Follow us @BoneJointOpen

Freely available online OPEN ACCESS

BJO

■ KNEE

Comparing surgical strategies for end-stage anteromedial osteoarthritis

TOTAL VERSUS UNICOMPARTMENTAL KNEE ARTHROPLASTY

M. Mikkelsen, H. A. Wilson, K. Gromov, A. J. Price, A. Troelsen

From Copenhagen University Hospital Hvidovre, Copenhagen, Denmark

Aims

Treatment of end-stage anteromedial osteoarthritis (AMOA) of the knee is commonly approached using one of two surgical strategies: medial unicompartmental knee arthroplasty (UKA) or total knee arthroplasty (TKA). In this study we aim to investigate if there is any difference in outcome for patients undergoing UKA or TKA, when treated by high-volume surgeons, in high-volume centres, using two different clinical guidelines. The two strategies are 'UKA whenever possible' vs TKA for all patients with AMOA.

Methods

A total of 501 consecutive AMOA patients (301 UKA) operated on between 2013 to 2016 in two high-volume centres were included. Centre One employed clinical guidelines for the treatment of AMOA allowing either UKA or TKA, but encouraged UKA wherever possible. Centre Two used clinical guidelines that treated all patients with a TKA, regardless of wear pattern. TKA patients were included if they had isolated AMOA on preoperative radiographs. Data were collected from both centres' local databases. The primary outcome measure was change in Oxford Knee Score (OKS), and the proportion of patients achieving the patient-acceptable symptom state (PASS) at one-year follow-up. The data were 1:1 propensity score matched before regression models were used to investigate potential differences.

Results

The matched cohort included 400 patients (mean age 67 years (SD 9.55), 213 (53%) female, mean BMI 30.2 kg/m², 337 (84%) American Society of Anesthesiologists grade ≤ 2). We found a mean adjusted difference in change score of 3.02 points (95% confidence interval (CI) 1.41 to 4.63; $p < 0.001$) and a significantly larger likeliness of achieving PASS (odds ratio 3.67 (95% CI 1.73 to 8.45); $p = 0.001$) both in favour of the UKA strategy.

Conclusion

UKA and TKA are both good strategies for treating end-stage AMOA. However, when compared as a strategy, UKA achieved larger improvements in OKS, and were more likely to reach the PASS value at one-year follow-up.

Cite this article: *Bone Jt Open* 2022;3-5:441–447.

Keywords: Unicompartmental knee arthroplasty, Knee replacement, Patient-reported outcome measurement, Oxford Knee Score, Anteromedial osteoarthritis

Correspondence should be sent to Mette Mikkelsen; email: mette.mikkelsen.02@regionh.dk

doi: 10.1302/2633-1462.35.BJO-2021-0174.R1

Bone Jt Open 2022;3-5:441–447.

Introduction

Historically, end-stage osteoarthritis has been treated with total knee arthroplasty (TKA).[1] However, up to 47% of all patients undergoing TKA may be eligible for a smaller partial knee arthroplasty.[2,3] Medial unicompartmental knee arthroplasties (UKAs) are commonly used in the treatment of end-stage isolated anteromedial osteoarthritis (AMOA). Medial UKAs have been demonstrated to have lower mortality rates, shorter hospital admissions, lower infection rates, and fewer complications, and to be more cost-effective compared to TKA in the treatment of AMOA.[4-7] Despite the apparent advantages of UKA, it only accounts for 8.9% of all primary knee arthroplasties performed annually in the UK.[8] This low usage rate is commonly motivated by the higher revision rates reported in the national registries.[9] However, studies from the last decade report significantly lower revision rates, and the largest randomized controlled trial (RCT) comparing UKA and TKA, the TOPKAT study,[7] found no difference in revision rates between the two strategies during a five-year follow-up on 528 patients across 27 sites in the UK.[7] Furthermore, using only revision rates to compare UKA and TKA as a standalone indicator for performance is problematic, as the threshold for revision is lower for UKA and revision indications differ between the two treatment strategies.[4,10-13] Therefore, multifactorial evaluation of outcome, including patient-reported outcome measures (PROM), is gaining popularity both in the literature and in the shared decision-making process of clinical practice.[14,15] This approach is supported by the introduction of joint-specific PROMs into several large registries internationally.[8,10,11]

Previous registry studies have shown a small but significant difference between TKA and UKA when measuring the knee-specific PROM Oxford Knee Score (OKS).[16,17] However, most registries do not have the option of selecting TKA patients based on preoperative wear pattern, making a direct cohort comparison of patients with isolated AMOA impossible.

Understanding of optimal patient selection, and surgical strategy for UKA, has greatly improved in the last decade, with greater focus on the importance of optimal clinical strategy including correct patient selection, high UKA usage rates, and high surgical UKA volume being the most influential factors in UKA outcome.[12,18,19] Thus, we designed a study which ensured patients were treated in the optimal set-up for the treatment strategy they received. The optimal set-up was achieved by only including UKA patients from an experienced UKA centre, which adheres to the current recommendations for UKA practice. TKA patients were included from a centre which did not offer UKA as a treatment option. In this way, we aimed to limit the risk of UKAs being done by low UKA usage or low-volume surgeons, and to ensure the healthcare professionals included in the treatment were familiar with the treatment trajectory for the two strategies respectively.

We hypothesized that ensuring an optimal set-up for each strategy and limiting our TKA population to potential UKA candidates, namely patients with AMOA, would result in a larger than previously reported difference between the two strategies. Thus, we aimed to compare UKA and TKA as surgical strategies when performed in their optimal set-up using one-year change in OKS, and the likeliness of achieving a patient-acceptable symptom state (PASS), as outcomes. To that end, we designed a two-centre retrospective cohort study where UKA surgeries were performed in patients selected using current guidelines at a high-usage centre by a high-usage surgeon and TKA surgeries were performed at a different high-volume centre which did not offer UKA surgeries.

Methods

Participants and study design. We designed a two-centre retrospective cohort study with 501 (301 UKA) consecutive knee arthroplasty patients with AMOA. Patients with available preoperative and one-year follow-up OKS were included. TKA patients who did not have AMOA on preoperative radiographs, or had an incomplete set of radiographs, were excluded.[20,21] Further TKA patients who had simultaneous bilateral surgery or previous corrective surgery were excluded to ensure comparable pathology and recovery potential with the UKA patients.[22] UKA patients had primary AMOA as primary surgical indication, and were all treated at centre one, with the cementless Oxford Phase 3 Partial Knee (Zimmer Biomet, UK) from 4 April 2014 to 22 November 2016. The included TKA patients with AMOA on their preoperative radiographs were treated at centre two from 1 January 2013 to 1 April 2016. UKA was implemented at centre two in mid-2016, by which time the inclusion of TKAs was concluded. The number of participants was controlled by how many patients were available in the databases. The start date of inclusion was determined by the date of implementation of the databases. Patient demographics included age, sex, BMI, American Society of Anesthesiologists (ASA) grade,[23] and date of surgery.

Source of data. Our outcome measure was the 12-item knee-specific OKS questionnaire, containing two domains: knee pain and function. Questions have five response options and are combined into a single score, ranging from 0 to 48, with high scores indicating low disability.[24,25] The score was used to calculate the PASS, a dichotomous interpretive tool designed to evaluate the patients' satisfaction with their symptoms at the specific timepoint after the intervention.[26,27] The OKS questionnaire was collected in connection to the preoperative consultation with the help of a research assistant, and at one-year follow-up by email or letter. If the patient did not reply to the questionnaire within an acceptable timeframe, a research assistant called the patient and, if needed, helped the patient fill out the questionnaire. Data were collected from the two centres' local databases, both with 100% completeness. Response rates for OKS in the databases were 87.9% for UKAs and 44.6% for TKAs across the inclusion period.

Statistical analysis. Propensity scores were calculated using logistic regression to estimate the effect of the confounders (preoperative OKS, age, sex, ASA grade, and BMI) on our exposure and combine these into individual scores. The scores were then used to match a UKA patient

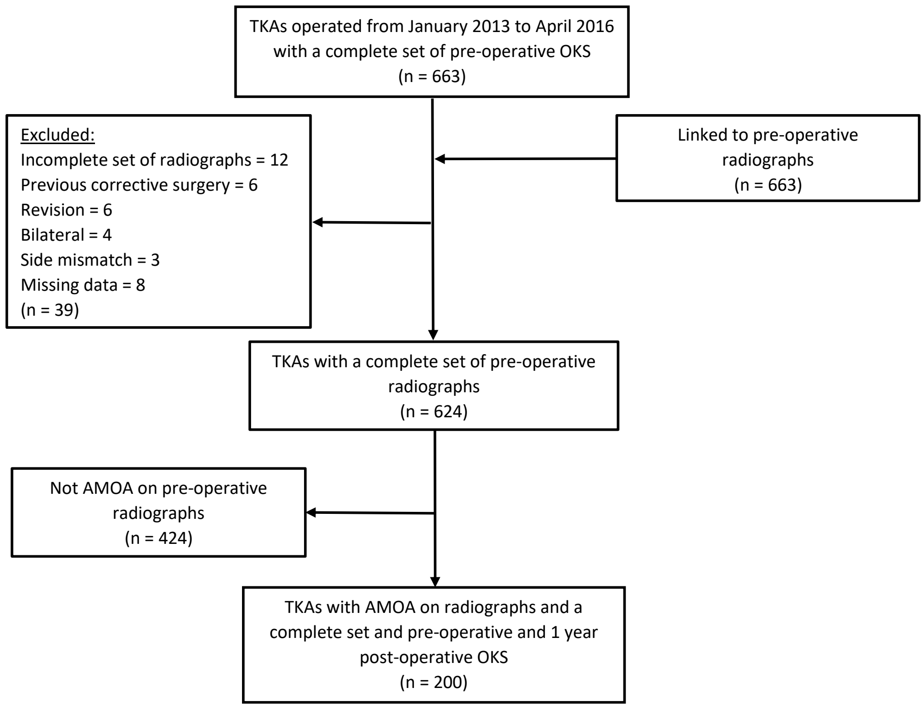

Fig. 1

Flowchart of selection process for total knee arthroplasty (TKA) patients. AMOA, anteromedial osteoarthritis; OKS, Oxford Knee Score.

Table I. Unmatched and propensity score matched demographic data for patients having medial unicompartmental knee arthroplasty or total knee arthroplasty. Changes in total knee arthroplasty from unmatched to matched data are due to multiple imputation of missing values.

	Unmatched			**1:1 Matched**		
Variable	**UKA**	**TKA**	**SMD**	**UKA**	**TKA**	**SMD**
Total, n	301	200		200	200	
Mean age at surgery, yrs (SD)	67.92 (9.94)	67.47 (9.21)	0.047	66.83 (9.87)	67.47 (9.21)	0.066
Mean BMI, kg/m² (SD)	30.72 (5.65)	30.13 (5.34)	0.107	30.37 (5.72)	30.10 (5.33)	0.047
Mean preoperative OKS (SD)	20.99 (7.33)	23.55 (6.53)	0.369	23.36 (6.87)	23.55 (6.53)	0.029
Female sex, n (%)	147 (48.8)	107 (53.5)	0.093	106 (53.0)	107 (53.5)	0.010
ASA grade, n (%)			0.154			0.045
1	45 (15.0)	34 (17.4)		37 (18.5)	35 (17.5)	
2	221 (73.4)	130 (66.7)		133 (66.5)	132 (66.0)	
3	35 (11.6)	31 (15.9)		30 (15.0)	33 (16.5)	

ASA, American Society of Anesthesiologists; OKS, Oxford Knee Score; SD, standard deviation; SMD, standardized mean difference; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

to each TKA patient using the nearest neighbour method. Standardized mean differences of 0.1 or less were used as a measure of sufficient balances between the treatment groups.[28] The difference in date of surgery between the groups was tested using an unpaired *t*-test.

Missing values that were missing at random were handled by multiple imputation (multivariate imputation by chained equations).[29] Continuous variables were imputed using predictive mean matching, and categorical variables were imputed by polytomous logistic regression. Sensitivity analysis was done using plots.

Change in OKS from preoperative to one-year follow-up (change score) was the primary outcome. The secondary outcome – likeliness of achieving PASS – was calculated from the one-year follow-up OKS. The difference in change score between UKA and TKA was investigated by multiple linear regression. To adjust for any residual imbalance between treatment groups' age, sex, BMI, and ASA grade, they were included as covariates in the regression. Logistic regression was used to compare the proportion of patients achieving PASS after one year, adjusting for age, sex, BMI, ASA grade, and preoperative

Table II. Mean change in Oxford Knee Score at one-year follow-up for unicompartmental knee arthroplasty and total knee arthroplasty, and difference using multiple linear regression.

Measure	UKA	TKA	Adjusted mean difference	p-value
Mean OKS change (95% CI)	18.57 (10.42 to 26.72)	15.55 (7.39 to 23.71)	3.02 (1.41 to 4.63)	< 0.001

CI, confidence interval; OKS, Oxford Knee Score; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

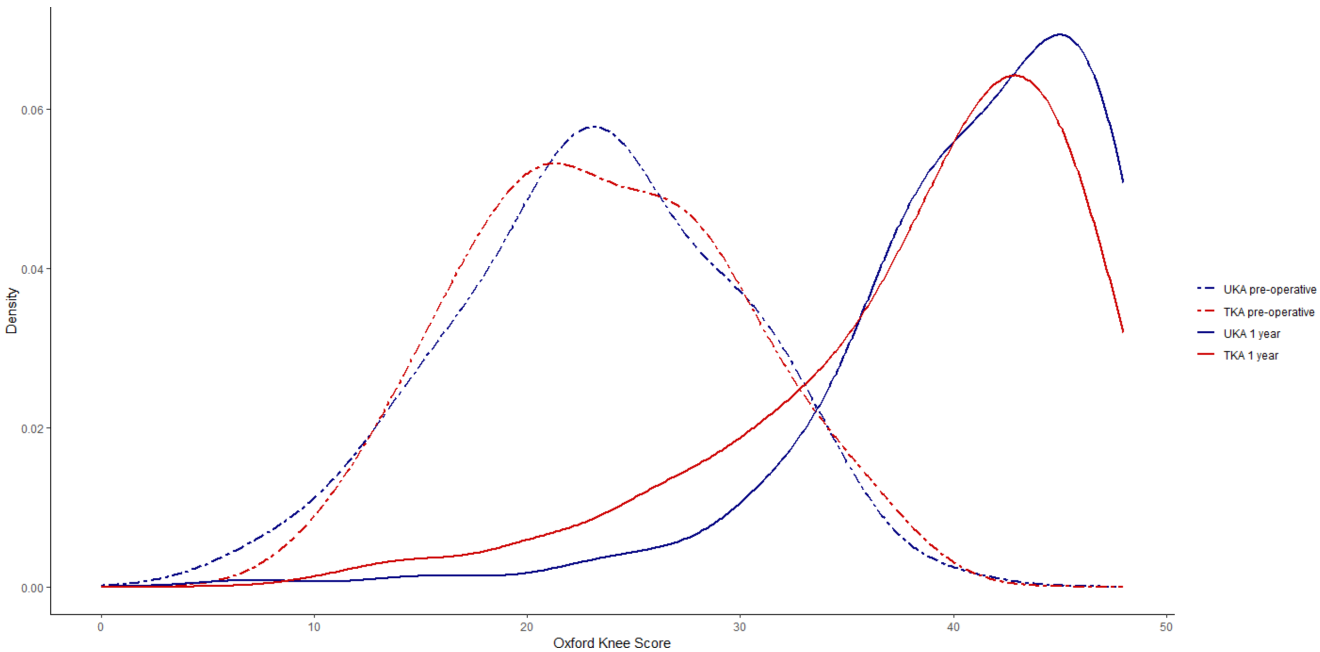

Fig. 2

Density plot showing the distribution of preoperative and one-year postoperative Oxford Knee Score stratified by surgical strategy. TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

OKS. To control the interaction between preoperative OKS and one-year follow-up OKS, we stratified preoperative OKS into three by range. The PASS at one-year follow-up was defined as an OKS above 30.[30] Any p-values less than 0.05 were considered statistically significant. All statistics were calculated using R v. 3.6.0 (R Foundation for Statistical Computing, Austria).

Ethics. The study was approved by the Danish Data Protection Agency under journal number VD-2018-313.

Results

A total of 663 TKAs had OKS available; after radiological analysis, 200 TKAs had AMOA and were included in the study (Figure 1). All patients receiving a UKA were included. The cohort prior to matching composed of 501 (301 UKA) patients with mean age of 68 years (standard deviation (SD) 9.58) and 254 (51%) female. After propensity score matching, the cohort included 400 (200 UKA), mean age of 67 years, 213 (53%) female, mean BMI of 30.23 kg/m^2, and 337 (66%) had ASA grade 2 (Table I). Prior to matching, the cohort had significant differences for preoperative OKS, and TKAs were performed 0.4 years earlier than UKA (95% confidence interval (CI) 0.3 to 0.5; p < 0.001, unpaired *t*-test). Two patients had missing ASA grade, and four had no BMI value; the values were missing at random and were imputed. Preoperative OKS and one-year postoperative OKS displayed a small positive interaction. Matching provided sufficient balance between the treatment groups (Table I).

At one-year follow-up, the UKA strategy achieved a statistically significant higher change score with a mean adjusted difference of 3.02 points (95% CI 1.41 to 4.63; p < 0.001, multiple linear regression) (Table II).

The distribution of OKS at one-year follow-up suggests UKA patients experience larger improvements in pain and function than TKA patients (Figure 2), which was supported by the significantly larger proportion of UKA patients achieving the PASS with odds ratio (OR) of 3.67 (95% CI 1.73 to 8.45; p = 0.001, logistic regression) in favour of the UKA strategy (Table III).

Discussion

As expected, both strategies show substantial improvements at one-year follow-up. The UKA strategy achieved larger improvements than the TKA strategy, with a mean adjusted difference in change score of 3.02 points

Table III. Proportion of patients achieving the patient-acceptable symptom state (Oxford Knee Score > 30.18) at one-year follow-up, and associated logistic regression results.

Measure	UKA	TKA	OR (95% CI)	p-value
Achieved PASS, n (%)	189 (94.5)	169 (84.5)	3.67 (1.73 to 8.45)	0.001

CI, confidence interval; OR, odds ratio; PASS, patient-acceptable symptom state; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

(Table II) and with 94.5% (n = 189) compared to 84.5% (n = 169) of patients achieving the PASS (Table III), supporting the distributions seen in Figure 2.

While the difference in change score presented in this study is statistically significant, the clinical significance is less certain. The minimal important difference (MID) for OKS was calculated by Beard et al[31] to be 4.84 points, a value representing the score difference needed for it to be clinically significant. Though our difference in OKS was larger than previously published series, the difference was still less than the MID.[7,17,32] However, using the MID on these data at group level is not considered optimal, as pointed out by Copay et al.[33] An alternative interpretation is to look at the change score for each group and determine if the two groups on average experience different levels of improvement. The tool categorized the change in OKS on a group level into four categories: 'much worse', 'about the same', 'a little better', 'much better' based on a transition anchor question.[34] Our UKA group had a mean adjusted change of 18.57 (10.42 to 26.72) and the TKA patients had one of 15.55 (7.39 to 23.71). The cut-off between 'a little better' and 'much better' is 16 points, thus the UKA patients on a group level reported greater improvements than TKA patients one year after their surgery. That being said, the tool is developed on six months' follow-up, making us cautious when forming any conclusions based on this.

Regarding the secondary outcome, PASS was chosen as a means of interpreting the final score. It gave us an opportunity to illustrate the difference between the two strategies in a way that was easier to interpret and convey to patients as part of the shared decision-making process. Communicating a three-point difference in mean adjusted change score to a patient can be challenging, but communicating an OR and a percentage is much more intuitive to patients and other non-healthcare professionals. We found, on average, the UKA strategy gave more than three times higher odds of reaching an acceptable symptom state at one-year follow-up (Table III). The use of interpretative tools for PROMs is relatively new, and a field where methods for determining these values is still being discussed, which means that we need to be careful when disregarding or praising results based on these tools. We have used the current best guess for MID, PASS, and the chance score categories. However, it is likely that these will change over the coming years.

The focus of this study was on the overall strategy implemented in the treatment of these patients. The design ensured that the entire course of treatment for each strategy took place under the optimal conditions. This was achieved, as both strategies were delivered by high-volume surgeons working in high-volume centres, using well-established protocols. Perioperative and postoperative care was delivered at each centre by experienced multidisciplinary teams familiar with their centres' strategy, limiting the risk of bias.[18] This strategy in the design of our study eliminated the key external factors previously reported for UKA outcome, such as patient selection, the surgeons' UKA usage, and surgical UKA volume.[19,22]

We chose to include TKA patients based on the wear pattern on preoperative radiographs to ensure patients had similar pathology in both strategy groups. This allowed us to limit the confounding effect of extent and pattern of OA, which has been demonstrated to affect the outcome of arthroplasty.[21] Outside of RCT data, we have been unable to find other studies that control for the OA wear pattern. To further limit confounding factors, we propensity score-matched the cohorts, and included available confounders as covariates in the regression analysis, thereby adjusting for any residual preoperative differences between the two groups.

The two-centre design made this study vulnerable to confounding by different thresholds for indication for surgery, and selection bias. To address this, we only included TKA patients with AMOA, and propensity score-matched the groups.[35] Despite this, we expect there to be residual selection bias from the design on known and unknown confounders. The study relied on pre-existing data from the two centres' databases. The database at the TKA centre had a low response rate in 2013 of 30% during the implementation of the database, corresponding to 38 included TKA patients (19%). The low response rate made attrition bias a concern, but the high level of similarity in the non-responder analysis supported the decision to include the 2013 patients (Supplementary Table i).

Further to this, the two centres employed multiple outcome measures for their arthroplasty patients, however they only had one PROM in common, limiting us to the OKS. Both groups had a mean BMI over 30; previous studies have demonstrated that patients undergoing TKA with a BMI over 30 have an increased risk of complications, but will see improvements similar to those seen in non-obese patients.[36,37] Lastly, we only had one-year follow-up available, and were unable to evaluate long-term differences. However, the magnitude of difference we found between the strategies exceeds those previously reported in the literature for this stage of recovery.[16,17] We argue this increased difference is due to the UKA strategy being carried out with strict adherence to the current recommendations for UKA practice.

In conclusion, this study demonstrated good one-year outcomes for the treatment of AMOA with both TKA and UKA. We found a more significant difference than previously reported in terms of change of OKS score between UKA and TKA, in favour of using a strategy of UKA where possible over TKA for all AMOA patients. Additionally, patients from the UKA strategy group were significantly more likely to achieve the PASS at one-year follow-up. We argue these findings further contextualize this area of research, and are presented in a way that aids further understanding of the potential of the UKA strategy.

Take home message

- Unicompartmental knee arthroplasty (UKA) as a strategy provides more than three times higher odds for patients of reaching the patient-acceptable symptom state one year after surgery compared to total knee arthroplasty (TKA).
- Ensuring UKA surgery is performed in its optimal set-up produces larger differences between UKA and TKA in Oxford Knee Scores.

Supplementary material

Non-responder analysis of all total knee arthroplasty patients from centre one during the inclusion period.

References

1. **Price AJ**, **Alvand A**, **Troelsen A**, **et al**. Knee replacement. *Lancet*. 2018;392(10158):1672–1682.
2. **Murray DW**, **Parkinson RW**. Usage of unicompartmental knee arthroplasty. *Bone Joint J*. 2018;100-B(4):432–435.
3. **Willis-Owen CA**, **Brust K**, **Alsop H**, **Miraldo M**, **Cobb JP**. Unicondylar knee arthroplasty in the UK National Health Service: an analysis of candidacy, outcome and cost efficacy. *Knee*. 2009;16(6):473–478.
4. **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.
5. **Siman H**, **Kamath AF**, **Carrillo N**, **Harmsen WS**, **Pagnano MW**, **Sierra RJ**. Unicompartmental knee arthroplasty vs total knee arthroplasty for medial compartment arthritis in patients older than 75 years: comparable reoperation, revision, and complication rates. *J Arthroplasty*. 2017;32(6):1792–1797.
6. **Drager J**, **Hart A**, **Khalil JA**, **Zukor DJ**, **Bergeron SG**, **Antoniou J**. Shorter hospital stay and lower 30-day readmission after unicondylar knee arthroplasty compared to total knee arthroplasty. *J Arthroplasty*. 2016;31(2):356–361.
7. **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): 5-year outcomes of a randomised controlled trial. *Lancet*. 2019;394(10200):746–756.
8. **No authors listed**. NJR 15th annual report 2018. 2018. https://reports.njrcentre.org.uk/Portals/7/PDFdownloads/NJR%2015th%20Annual%20Report%202018.pdf (date last accessed 13 April 2022).
9. **Chawla H**, **van der List JP**, **Christ AB**, **Sobrero MR**, **Zuiderbaan HA**, **Pearle AD**. Annual revision rates of partial versus total knee arthroplasty: A comparative meta-analysis. *Knee*. 2017;24(2):179–190.
10. **Franklin PD**, **Lewallen D**, **Bozic K**, **Hallstrom B**, **Jiranek W**, **Ayers DC**. Implementation of patient-reported outcome measures in U.S. Total joint replacement registries: rationale, status, and plans. *J Bone Joint Surg Am*. 2014;96 Suppl 1(Suppl 1):104–109.
11. **Pearse AJ**, **Hooper GJ**, **Rothwell A**, **Frampton C**. Survival and functional outcome after revision of a unicompartmental to a total knee replacement: the New Zealand National Joint Registry. *J Bone Joint Surg Br*. 2010;92-B(4):508–512.
12. **Badawy M**, **Fenstad AM**, **Bartz-Johannessen CA**, **et al**. Hospital volume and the risk of revision in Oxford unicompartmental knee arthroplasty in the Nordic countries -an observational study of 14,496 cases. *BMC Musculoskelet Disord*. 2017;18(1):1–8.
13. **Johnson WB**, **Engh CA**, **Parks NL**, **Hamilton WG**, **Ho PH**, **Fricka KB**. A lower threshold for revision of aseptic unicompartmental vs total knee arthroplasty. *Bone Joint J*. 2020;102-B(6_Supple_A):91–95.
14. **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.
15. **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.
16. **Liddle AD**, **Pandit H**, **Judge A**, **Murray DW**. Patient-reported outcomes after total and unicompartmental knee arthroplasty: A study of 14,076 matched patients from the National Joint Registry for England and Wales. *Bone Joint J*. 2015;97-B(6):793–801.
17. **Burn E**, **Sanchez-Santos MT**, **Pandit HG**, **et al**. Ten-year patient-reported outcomes following total and minimally invasive unicompartmental knee arthroplasty: a propensity score-matched cohort analysis. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(5):1455–1464.
18. **Hamilton TW**, **Rizkalla JM**, **Kontochristos L**, **et al**. The interaction of caseload and usage in determining outcomes of unicompartmental knee arthroplasty: a meta-analysis. *J Arthroplasty*. 2017;32(10):3228–3237.
19. **Liddle AD**, **Pandit H**, **Judge A**, **Murray DW**. Optimal usage of unicompartmental knee arthroplasty: A study of 41,986 cases from the National Joint Registry for England and Wales. *Bone Joint J*. 2015;97-B(11):1506–1511.
20. **Mikkelsen M**. *Unicompartmental Knee Arthroplasty: A Radiographic indications study*. University of Copenhagen, 2016.
21. **Jessing IR**, **Mikkelsen M**, **Gromov K**, **Husted H**, **Kallemose T**, **Troelsen A**. Patients with anteromedial osteoarthritis achieve the greatest improvement in patient reported outcome after total knee arthroplasty. *Arch Orthop Trauma Surg*. 2020;140(4):517–525.
22. **Hamilton TW**, **Pandit HG**, **Lombardi AV**, **et al**. Radiological Decision Aid to determine suitability for medial unicompartmental knee arthroplasty: development and preliminary validation. *Bone Joint J*. 2016;98-B(10 Supple B):3–10.
23. **Saklad M**. Grading of patients for surgical procedures. *Anesthesiol*. 1941;2(5):281–284.
24. **Murray DW**, **Fitzpatrick R**, **Rogers K**, **et al**. The use of the Oxford hip and knee scores. *J Bone Joint Surg Br*. 2007;89-B(8):1010–1014.
25. **Dawson J**, **Fitzpatrick R**, **Murray D**, **Carr A**. Questionnaire on the perceptions of patients about total knee replacement. *J Bone Joint Surg Br*. 1998;80-B(1):63–69.
26. **Tubach F**, **Ravaud P**, **Baron G**, **et al**. Evaluation of clinically relevant states in patient reported outcomes in knee and hip osteoarthritis: the patient acceptable symptom state. *Ann Rheum Dis*. 2005;64(1):34–37.
27. **Judge A**, **Arden NK**, **Cooper C**, **et al**. Predictors of outcomes of total knee replacement surgery. *Rheumatology (Oxford)*. 2012;51(10):1804–1813.
28. **Austin PC**. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med*. 2009;28(25):3083–3107.
29. **Van BS**, **Groothuis-Oudshoorn K**. MICE: multivariate imputation by chained equations in R. *J Stat Softw*. 2011;45(3):1–67.
30. **Ingelsrud LH**, **Terluin B**, **Gromov K**, **Price A**, **Beard D**, **Troelsen A**. Which Oxford Knee Score level represents a satisfactory symptom state after undergoing a total knee replacement? *Acta Orthop*. 2021;92(1):85–90.
31. **Beard DJ**, **Harris K**, **Dawson J**, **et al**. Meaningful changes for the Oxford hip and knee scores after joint replacement surgery. *J Clin Epidemiol*. 2015;68(1):73–79.
32. **Liddle AD**, **Judge A**, **Pandit H**, **Murray DW**. Determinants of revision and functional outcome following unicompartmental knee replacement. *Osteoarthr Cartil*. 2014;22(9):1241–1250.
33. **Copay AG**, **Eyberg B**, **Chung AS**, **Zurcher KS**, **Chutkan N**, **Spangehl MJ**. Minimum clinically important difference: current trends in the orthopaedic literature, Part II: lower extremity: a systematic review. *JBJS Rev*. 2018;6(9):e2.
34. **Mikkelsen M**, **Gao A**, **Ingelsrud LH**, **Beard D**, **Troelsen A**, **Price A**. Categorization of changes in the Oxford Knee Score after total knee replacement: an interpretive tool developed from a data set of 46,094 replacements. *J Clin Epidemiol*. 2021;132:18–25.

35. **Dahabreh IJ**, **Sheldrick RC**, **Paulus JK**, **et al**. Do observational studies using propensity score methods agree with randomized trials? A systematic comparison of studies on acute coronary syndromes. *Eur Heart J*. 2012;33(15):1893–1901.
36. **Baker P**, **Petheram T**, **Jameson S**, **Reed M**, **Gregg P**, **Deehan D**. The association between body mass index and the outcomes of total knee arthroplasty. *J Bone Joint Surg Am*. 2012;94-A(16):1501–1508.
37. **Brown MJC**, **Vella-Baldacchino M**, **O'Flaherty E**, **Jenkins PJ**. Predicting patient reported outcome in total knee arthroplasty using body mass index and limb measurements. *Knee*. 2018;25(5):915–922.

Author information:
- M. Mikkelsen, MD, PhD, PhD Student
- K. Gromov, MD, PhD, Consultant Orthopaedic Surgeon, Associate Professor
- A. Troelsen, MD, PhD, Dr.med, Consultant Orthopaedic Surgeon, Professor
Department of Orthopaedic Surgery, Clinical Orthopaedic Research Hvidovre, Copenhagen University Hospital Hvidovre, Copenhagen, Denmark.
- H. A. Wilson, MD, DPhil, DPhil Student
- A. J. Price, BA, MBB(Ch), FRCS, FRCS (Tr&Orth), DPhil, Professor
Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Science, University of Oxford, Oxford, UK.

Author contributions:
- M. Mikkelsen: Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Visualization, Project administration, Writing – original draft, Writing – review & editing.
- H. A. Wilson: Conceptualization, Data curation, Writing – original draft, Writing – review & editing.
- K. Gromov: Conceptualization, Supervision, Writing – review & editing.
- A. J. Price: Conceptualization, Methodology, Supervision, Writing – review & editing.
- A. Troelsen: Conceptualization, Methodology, Project administration, Supervision, Resources, Writing – review & editing.

Funding statement:
- The authors received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement:
- A. Troelsen reports consultancy payments, a research support grant, payment for lectures including service on speakers bureaus, travel/accommodation/meeting expenses, and advisory board membership from Zimmer Biomet, unrelated to the study. A. J. Price reports consultancy payments from Zimmer Biomet, unrelated to the study. K. Gromov reports research support and institutional support grants from Zimmer Biomet, unrelated to the study.

Acknowledgements:
- The authors would like to thank Håkan Sandholt for his guidance and assistance with the statistical analysis.

Open access funding
- The authors confirm that the open access fee for this study was self-funded.