})	Uncemented mobile bearing	Reference		Reference	
	Cemented mobile bearing	0.94 (0.71 to 1.23)	0.634	0.99 (0.76 to 1.31)	0.967
	Cemented fixed bearing	0.95 (0.64 to 1.39)	0.785	0.90 (0.61 to 1.34)	0.601
101 to 620 (P_{75} to P_{100})	Uncemented mobile bearing	Reference		Reference	
	Cemented mobile bearing	1.91 (1.45 to 2.51)	< 0.001	1.78 (1.34 to 2.35)	< 0001
	Cemented fixed bearing	1.53 (0.96 to 2.42)	0.072	1.33 (0.81 to 2.18)	0.256

*Median follow-up of uncemented mobile bearing, cemented mobile bearing and cemented fixed bearing is 2.0 (0 to 12), 4.8 (0 to 12), and 4.1 (0 to 12).
†Adjusted for age, sex, American Society of Anesthesiologists grade, previous surgery to the same knee, and surgical approach.
‡Crude cox proportional hazard model.
§Multivariate proportional hazard model.
CI, confidence interval; HR, hazard ratio.

Table III. Crude five years revision rate (95% confidence interval) stratified by prior operations, American Society of Anesthesiologists grade, and hospital volume.

Variable	Uncemented mobile bearing UKA	Cemented mobile bearing UKA	Cemented fixed bearing UKA
Previous knee surgery			
Yes	7.1 (5.5 to 8.7)	10.9 (9.7 to 12.1)	11.6 (9.6 to 13.6)
No	6.5 (5.3 to 7.7)	8.0 (7.2 to 8.8)	8.2 (6.8 to 9.6)
p-value*	0.197	< 0.001	0.001
ASA grade			
I	7.0 (5.0 to 9.0)	9.5 (8.5 to 10.5)	9.0 (7.2 to 10.8)
II-III-IV	6.6 (5.6 to 7.6)	8.8 (8.0 to 9.6)	10.7 (9.1 to 12.3)
p-value*	0.766	0.102	0.098
Annual hospital volume			
1 to 25 (P_0 to P_{25})	12.1 (8.2 to 16.0)	9.9 (8.7 to 11.1)	10.7 (9.1 to 12.3)
26 to 43 (P_{25} to P_{50})	8.8 (6.4 to 11.2)	9.5 (8.5 to 10.5)	10.3 (7.8 to 12.8)
44 to 100 (P_{50} to P_{75})	6.7 (4.9 to 8.5)	7.5 (6.3 to 8.7)	8.2 (5.5 to 10.9)
101 to 620 (P_{75} to P_{100})	5.1 (3.9 to 6.3)	9.2 (7.2 to 11.2)	7.2 (3.9 to 10.5)
p-value*	< 0.001	0.255	0.397

*Log-rank test.
ASA, American Society of Anesthesiologists; UKA, unicompartmental knee arthroplasty.

groups. Patients who underwent knee surgery prior to cemented mobile bearings and cemented fixed bearing UKAs had significantly higher revision rates than those without ($p < 0.001$ and $p = 0.001$, respectively, log-rank test), while no difference in revision rates was found in patients undergoing an uncemented mobile bearing UKA. In all UKA groups, patients with ASA grade I reported similar revision rates as those with ASA grades higher than I. Increasing annual hospital volume was significantly associated with a decreased revision rate for uncemented mobile bearings ($p < 0.001$, log-rank test); no significant association was observed for cemented mobile bearings and cemented fixed bearings.

Distributions of reasons and type of revision in patients with a follow-up less than two years are reported in Tables IV and V. A common reported reason for revision was progression of OA across all types of UKAs with a proportion of 18.6% (41/220) in uncemented mobile bearing, 22.1% (110/498) in cemented mobile bearing and 21.6% (37/171) in cemented fixed bearings. Instability was more common in uncemented mobile bearings (23.6%; 52/2020) than cemented mobile bearings (14.5%; 72/498) and cemented fixed bearings (11.7%; 20/171). This reason was defined in the register as "instability of the knee implant, resulting in inadequate flexion, malposition or malalignment of the implant". Other disparities were observed in tibial loosening with proportions of 12.3% (27/220), 20.3% (101/498), and 41.5% (71/171) for uncemented mobile bearings, cemented mobile bearings and cemented fixed bearings, respectively. In isolated tibial loosening, figures were 6.8% (15/220), 14.7% (73/498) and 28.7% (49/171), respectively. Higher rates of periprosthetic fractures were reported after uncemented mobile bearings (10.0%; 22/220) compared to cemented mobile bearings (2.8%; 14/498) and cemented fixed bearings (3.5%; 6/171). Evaluation of revision types showed bearing exchange were undertaken more often in uncemented mobile bearings (40%; 88/220) than in cemented mobile bearings (24.3%; 121/498) and cemented fixed bearings (5.3%; 9/171).

Table IV. Reasons for revision for cemented mobile bearing, uncemented mobile bearing, and cemented fixed bearing medial unicompartmental knee arthroplasty (UKA) within the first two years.

Revision reason	Uncemented mobile bearing UKA (n = 220), n (%)*	Rank	Cemented mobile bearing UKA (n = 498), n (%)*	Rank	Cemented fixed bearing UKA (n = 171), n (%)	Rank
Progression osteoarthritis	41 (18.6)	2	110 (22.1)	1	37 (21.6)	2
Loosening tibial component	27 (12.3)	3	101 (20.3)	2	71 (41.5)	1
Malalignment	16 (7.3)	6	76 (15.3)	3	30 (17.5)	3
Instability†	52 (23.6)	1	72 (14.5)	4	20 (11.7)	4
Loosening femoral component	6 (2.7)	9	46 (9.2)	5	19 (11.1)	5
Polyethylene wear	11 (5.0)	7	15 (3.0)	8	4 (2.3)	9
Infection	17 (7.7)	5	33 (6.6)	6	7 (4.1)	7
Periprosthetic fracture	22 (10.0)	4	14 (2.8)	9	6 (3.5)	8
Patellar pain	10 (4.5)	8	28 (5.6)	7	13 (7.6)	6
Arthrofibrosis	2 (0.9)	10	4 (0.8)	10	0 (0.0)	= 11
Patellar dislocation	0 (0.0)	11	0 (0)	11	0 (0.0)	= 11
Unspecified	60 (27.3)	N/A	136 (27.3)	N/A	30 (17.5)	N/A

More than one reason for revision could be registered.
*Any reason for revision was not selected from listed choices in 22 uncemented mobile bearings, 36 cemented mobile bearings, and ten cemented fixed bearings.
†Instability is defined in the register as "instability of the knee implant, resulting in inadequate flexion, malposition, or malalignment of the implant".
N/A, not applicable.

Table V. Reasons types for cemented mobile bearing, uncemented mobile bearing, and cemented fixed bearing medial unicompartmental knee arthroplasty (UKA) within the first two years.

Reason	Uncemented mobile bearing UKA (n = 220), n (%)	Rank	Cemented mobile bearing UKA (n = 498), n (%)	Rank	Cemented fixed bearing UKA (n = 171), n (%)	Rank
Bearing exchange*	88 (40.0)	2	121 (24.3)	2	9 (5.3)	2
Partial revision†	15 (6.8)	3	27 (5.4)	3	7 (4.1)	3
Revision to TKA	110 (50.0)	1	338 (67.9)	1	154 (90.0)	1
Removal	6 (2.7)	4	4 (0.8)	4	1 (0.6)	4
Missing	1 (0.5)	N/A	8 (1.6)	N/A	0 (0.0)	N/A

*Polyethylene exchange.
†revision of at least femur or tibia component.
N/A, not applicable; TKA, total knee arthroplasty.

Discussion

The main finding of this study was that the risk of revision was higher for cemented mobile bearings compared to uncemented mobile bearings, but only in those hospitals performing more than 100 cases per year. The adjusted risk of revision between cemented fixed bearing and uncemented mobile bearing was comparable, independent of annual hospital volume. Compared with cemented mobile and fixed bearings, surgeons observed less tibial component loosening, but more instability and prosthetic fractures within two years following uncemented mobile bearing UKA. Surgeons performed bearing exchange more frequently after uncemented mobile bearing UKAs than after cemented mobile and fixed bearing UKAs.

The yearly volume of different UKA designs documented in the Dutch Arthroplasty Register was similar to other registries, and indicates the optimal fixation and bearing type remains unclear.[6-8] Further studies have emerged showing a trend towards improved survival in uncemented mobile bearings compared to their cemented version.[23,26,27] Although these studies are in line with our findings of high-volume hospitals with at least 100 cases per year, this is the first study comparing survivorship of uncemented mobile bearings with cemented fixed bearings. This comparison showed comparable risk of revision, independent of annual hospital volume. The results suggest an increased risk of revision for the more technically demanding mobile bearings may be mitigated by higher volumes and use of uncemented fixation.

We were unable to include uncemented fixed bearings in our analysis as these specific designs are not commonly used. Three small case series of uncemented fixed bearings have shown variable survival results.[28–30] A recent study by Kagan et al,[31] including 177 procedures, reported encouraging results with ten-year revision rates of 8% for uncemented fixed bearing, and 11% for the cemented version. Larger studies are needed to compare survivorship of uncemented with cemented fixed bearing designs.

Increased use of uncemented mobile bearings in high-volume hospitals presented in our study was expected. For uncemented fixation accurate bone resections are necessary to obtain good fixation of the implants. As such, surgeons in low-volume hospitals may prefer to implant UKAs with cement. In reviewing the effect of annual hospital volume on five-year revision rate in uncemented mobile bearings, there was an association between increasing hospital volumes with revision rates approaching those of TKAs.[32] This association was less pronounced in the cemented UKA groups. This finding may be explained by the unadjusted nature of the stratified analysis. Our adjusted analysis suggests use of uncemented compared to cemented mobile bearings leads to improved short- to mid-term survival only in hospitals performing more than 100 cases per year. Similar survival results to uncemented mobile bearings can be achieved with cemented fixed bearings, independent of annual hospital volume.

The variation in proportions of patients with previous surgeries to the same knee between the three UKA groups could be related to annual hospital volume. High-volume hospitals may have a lower threshold for proceeding with UKA, while low-volume hospitals may perform other knee surgeries prior to UKA. In this study, UKA groups performed in low-volume hospitals had more patients with previous surgeries to the same knee. Our stratified analysis, though unadjusted, revealed that previous surgeries and commonly arthroscopic procedures[33] were associated with higher revision rates for both cemented mobile and fixed bearings. This finding is consistent with a recent study showing knee arthroscopy within two years prior to UKA is associated with an increased rate of UKA conversion to TKA.[34] This implies that patients may benefit from nonsurgical management until they become candidates for UKA.

A larger percentage of patients receiving uncemented mobile bearings were graded as ASA II to IV compared to patients receiving cemented UKAs but this had little effect on revision rates. The different distributions regarding ASA grade can be explained by the association of increasing age with increasing ASA grades. Technically, ASA grades do not include age as a criterion, but despite this, some anaesthesiologists may assign a higher ASA grade to otherwise healthy elderly patients.[35]

One aim of uncemented UKA designs was to reduce the number of interfaces which could fail and thereby decrease the rate of aseptic loosening, especially on the tibial side. Our results show that isolated tibial loosening was less frequently observed in uncemented mobile bearings compared to cemented mobile and fixed bearings within the first two years. Other studies report similar findings for uncemented mobile bearing designs compared to their cemented versions.[23,26] Our results show higher rates of instability and periprosthetic fractures after uncemented mobile bearing compared to the cemented UKA groups. A biomechanical study reported the mechanical stability of uncemented tibial components was directly associated with the density of foam and significantly improved in poor quality foam by the use of bone cement.[36] Several authors have suggested performing a bone quality appraisal prior to deciding on fixation.[18,37,38] The high rate of periprosthetic fractures in uncemented UKAs may be associated with the bone quality. A cadaver study by Seeger et al[39] showed that patients with poor bone quality treated with uncemented UKA are at higher risk for periprosthetic tibial plateau fractures. They recommended use of cemented implants in this specific group of patients. In order to understand the effect of bone quality on revision rates after uncemented UKA designs, large cohort studies are needed.

In this study, we found a higher rate of bearing exchange in uncemented mobile bearings compared to cemented fixed bearings within the first two years. This may relate to the specific complication of bearing dislocation in mobile bearings. A common treatment of this complication involves reoperation to identify any potential causes for the bearing to dislocate following which, the bearing is replaced. A less common finding was the higher rate of bearing exchange in uncemented compared to cemented mobile bearings. A randomized controlled trial by Kendrick et al[40] compared the migration of uncemented and cemented mobile bearing UKAs performed by the designers of the system. They reported uncemented tibial components migrated significantly more into the tibial bone in the first two years than cemented tibial components (mean 0.34 mm vs 0.13 mm, respectively; $p < 0.001$, Mann-Whitney U test). A recent study by Inui et al[41] reported two cases of bearing dislocation after uncemented mobile bearing UKA caused by femoral component migration. We assume that the higher proportion of bearing exchange in uncemented mobile bearings is a result of higher risks of component migration leading to an increased space available for the bearing to dislocate.

There are limitations which should be considered when evaluating our findings. Residual confounding factors may be present due to unmeasured and incompletely measured variables as only adjustments for factors present within the database of the Dutch Arthroplasty Register could be made. The median follow-up differed widely among the uncemented mobile bearings and cemented designs. For the primary analysis of survivorship, we used the Kaplan-Meier survival and multivariate Cox regression analyses, as these methods are designed for the analysis of patients with different lengths of follow-up. This analysis was not appropriate for the secondary analyses of reasons and type of revision. We decided to only analyze the reasons and type of revision in all patients with a follow-up within two years to equalize the median follow-up between groups leading to fewer difficulties with data interpretation. Due to the low number of revisions in the majority of subgroups, it was not possible to make any adjustments. Finally, bearing dislocation was not a predefined reason for revision in the Dutch Arthroplasty Register, which prevents adequate evaluation in uncemented and cemented mobile bearings. Nevertheless, the majority of bearing exchanges in mobile bearings are likely undertaken as a result of bearing dislocation.

In conclusion, our results show that medial UKA with cemented fixed bearings can achieve comparable short- to mid-term survival results as those with uncemented mobile bearings, irrespective of annual hospital volume. Our data reveals that uncemented instead of cemented fixation in mobile bearings leads to improved survival, but only in those hospitals performing more than 100 cases per year. These findings suggest that the increased risk of revision for the technically more demanding mobile compared to fixed bearings can be mitigated by having a higher volume and use of uncemented fixation. The high rates of instability, periprosthetic fracture, and bearing exchange within the first two years after uncemented mobile bearing UKA are important subjects for future research.

Take home message

- Medial unicompartmental knee arthroplasty with cemented fixed bearings could achieve comparable short- to mid-term survival results as with uncemented mobile bearings, regardless of annual hospital volume.
- Uncemented instead of cemented fixation in mobile bearings shows improved survival, but only in hospitals performing more than 100 cases per year.

Twitter

Follow G. M. M. J. Kerkhoffs @KerkhoffsG

References

1. **Liddle AD**, **Judge A**, **Pandit H**, **Murray DW**. Adverse outcomes after total and unicompartmental knee replacement in 101,330 matched patients: a study of data from the National Joint Registry for England and Wales. *Lancet*. 2014;384(9952):1437–1445.
2. **Beard DJ**, **Davies LJ**, **Cook JA**, **et al**. The clinical and cost-effectiveness of total versus partial knee replacement in patients with medial compartment osteoarthritis (TOPKAT): five-year outcomes of a randomised controlled trial. *Lancet*. 2019;394(10200):746–756.
3. **Lombardi AV**, **Berend KR**, **Walter CA**, **Aziz-Jacobo J**, **Cheney NA**. Is recovery faster for mobile-bearing unicompartmental than total knee arthroplasty? *Clin Orthop Relat Res*. 2009;467(6):1450–1457.
4. **Newman J**, **Pydisetty RV**, **Ackroyd C**. Unicompartmental or total knee replacement: The 15-year results of a prospective randomised controlled trial. *J Bone Joint Surg Br*. 2009;91-B(1):52–57.
5. **Wilson HA**, **Middleton R**, **Abram SGF**, **et al**. Patient relevant outcomes of unicompartmental versus total knee replacement: systematic review and meta-analysis. *BMJ*. 2019;364:l352.
6. **No authors listed**. 16th Annual Report. National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. 2019. https://reports.njrcentre.org.uk/Portals/0/PDFdownloads/NJR%2016th%20Annual%20Report%202019.pdf (date last accessed 10 May 2021).
7. **No authors listed**. Annual Report. Norwegian Arthroplasty Register. 2019. http://nrlweb.ihelse.net/eng/Rapporter/Report2019_english.pdf (date last accessed 10 May 2021).
8. **No authors listed**. 20th Annual Report. Australian Orthopaedic Association National Joint Replacement Registry. 2019. https://aoanjrr.sahmri.com/documents/10180/668596/Hip%2C+Knee+%26+Shoulder+Arthroplasty/c287d2a3-22df-a3bb-37a2-91e6c00bfcf0 (date last accessed 10 May 2021).
9. **Goodfellow JW**, **O'Connor JJ**, **Murray DW**. A critique of revision rate as an outcome measure: Re-interpretation of knee joint registry data. *J Bone Joint Surg Br*. 2010;92-B(12):1628–1631.
10. **Kennedy JA**, **Palan J**, **Mellon SJ**, **et al**. Most unicompartmental knee replacement revisions could be avoided: a radiographic evaluation of revised Oxford knees in the National Joint Registry. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(12):3926–3934.
11. **Liddle AD**, **Pandit H**, **Judge A**, **Murray DW**. Effect of surgical caseload on revision rate following total and unicompartmental knee replacement. *J Bone Joint Surg Am*. 2016;98-A(1):1–8.
12. **Blaney J**, **Harty H**, **Doran E**, **et al**. Five-year clinical and radiological outcomes in 257 consecutive cementless Oxford medial unicompartmental knee arthroplasties. *Bone Joint J*. 2017;99-B(5):623–631.
13. **Kerens B**, **Schotanus MGM**, **Boonen B**, **et al**. Cementless versus cemented Oxford unicompartmental knee arthroplasty: early results of a non-designer user group. *Knee Surg Sports Traumatol Arthrosc*. 2017;25(3):703–709.
14. **Gulati A**, **Chau R**, **Pandit HG**, **et al**. The incidence of physiological radiolucency following Oxford unicompartmental knee replacement and its relationship to outcome. *J Bone Joint Surg Br*. 2009;91-B(7):896–902.
15. **Batailler C**, **Malemo Y**, **Demey G**, **Kenney R**, **Lustig S**, **Servien E**. Cemented vs uncemented femoral components: a randomized, controlled trial at 10 years minimum follow-up. *J Arthroplasty*. 2020;35(8):2090–2096.
16. **Rand JA**, **Trousdale RT**, **Ilstrup DM**, **Harmsen WS**. Factors affecting the durability of primary total knee prostheses. *J Bone Joint Surg Am*. 2003;85-A(2):259–265.
17. **Aprato A**, **Risitano S**, **Sabatini L**, **Giachino M**, **Agati G**, **Massè A**. Cementless total knee arthroplasty. *Ann Transl Med*. 2016;4(7):129.
18. **Stempin R**, **Stempin K**, **Kaczmarek W**. Medium-Term outcome of cementless, mobile-bearing, unicompartmental knee arthroplasty. *Ann Transl Med*. 2019;7(3):41.
19. **Campi S**, **Pandit HG**, **Oosthuizen CR**. The Oxford medial unicompartmental knee arthroplasty: the South African experience. *J Arthroplasty*. 2018;33(6):1727–1731.
20. **Leenders AM**, **Schotanus MGM**, **Wind RJP**, **Borghans RAP**, **Kort NP**. A high rate of tibial plateau fractures after early experience with patient-specific instrumentation for unicompartmental knee arthroplasties. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(11):3491–3498.
21. **Mohammad HR**, **Kennedy JA**, **Mellon SJ**, **Judge A**, **Dodd CA**, **Murray DW**. Ten-year clinical and radiographic results of 1000 cementless Oxford unicompartmental knee replacements. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(5):1479–1487.
22. **Mohammad HR**, **Matharu GS**, **Judge A**, **Murray DW**. The effect of surgeon caseload on the relative revision rate of cemented and cementless unicompartmental knee replacements: An analysis from the National joint registry for England, Wales, Northern Ireland and the Isle of Man. *J Bone Joint Surg Am*. 2020;102-A(8):644–653.
23. **Knifsund J**, **Reito A**, **Haapakoski J**, **et al**. Short-Term survival of cementless Oxford unicondylar knee arthroplasty based on the Finnish arthroplasty register. *Knee*. 2019;26(3):768–773.
24. **Dutch Arthroplasty Register (LROI)**. Annual report. 2019. https://www.lroi-rapportage.nl/media/pdf/PDF%20Online%20LROI%20annual%20report%202019.pdf (date last accessed 10 May 2021).
25. **Verduijn M**, **Grootendorst DC**, **Dekker FW**, **Jager KJ**, **le Cessie S**. The analysis of competing events like cause-specific mortality--beware of the Kaplan-Meier method. *Nephrol Dial Transplant*. 2011;26(1):56–61.
26. **Mohammad HR**, **Matharu GS**, **Judge A**, **Murray DW**. Comparison of the ten-year outcomes of cemented and cementless unicompartmental knee replacements: data from the National joint Registry for England, Wales, Northern Ireland and the Isle of man. *Acta Orthop*. 2020;91(1):76–81.
27. **Schlueter-Brust K**, **Kugland K**, **Stein G**, **et al**. Ten year survivorship after cemented and uncemented medial Uniglide® unicompartmental knee arthroplasties. *Knee*. 2014;21(5):964–970.
28. **Lecuire F**, **Berard JB**, **Martres S**. Minimum ten-year follow-up results of alpina cementless hydroxyapatite-coated anatomic unicompartmental knee arthroplasty. *Eur J Orthop Surg Traumatol*. 2014;24(3):385–394.
29. **Hall MJ**, **Connell DA**, **Morris HG**. Medium- to long-term results of the UNIX uncemented unicompartmental knee replacement. *Knee*. 2013;20(5):328–331.
30. **Epinette J-A**, **Manley MT**. Is hydroxyapatite a reliable fixation option in unicompartmental knee arthroplasty? A 5- to 13-year experience with the hydroxyapatite-coated unix prosthesis. *J Knee Surg*. 2008;21(4):299–306.
31. **Kagan R**, **Anderson MB**, **Bailey T**, **Hofmann AA**, **Pelt CE**. Ten-year survivorship, patient-reported outcomes, and satisfaction of a fixed-mearing unicompartmental knee arthroplasty. *Arthroplast Today*. 2020;6(2):267–273.
32. **Badawy M**, **Espehaug B**, **Indrekvam K**, **Engesæter LB**, **Havelin LI**, **Furnes O**. Influence of hospital volume on revision rate after total knee arthroplasty with cement. *J Bone Joint Surg Am*. 2013;99-A(18):e131.
33. **No authors listed**. Annual report. Dutch Arthroplasty Register (LROI). 2017. https://www.lroi-report.nl/app/uploads/2020/10/PDF-LROI-annual-report-2017-min.pdf (date last accessed 10 May 2021).
34. **Fassihi SC**, **Gu A**, **Wessel LE**, **Thakkar SC**, **Sculco PK**, **Ast MP**. Prior knee arthroscopy increases the failure rate of subsequent unicompartmental knee arthroplasty. *J Arthroplasty*. 2021;36(5):1556-1561.
35. **Fitz-Henry J**. The ASA classification and peri-operative risk. *Ann R Coll Surg Engl*. 2011;93(3):185–187.
36. **Lee RW**, **Volz RG**, **Sheridan DC**. The role of fixation and bone quality on the mechanical stability of tibial knee components. *Clin Orthop Relat Res*. 1991;273:177–183.
37. **Eckert JA**, **Jaeger S**, **Klotz MC**, **Schwarze M**, **Bitsch RG**. Can intraoperative measurement of bone quality help in decision making for cementless unicompartmental knee arthroplasty? *Knee*. 2018;25(4):609–616.
38. **Tuncer M**, **Patel R**, **Cobb JP**, **Hansen UN**, **Amis AA**. Variable bone mineral density reductions post-unicompartmental knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(8):2230–2236.
39. **Seeger JB**, **Haas D**, **Jäger S**, **Röhner E**, **Tohtz S**, **Clarius M**. Extended sagittal saw cut significantly reduces fracture load in cementless unicompartmental knee arthroplasty compared to cemented tibia plateaus: an experimental cadaver study. *Knee Surg Sports Traumatol Arthrosc*. 2012;20(6):1087–1091.
40. **Kendrick BJL**, **Kaptein BL**, **Valstar ER**, **et al**. Cemented versus cementless Oxford unicompartmental knee arthroplasty using radiostereometric analysis: a randomised controlled trial. *Bone Joint J*. 2015;97-B(2):185–191.
41. **Inui H**, **Taketomi S**, **Yamagami R**, **Kawaguchi K**, **Tanaka S**. Femoral migration of the cementless Oxford which caused the bearing dislocation: a report of two cases. *BMC Musculoskelet Disord*. 2020;21(1):356.

Author information:
J. A. Burger, MD, Research Fellow
A. D. Pearle, MD, Professor of Orthopedic Surgery, Attending Orthopedic Surgeon
Department of Orthopaedic Surgery and Computer Assisted Surgery Center, Hospital for Special Surgery, Weill Medical College of Cornell University, New York, USA.

H. A. Zuiderbaan, MD, PhD, Orthopedic Surgeon, Department of Orthopaedic Surgery, Medische Kliniek Velsen, Velsen, Netherlands.

I. N. Sierevelt, MsC, Clinical Epidemiologist, Department of Orthopaedic Surgery, Spaarne Gasthuis, Hoofddorp, Netherlands; Specialized Centre of Orthopedic Research and Education (SCORE), Xpert Orthopedics, Amsterdam, Netherlands.

L. van Steenbergen, PhD, Clinical Epidemiologist, Department of the Dutch Arthroplasty Register, Hertogenbosch, Netherlands.

P. A. Nolte, MD, PhD, Orthopedic Surgeon, Department of Orthopaedic Surgery, Spaarne Gasthuis, Hoofddorp, Netherlands.

G. M. M. J. Kerkhoffs, MD, PhD, Orthopedic Surgeon, Professor of Orthopedic Surgery, Department of Orthopedic Surgery, Amsterdam Movement Sciences (AMS), Amsterdam University Medical Centers, Amsterdam, Netherlands.

Author contributions:

J. A. Burger: Designed the study, Interpreted the data, Drafted, revised, and approved the manuscript.
H. A. Zuiderbaan: Designed the study, Interpreted the data, Revised and approved the manuscript.
I. N. Sierevelt: Designed the study, Analyzed and interpreted the data, Revised and approved the manuscript.
L. van Steenbergen: Designed the study, Interpreted the data, Revised and approved the manuscript.
P. A. Nolte: Designed the study, Interpreted the data, Revised and approved the manuscript.
A. D. Pearle: Designed the study, Interpreted the data, Revised and approved the manuscript.
G. M. M. Kerkhoffs: Designed the study, Interpreted the data, Revised and approved the manuscript.

Funding statement:

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ICMJE COI statement:

A. D. Pearle reports consultancy for Stryker, Zimmer, and Exactech, royalties from Zimmer, and stock/stock options from Engage Surgical, all of which are unrelated to this article.

This article was primary edited by P. Walmsley.