



# Larger range of motion and increased return to activity, but higher revision rates following unicompartmental versus total knee arthroplasty in patients under 65: a systematic review

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## Abstract

**Purpose** Due to the lack of comparative studies, a systematic review was conducted to determine revision rates of unicompartmental and total knee arthroplasty (UKA and TKA), and compare functional outcomes, range of motion and activity scores in patients less than 65 years of age.

**Methods** A literature search was performed using PubMed, Embase, and Cochrane systems since 2000. 27 UKA and 33 TKA studies were identified and included. Annual revision rate (ARR), functional outcomes, and return to activity were assessed for both types of arthroplasty using independent *t* tests.

**Results** Four level I studies, 12 level II, 16 level III, and 29 level IV were included, which reported on outcomes in 2224 UKAs and 4737 TKAs. UKA studies reported 183 revisions, yielding an ARR of 1.00 and extrapolated 10-year survivorship of 90.0%. TKA studies reported 324 TKA revisions, resulting in an ARR of 0.53 and extrapolated 10-year survivorship of 94.7%. Functional outcomes scores following UKA and TKA were equivalent, however, following UKA larger ROM (125° versus 114°, *p* = 0.004) and higher UCLA scores were observed compared to TKA (6.9 versus 6.0, *n.s.*).

**Conclusion** These results show that good-to-excellent outcomes can be achieved following UKA and TKA in patients less than 65 years of age. A higher ARR was noted following UKA compared to TKA. However, improved functional outcomes, ROM and return to activity were found after UKA than TKA in this young population. Comparative studies are needed to confirm these findings and assess factors contributing to failure at the younger patient population. Outcomes of UKA and TKA in patients younger than 65 years are both satisfying, and therefore, both procedures are not contraindicated at younger age. UKA has several important advantages over TKA in this young and frequently more active population.

**Level of evidence** IV.

**Keywords** Age · Survivorship · Annual revision rate · Functional outcomes · Range of motion · Unicompartmental knee arthroplasty · Total knee arthroplasty

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## Introduction

Medial unicompartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) are both effective treatment options for medial compartment knee osteoarthritis (OA). However, in younger patients with end-stage OA, the most suitable surgical option remains controversial. Surgical concerns include accelerated failure rates due to higher activity levels as well as increased likelihood of need for multiple subsequent revision surgeries [1–3].

Recent studies have shown good long-term survivorship and functional outcomes following TKA in younger patient cohorts [2–4]. Over the last decade, UKA has gained popularity as a viable alternative for TKA in the case of isolated

medial OA [5–8]. In the general knee arthroplasty population, increased postoperative range of motion (ROM) and greater bone stock preservation were noted following UKA compared to TKA. These benefits are of special interest for younger patients with higher sports participation rates, and increased risk for multiple revisions due to longer life expectancy [9–15]. Based on registry data, however, survival rates of medial UKA tend to be lower than TKA in young patients [16–18]. To our knowledge, comparative studies assessing overall UKA and TKA survivorship in younger patient cohorts are lacking. Outcomes of prior non-comparative cohort studies are difficult to generalize to the younger patient population, as only a low percentage of patients undergoing knee arthroplasty are generally aged less than 65 years. This is the first study to systematically review the literature on outcomes of UKA and TKA in patients under 65.

To gain more insight in the younger population, a systematic review was conducted to assess survivorship, functional outcomes and activity levels of medial UKA and TKA in patients less than 65 of age. The study aims were to (1) determine revision rates of both arthroplasty types in cohort studies, and (2) compare functional outcomes and activity scores following UKA and TKA in younger patients. The hypothesis was that good-to-excellent outcomes were achieved after both arthroplasty types in patients less than 65 years, and therefore, young age should not be considered a contraindication for either procedures.

## Materials and methods

### Search strategy and criteria

A systematic literature search was performed in PubMed, EMBASE and Cochrane Library databases to identify studies reporting survivorship, functional outcomes and/or activity scores of TKA and UKA. Search terms consisted of “unicompartmental”, “unicondylar”, “partial”, “UKA”, “UKR”, “PKA”, “PKR”, or “total” “TKA”, combined with “knee arthroplasty”, “knee replacement” or its Mesh term. Other keywords were “young”, “younger”, “middle-aged”, “outcomes”, “prosthesis failure” and its Mesh terms. Results were filtered for retrieval of only English language studies published since 2000. After removal of duplicates, two authors (LJK and JPL) independently screened all entries by both title and abstract. Subsequently, all eligible studies were scanned for full texts against the inclusion and exclusion criteria. Survivorship studies were screened for differentiation of age groups or young patients. Additionally, references of scanned articles were checked for any missed studies. The third author (HAZ) was consulted in case of disagreement.

Consensus was achieved with regards to inclusion and exclusion of all reviewed articles.

Inclusion criteria consisted of cohort studies that (1) reported survivorship, revision rates or functional outcomes in TKA and/or medial UKA patients aged < 65 years, (2) regarded primary OA as the main indication (> 70% of study cohort), (3) only included patients with intact ACLs for UKA, and (4) had minimum follow-up of 2 years. Exclusion criteria consisted of studies that (1) not reported cohort size and/or revisions separately for young patients or per age group, (2) assessed revision or complex primary procedures (e.g., bicondylar UKA, TKA in > 15° valgus knees), (3) assessed specific subgroups (e.g., ACL-deficient and obese patients), (4) were performed using the same database, or (5) were case reports or systematic reviews.

### Methodological quality assessment

Level of evidence was determined for all studies using the adjusted Oxford Centre for Evidence-based Medicine [19]. Methodological Index for Non-randomized Studies (MINORS) instrument was used to determine the methodological quality of studies and assess the risk of bias [20]. Mean scores and percentage of the maximum score were reported.

### Data extraction

PRISMA guidelines were used to perform this systematic review. The following data were collected in Excel 2016; study type, authors, year of publication, type of implant, age group and mean age, number of TKA or UKA, number of failures, mean follow-up, functional outcomes, ROM, and activity scores. Outcomes of this study included survivorship, revision rates, annual revision rate (ARR), patient-reported outcomes, ROM, and activity scores following UKA and TKA. ARR was defined as “revision rate per 100 observed component years”, which provides an average failure rate per follow-up year. This metric corrects for varying follow-up intervals between populations, allowing direct comparison between studies with different follow-up lengths [21–24]. All outcome scores were reported as a percentage of the maximum score, which enabled comparison of different functional outcome scores. Collected outcome scores included Knee Society Score (KSS), Oxford Knee Score (OKS), Hospital for Special Surgery (HSS) Score, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) Score, and Visual Analog Scale for pain (VAS). Raw scores were used for ROM, University of California at Los Angeles (UCLA) Activity Score, and Tegner Activity Score. Satisfaction was recorded using Likert scales and reported as percentage of patients that scored good/excellent.

## Statistical analysis

Follow-up, age, revision rates of UKA and TKA were calculated using a weighted-mean to correct for different cohort sizes. Total number of revisions and observed component years were extracted to calculate the ARR for each study. Log-transformed ARRs were pooled separately for UKA and TKA studies using Poisson-normal models with random effects. Pooled log-transformed ARRs were exponentiated to obtain pooled ARRs with 95% confidence intervals (CI). Between-study heterogeneity was tested using the  $\chi^2$  test and quantified using the  $I^2$  statistic. These statistical analyses were performed using the Metafor package Version 2.0–0 (Maastricht University, Maastricht, the Netherlands) implemented in R-software Version 3.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Additionally, functional outcomes and activity scores following UKA and TKA were assessed using independent  $t$  tests.

## Results

### Search results

After full-text review of 757 articles, a total of 61 cohort studies [3, 4, 7, 10, 25–81] were selected for inclusion. Only two comparative studies assessing functional outcomes after UKA and TKA were identified [10, 43]. Twenty-four non-comparative UKA studies [7, 26, 27, 29, 31–33, 35, 37, 39, 48, 50–52, 59, 64, 66, 67, 71–73, 76, 78, 81] and 35 TKA studies [3, 4, 25, 28, 30, 34, 36, 38, 40–42, 44–47, 49, 53–58, 60–63, 65, 68–70, 74, 75, 77, 79, 80] reported revision rates and/or functional outcomes (Fig. 1).

### Quality of studies and risk of bias

Four level I randomized controlled trials were included [34, 36, 54, 61]. Twelve studies were level II prospective studies [40, 41, 45–47, 52, 56, 69, 70, 74, 81]. The majority of studies were either level III retrospective observational studies [3, 7, 10, 28, 33, 35, 39, 42–44, 57, 58, 62, 64, 76, 79] or level IV case series [4, 25–27, 29, 31, 32, 37, 38, 48–51, 53, 55, 59, 60, 63, 65–68, 71–73, 75, 77, 78, 80]. Using the MINORS instrument, a mean score of 15.5 (standard deviation, SD 0.5) was observed for the two comparative studies, while 59 non-comparative studies scored 10.1 (SD 1.8), corresponding to 64.6% and 63.1% of the maximum, respectively. None of the included studies were blinded and only 5% reported power calculations. Heterogeneity mainly existed in type of prosthesis and surgical indication.

## Revision rates of UKA and TKA

Twenty-one cohort studies reported data on 2224 UKAs at a mean age of 54.7 years, stating 182 revisions, yielding a revision rate of 8.18% and ARR of 1.00 (95% CI 0.77–1.30) (Table 1; Fig. 2). This ARR corresponds to an extrapolated 5-, 10-, and 15-year survivorship of 95.0, 90.0 and 85.0%, respectively. Thirty-three cohort studies reported data on 4737 TKAs at a mean age of 51.7 years, reporting 324 revisions, which results in a revision rate of 6.95% and ARR of 0.53 (95% CI 0.36–0.78) (Table 1; Fig. 3). This corresponds to an extrapolated 5-, 10-, and 15-year survivorship of 97.4, 94.7 and 92.1%, respectively. The revision rates and follow-up intervals of all individual cohort studies were plotted (Fig. 4).

## Functional outcomes

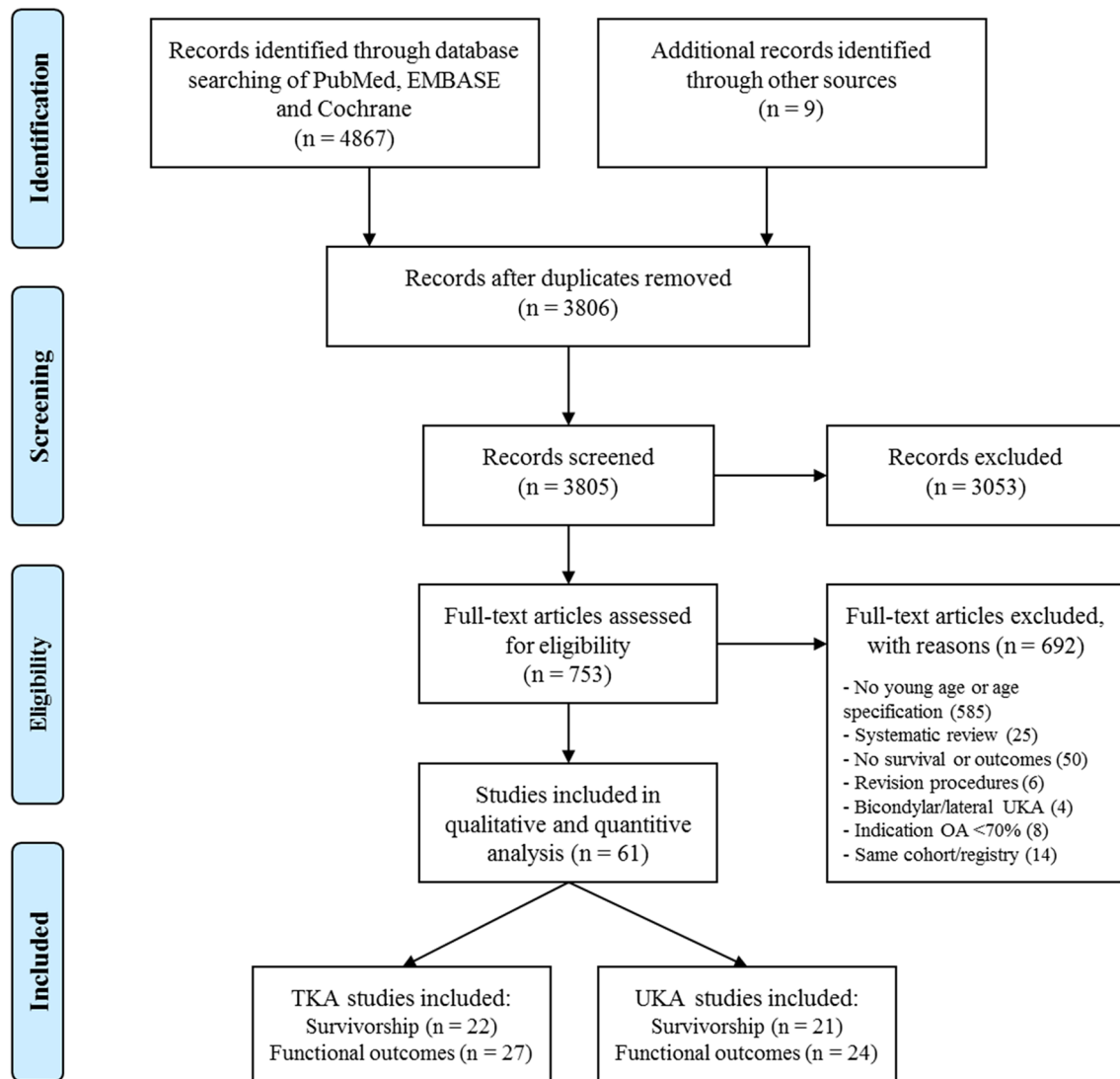
Functional outcomes were reported by 49 cohort studies, which included scores of 2012 UKAs at mean follow-up of 7.2 years (range 2.0–17.2) and 8664 TKAs at mean follow-up of 6.7 years (2.0–25.1). Overall, no significant differences were observed in any outcome scores between UKA and TKA (Table 2; Fig. 5). At long-term follow-up (9.7 years for UKA and 11.1 years for TKA), only KSS total scores were significantly higher following UKA compared to TKA ( $88.1 \pm 4.5$  and  $85.8 \pm 5.7$ , respectively,  $p = 0.04$ ) (Fig. 6).

## Range of motion and activity scores

A total of 35 studies reported ROM and/or activity scores, including 1590 UKAs and 2487 TKAs. Eleven UKA studies [26, 27, 31–33, 43, 48, 50, 64, 67, 72, 76, 81], 14 TKA studies [4, 30, 38, 43, 45, 46, 53–55, 57, 58, 61, 63, 68, 74] and two comparative studies [10, 43] reported larger ROM following UKA compared to TKA ( $125^\circ$  and  $114^\circ$ , respectively,  $p = 0.004$ ). A similar trend was observed with regard to UCLA scores, six UKA studies [10, 26, 32, 66, 72, 78] reported higher overall scores at each follow-up interval than five TKA studies [10, 46, 58, 62, 63] (6.9 and 6.0, respectively, n.s.). In eight studies [7, 35, 52, 53, 55, 63, 78, 81], similar Tegner scores were observed after both arthroplasty types (Table 3).

## Discussion

The most important finding of this study was that good-to-excellent outcomes can be achieved with UKA and TKA in patients less than 65 years of age. More specifically, the ARR of medial UKA was higher compared to TKA (1.00 and 0.53, respectively). On the contrary, significantly larger ROM and higher activity scores were observed following



**Fig. 1** PRISMA flow diagram of study inclusion process. *TKA* total knees arthroplasty, *UKA* unicompartmental knee arthroplasty

**Table 1** Revision rates of unicompartmental and total knee arthroplasty of all studies and registries

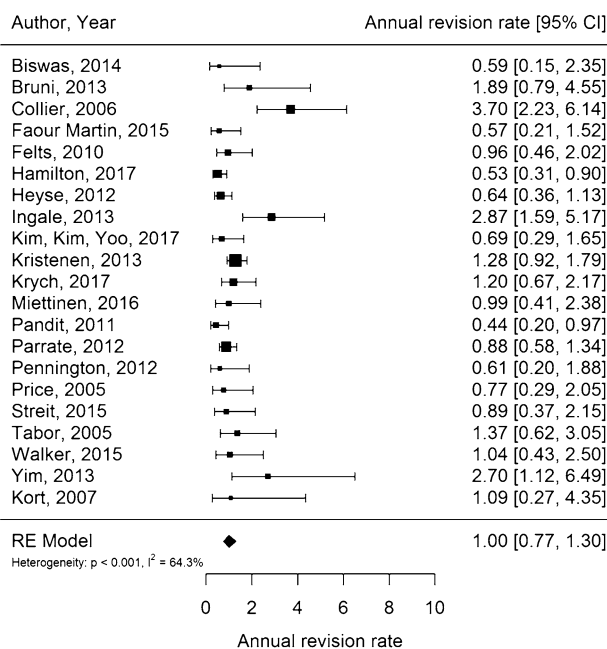
Type of arthroplasty	No. of studies	Mean age (years)	No. of arthroplasties	No. revisions	Revision rate (%)	Mean follow-up (years)	Observed component years	Annual revision rate
UKA	21	54.7	2224	182	8.18	8.41	18,696.0	1.00
TKA	22	51.7	4737	324	6.95	9.77	46,245.9	0.53

Annual revision rate is the revision rate corrected for follow-up interval (observed years)

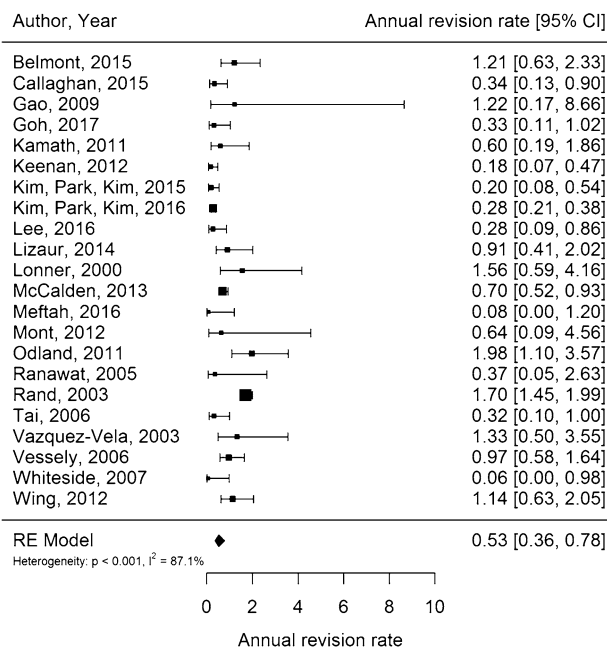
No. number *TKA* total knee arthroplasty, *UKA* unicompartmental knee arthroplasty

UKA at mid- to long-term follow-up. Overall functional outcome scores were equivalent after both procedures in this patient population. This study emphasizes the importance of assessing these outcomes using a systematic approach, as the number of younger patients is often small in individual

cohort studies, particularly for UKA. Furthermore, a corresponding increase in knee OA is expected as surges in obesity and sport-related injuries are anticipated to continue [82]. Therefore, higher demand for knee arthroplasty is predicted in the younger population [83, 84]. Finally, this



**Fig. 2** Forest plot of UKA studies reporting annual revision rates in younger patients. ARR annual revision rate; 95% CI confidence interval



**Fig. 3** Forest plot of TKA studies reporting annual revision rates in younger patients. ARR annual revision rate; 95% CI confidence interval

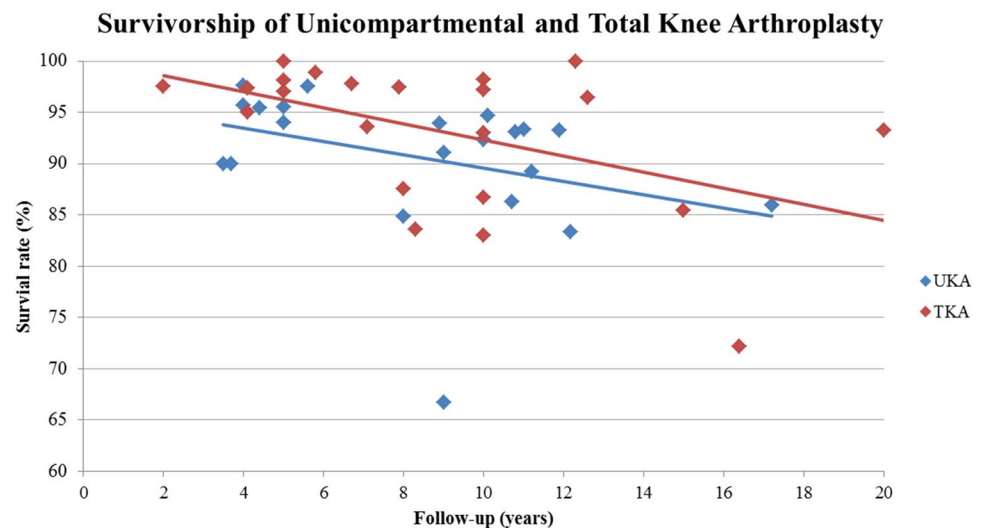
review stresses the need for comparative clinical studies to assess outcomes of UKA and TKA, as they are currently lacking.

In this systematic review, an ARR of 1.00 following UKA and 0.53 following TKA were noted in patients less than 65 years of age, corresponding to an extrapolated 10-year survivorship of 90.0% and 94.7%, respectively. Many studies have found similar survivorship differences between UKA and TKA in the typical arthroplasty population (> 65 years), and therefore may be attributed to the following factors [85, 86]. First, UKA survival is highly sensitive to technical parameters, including lower leg alignment and component position [87–89]. However, the role of alignment in the setting of TKA is currently debated, as several authors showed good results for both kinematically and mechanically aligned knees [90, 91]. The window for optimal postoperative alignment in UKA is relatively small ( $1^{\circ}$ – $4^{\circ}$  of varus). Since undercorrection is associated with accelerated polyethylene wear, and overcorrection induces OA progression of the contralateral compartment [87, 89, 92, 93]. Therefore, it can be argued that coronal alignment might be even more important in younger active patients, as they impart increased stresses along the knee joint for longer durations [10, 15, 78]. A second potential explanation for higher UKA revision rates compared to TKA relates to surgical thresholds. Several authors have suggested a lower threshold may exist for revising an UKA to a TKA, due to relative ease of the procedure [21, 94]. Moreover, surgical inexperience of low-volume surgeons and the preserved bone stock after UKA surgery might contribute to the lower threshold [86, 94, 95]. Additionally, UKA are more often revised for unexplained pain compared to TKA (23% and 9% of all revisions, respectively) [96].

Numerous registry studies and systematic reviews have assessed survivorship in the general arthroplasty population (> 65 years) [21, 97, 98]. Compared to the most recent Finnish registry study, our extrapolated 10-year UKA survivorship was higher than their survival rate in the general population with a mean age of 63.5 years (90.0 versus 80.6%) [98]. A systematic review by Rodriguez reported a survival rate at 10 years of 88% for UKA and 94% for TKA, which findings were similar to our results in a younger population (90.0 and 94.7%, respectively) [99]. Another recent systematic review has compared UKA with TKA in the general OA population (mean age 67.4 and 68.6 years, respectively) using ARR. The authors found a lower ARR (0.46) for TKA, but surprisingly, an equivalent ARR for UKA (1.04) was found compared to our results [21]. In summary, TKA survivorship was higher relative to UKA, but UKA survivorship seems not to be negatively affected by age at the time of surgery. More recent cohort studies by Pandit and Kristenen et al. showed comparable results between the general and younger arthroplasty population, which matches our findings as well as those of a systematic review by Chawla et al. [7, 21, 51]. However, future studies are needed to confirm these findings.



**Fig. 4** All included studies reporting survivorship of UKA and TKA in young patients



**Table 2** Functional outcome scores reported by 49 cohort studies

	Mean or % of maximum (range)		p value	References
	UKA	TKA		
OKS	40.8 (40.0–41.4)	36.4 (29.0–42.9)	n.s	[3, 7, 27, 35, 42, 44, 49, 70, 72]
HSS	94.0	89.3 (85.3–93.2)	n.s	[45, 55, 61, 66, 67]
WOMAC	84.6% (79.6–89.2)	76.5% (69.5–83.9)	n.s	[27, 46, 48, 50, 54, 58]
KSS total	87.5% (77.6–95.5)	87.7% (74.8–96.5)	n.s	[3, 4, 7, 27, 30–32, 35, 37–39, 45, 46, 48, 50, 53–55, 57–61, 63, 64, 68, 71, 73, 74, 76, 79]
Satisfaction	93.8% (83.0–100)	90.3% (81.0–95.6)	n.s	[3, 31, 32, 43, 46, 48, 49, 53, 62, 65, 66, 71, 72, 78]
VAS	2.1 (1.6–3.0)	2.3 (1.9–2.6)	n.s	[27, 43, 44, 72]

Satisfaction was defined as % of patients that scored a good to excellent rate

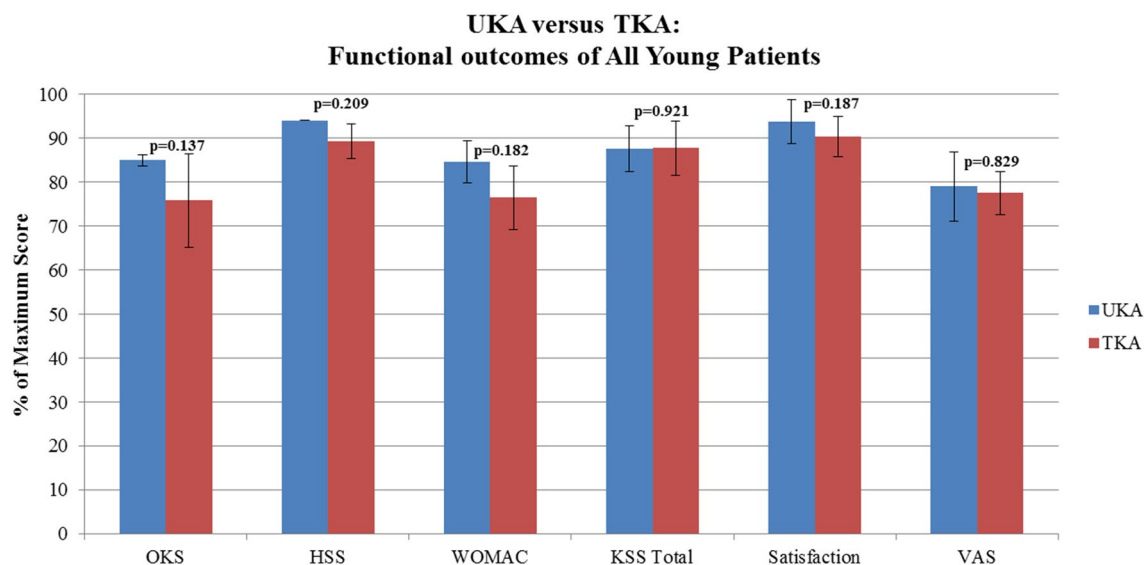
HSS Hospital for Special Surgery Score, KSS Knee Society Score, OKS Oxford Knee Score, VAS Visual Analog Pain Scale, WOMAC Western Ontario and McMaster Universities Osteoarthritis Index Score

When reviewing functional outcomes, it was found that OKS, HSS, and WOMAC scores were higher following UKA than TKA, although equivalent KSS scores were observed. At mid- and long-term follow-up, these patient-reported outcome scores continued to favor UKA (Fig. 6). This might be explained by the nature of UKA surgery including increased preservation of bone stock, larger ROM, maintenance of proprioception, and restoration of native knee kinematics [100, 101]. These factors likely allow patients to ‘forget’ their artificial joint more often [102, 103]. This may influence postoperative satisfaction rates, as our data suggests that UKA patients were more satisfied overall (good to excellent satisfaction in 94% of UKA versus 90% of TKA) [32, 43, 78]. Interestingly, only KSS scores were equivalent for both UKA and TKA. The sensitivity of the KSS has been questioned by authors [104, 105]. According to Na et al., the KSS fails to differentiate between moderate and high functional levels,

which is of special interest in younger patients as they require increased motion and strength [105].

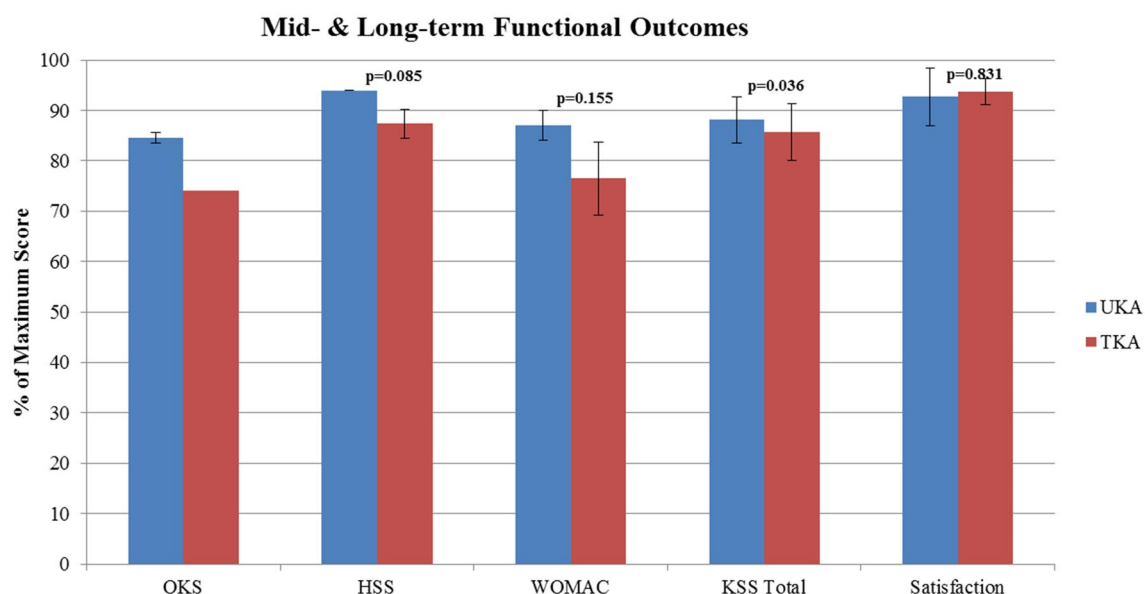
Additionally, this systematic review showed increased ROM and UCLA scores following UKA, indicating young patients return to high level activities compared moderate levels after TKA [106]. Several studies have similarly showed higher and often quicker return to activity following UKA [12, 15, 107]. Naal et al. showed a 95% return to activity rate and the majority the patients (90.3%) maintained or improved their ability to participate in sports [12]. The review by Witjes et al. found that TKA patients were also able to return to low- and high-impact sports, although to a lesser extent (36–89%) [15]. Finally, the comparative study by Ho et al. demonstrated a difference in timing, UKA patients were able to return to sports more quickly following surgery [10].

This study has several limitations. First, indications for UKA and TKA differ, as both types of arthroplasty can



**Fig. 5** Functional outcomes of all studies at mean follow-up was 7.4 years for UKA, and 6.7 years for TKA. *OKS* Oxford Knee Score, *HSS* Hospital for Special Surgery score, *WOMAC* Western Ontario

and McMaster Universities Osteoarthritis Index score, *KSS* Knee Society Score, *VAS* Visual Analog Scale



**Fig. 6** Mid- to long-term functional outcomes following UKA and TKA (mean follow-up 9.7 and 11.1 years, respectively). *OKS* Oxford Knee Score, *HSS* Hospital for Special Surgery score, *WOMAC* West-

ern Ontario and McMaster Universities Osteoarthritis Index score, *KSS* Knee Society Score

be performed in the setting of medial OA, whereas only TKA is indicated for tricompartmental OA. Although primary diagnosis was OA in at least 70% of patients, this study was limited as most UKA studies report on solely OA patients. Furthermore, based on OA severity, preoperative outcome scores may have been different between UKA and TKA, but few studies specified which knee compartments were involved. This review has focused on cohort studies;

therefore, it is likely limited to outcomes in high or moderately high-volume studies and may not reflect results from low-volume centers. Registry studies that include low-volume centers demonstrate higher revision rates (6.0–21.1%) [2, 108–111]. However, this difference has already been shown by many other studies [21, 95, 112, 113]. Nonetheless, this systematic review stresses the need for comparative studies assessing survivorship and functional outcomes in

**Table 3** Activity scores following unicompartmental and total knee arthroplasty, overall and split at five-year follow-up

Type of arthroplasty	No. of arthroplasties	Mean follow-up (years)	Range of motion	UCLA	Tegner activity scale
Overall					
UKA	1590	7.0 (2.0–17.2)	125° (101–138)	6.9 (6.4–7.5)	3.4 (2.6–4.3)
TKA	2487	8.0 (2.0–25.1)	114° (100–132)	6.0 (4.7–7.6)	3.2 (3.0–3.4)
<i>p</i> value			0.004	n.s	n.s
Follow-up ≤ 5 years					
UKA	631	3.7 (2.0–5.0)	122° (101–130)	7.1 (6.8–7.5)	3.6 (2.6–4.3)
TKA	843	3.1 (2.0–5.0)	113° (110–123)	6.2 (6.1–6.3)	–
<i>p</i> value			n.s	0.030	–
Follow-up > 5 years					
UKA	959	9.9 (5.6–17.2)	126° (115–138)	6.5 (6.4–6.5)	3.2 (3.1–3.2)
TKA	1644	11.1 (6.2–25.1)	114° (100–132)	6.0 (4.7–7.6)	3.2 (3.0–3.4)
<i>p</i> value			0.015	n.s	n.s

No. number, *n.s.* non-significant, *TKA* total knee arthroplasty, *UCLA* University of California at Los Angeles Activity Score, *UKA* unicompartmental knee arthroplasty

younger patients for optimal statistical comparison between UKA and TKA [83]. Most studies have used different age cutoff values to define younger patients, and therefore, mean age was calculated and found slightly higher in the UKA group (54.7 years) versus TKA (51.7 years). However, this difference was not considered clinically relevant by the authors. Finally, a possible selection bias exists as non-English articles were excluded.

This study provides an overview of the outcomes of UKA and TKA in a younger patient population, showing good-to-excellent outcomes following both procedures. Improvements in surgical design and techniques have resulted in a decreasing threshold for offering patients UKA and TKA, which in turn, has resulted in younger, more active patients accessing these surgeries. Due to the high number of patients included, this study can be used to guide surgeons, inform patients and manage their expectations with regard to risk of revision, functional outcomes and return to activity. Furthermore, this study shows that comparative studies of UKA versus TKA in younger patients are lacking in the current literature.

## Conclusion

This systematic review showed good-to-excellent outcomes are achievable with medial UKA and TKA in the young and often more active patient population. Cohort studies reported ARR of 1.00 for UKA and 0.53 for TKA in patients less than 65 years of age, corresponding to an extrapolated 10-year survivorship of 90 and 94.7%, respectively. Increased ROM and higher activity scores were observed following UKA compared to TKA; however, equivalent functional outcomes were reported. Despite a moderate level of evidence, this

review suggests that young age may not be a contraindication for either TKA or UKA.

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**Author contributions** LK performed the literature search, scanned all abstracts and full texts of the included articles and wrote the manuscript. JL screened all abstracts and full texts as a second author, helped to draft the manuscript. HA determined the quality of all included studies and helped to draft the manuscript. AP coordinated this study, participated in its design and helped to draft the manuscript. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest** Andrew D. Pearle is a consultant and receives research support from Stryker Corp, and has royalties from Zimmer Biomet. The other authors declare that they have no conflict of interests.

**Funding** No funding has been received for this study.

**Ethical approval** No ethical approval was obtained, because this study was a systematic review using de-identified data from other cohort studies.

**Informed consent** Informed consent was not applicable for this study.

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