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Review

Outcomes of cementless unicompartmental and total knee arthroplasty: A systematic review

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ABSTRACT

Background: Aseptic loosening is a common failure mode in cemented unicompartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA). This led to the development of cementless designs but the historical outcomes were poor. Recent developments in cementless designs have improved outcomes, but the current status is unknown. Therefore, a systematic review was performed to assess recent outcomes of cementless knee arthroplasty.
Methods: A search was performed using PubMed, Embase and Cochrane systems and national registries for studies reporting outcomes since 2005. Fifty-two cohort studies and four registries reported survivorship, failure modes or functional outcomes of cementless UKA and TKA.
Results: Nine level I studies, six level II studies, three level III studies, 34 level IV studies and four registries were included. Three hundred eighteen failures in 10,309 cementless TKA procedures and 62 failures in 2218 cementless UKA procedures resulted in extrapolated five-year, 10-year and 15-year survivorship of cementless TKAs of 97.7%, 95.4% and 93.0%, respectively, and cementless UKA of 96.4%, 92.9% and 89.3%, respectively. Aseptic loosening was more common in cementless TKA (25%) when compared to UKA (13%). Functional outcomes of cementless TKA and UKA were excellent with 84.3% and 84.5% of the maximum possible scores, respectively.
Conclusions: This systematic review showed that good to excellent extrapolated survivorship and functional outcomes are seen following modern cementless UKA and TKA, with a low incidence of aseptic loosening following cementless UKA.
Level of evidence: Level IV.

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1. Introduction

Unicompartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) are two reliable arthroplasty treatments for unicompartmental and tricompartmental osteoarthritis (OA), respectively. Different fixation methods for these treatments consist of cemented fixation of femoral and tibial components, cementless fixation of both components or hybrid fixation (i.e., cementless femoral component with cemented tibial component). Cemented fixation is most commonly used, according to national registries with an incidence of 56% to 94% [1–4]. Recent systematic reviews reported excellent 10-year survivorship of cemented UKA and TKA (91.7% and 95.3%, respectively) [5,6].

It has been suggested that poor cement fixation could lead to aseptic loosening [7,8], which is the most common failure mode in cemented UKA [9] and TKA [8]. Over the last decade, there has been an increase in interest for cementless fixation in UKA and TKA [4,7,10]. Historically, however, results of cementless prosthesis fixation were disappointing, with revision rates up to 20% at early to mid-term follow-up for UKA [11–13] and TKA [14–16]. Recent improvements, such as coating of the prostheses with bioactive materials, should improve osseous ingrowth and biological cementless fixation [17] and therefore improve outcomes of cementless UKA and TKA.

Studies systematically reviewing outcomes of cementless UKA and TKA over the last decade are, however, lacking or partially based the conclusions on older studies [5]. Therefore, the goal of this systematic review was to assess recent outcomes of cementless UKA and TKA with regard to (I) survivorship, (II) failure modes and (III) functional outcomes in recent studies. We hypothesized that for both procedures excellent survivorship and functional outcomes have been reported in the recent literature. Secondly, we hypothesized that the incidence of aseptic loosening is lower using cementless designs when compared to cemented UKA and TKA in the literature.

2. Methods

2.1. Search strategy

A search in the electronic databases PubMed, Embase and Cochrane Library was performed for studies reporting outcomes of cementless UKA and TKA. The search algorithm for this search was "(cementless OR uncemented) AND (knee arthroplasty OR knee replacement OR unicompartmental knee arthroplasty OR unicompartmental knee replacement OR total knee arthroplasty OR total knee replacement OR TKA OR UKA OR TKR OR UKR)". Following removal of duplicates, two authors (JPL and DLS) independently scanned all studies by title and abstract for eligibility for this study. These selected studies were then scanned for full text on the inclusion and exclusion criteria. In addition, references of eligible articles were scanned for additional studies and registries were searched for outcomes of cementless knee arthroplasty. In case of any disagreement, a third author (ADP) was consulted and consensus was reached on inclusion and exclusion of all studies.

2.2. Selection criteria

Inclusion criteria for the search consisted of studies that (I) reported survivorship, revision rates or functional outcomes of primary cementless UKA or TKA, (II) were published between 2005 and 2016, (III) were minimum level IV studies according to adjusted Oxford Centre for Evidence-Based Medicine [18,19]. Exclusion criteria consisted of (I) main indication of surgery was not OA, (II) revision cases, (III) specific patient groups (e.g., only <55 years of age or only obese patients), (IV) hybrid fixation, (V) long stem fixation, (VI) not clearly reporting fixation methods, (VII) not reporting mean follow-up, (VIII) studies using the same database of patients or (IX) study designs of meta-analysis, reviews or case reports.

2.3. Methodological quality of studies

Level of Evidence of the studies was determined using the adjusted Oxford Centre for Evidence-based Medicine [18,19]. To assess methodological quality of studies, two different tools were used. For level I randomized clinical trials (RCT), the PEDro tool was used [20]. This tool assesses methodological quality of RCTs using 11 questions on blinding, randomizing method and study quality. For non-randomized studies, the Methodological Index for Non-randomized Studies (MINORS) instrument was used [21]. This tool assesses methodological quality of comparative and non-comparative non-randomized studies using 12 and eight questions, respectively. Mean scores and percentage of the maximum score were reported.

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2.4. Data collection

Data was collected in a datasheet in Excel 2011 (Microsoft Corp., Redmond, WA, USA). Parameters collected included authors, year of publication, number of knees undergoing cementless TKA and UKA, number of failures, mean follow-up, reported failure modes and functional outcomes. Outcomes of all individual studies with regard to revision rates at all different follow-up intervals were displayed in Figure 2. Outcomes of this study included revision rates, annual revision rate (ARR), failure modes and patient-reported functional outcomes of cementless UKA and TKA. In addition, outcomes were stratified by type of cementless fixation. ARR is defined as "revision rate per 100 observed component years" and gives an average failure rate per follow-up year. It is calculated by dividing the number of failures by the number of observed component years times 100, with the number of observed component years calculated by the number of total knees times the mean follow-up. This method enables comparing revision rates of different studies with varying follow-up intervals and is commonly used in orthopedic studies [22–25]. Furthermore, the ARR enables estimating and extrapolating overall survivorship of cementless UKA and TKA for all studies included in this systematic review. Failure modes were reported in percentage of total failures for both UKA and TKA. Finally, all outcome scores were collected and reported as the percentage of the maximum score, which enabled comparison of different functional outcome scores and calculating a mean overall score. Most commonly used outcomes score were included, which were Knee Society Score (KSS) Clinical and Functional, Oxford Score, Hospital for Special Surgery (HSS) score and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score.

2.5. Statistical analysis

Statistical analysis was performed using SPSS Statistics 21.0 (SPSS Inc., Armonk, NY, USA). Spearman correlation tests were performed to assess correlations between ARR and time of follow-up, since no correlation indicates it is possible to use all studies with different follow-up lengths for extrapolating survivorship of cementless UKA and TKA. Given the absence of studies directly comparing cementless UKA and TKA, heterogeneity of the studies and high incidence of level IV case series, no direct statistical comparison was made between outcomes of cementless UKA and TKA. Differences were considered significant when $p < 0.05$.

3. Results

3.1. Search results

After removing duplicates and reviewing title, abstract and full text of the articles, a total of 52 cohort studies [7,17,26–75] and four registries [1,3,4,76] were included in this study (Figure 1). Forty-three cohort studies [17,27–30,32–41,43–48,50–53, 55–58,61–66,68–75] and four registries [1,3,4,76] reported revision rates of cementless TKA while nine studies [7,26,31,42,49,54,59,60,67] and one registry [4] reported revision rates of cementless UKA. For TKA, 22 studies used porous

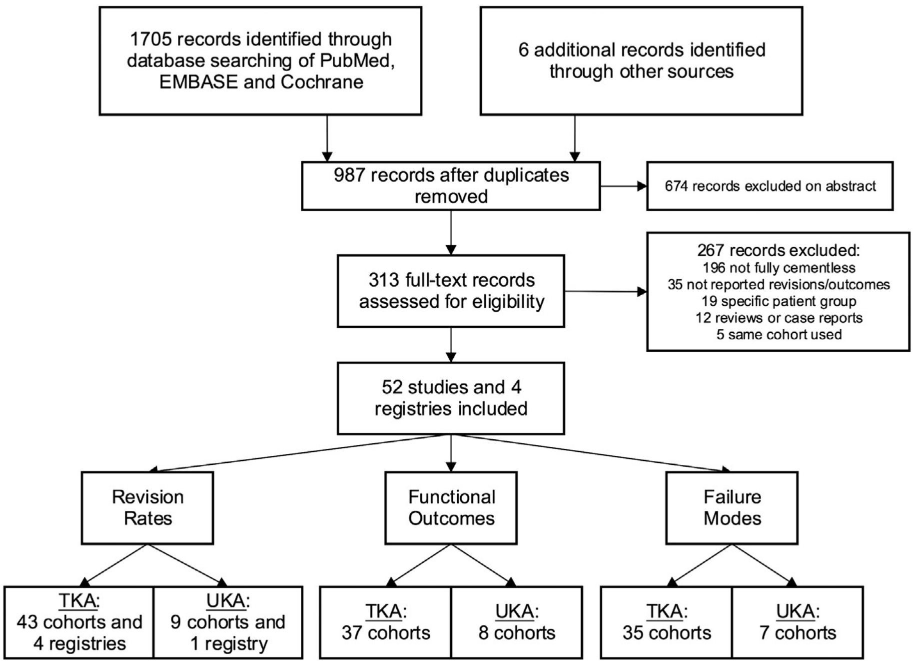

Figure 1. Flowchart of the study is shown.

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titanium TKA designs [27,28,30,33,34,37,39,43–46,53,61,63,65,66,68–72,75], while eight studies used hydroxyapatite (HA) coating [17,29,32,35,36,50,55,74], three studies used both porous titanium with HA coating [48,57,58], seven studies used trabecular metal [38,40,41,52,56,62,73] and three studies did not specify the cementless fixation method [47,51,64]. For UKA, five studies used a combination of porous titanium and HA coating [7,26,49,59,60], two studies only used HA [42,54], and two studies did not specify the use or used multiple different designs [31,67]. Thirty-seven cohort studies reported functional outcomes following cementless TKA [17,27,28,30,32–36,38–41,43–48,50,51,53,55,57,58,61–65,68,69,71–75], while eight studies reported functional outcomes following cementless UKA [7,26,31,42,49,59,60,67]. Thirty-five cohort studies reported failure modes of cementless TKA [17,27–30,32,34–36,39–41,43–48,52,53,55–58,61–63,66,68–70,72–75] and seven cohort studies reported failure modes of cementless UKA [7,26,42,49,54,60,67].

3.2. Methodological quality of studies

Nine studies were level I studies [17,29,33,38,40,41,59,62,66], six studies were level II [43,47,53,55,58,75], three studies were level III [26,51,63] and 34 studies were level IV studies [7,27,28,30–32,34–37,39,42,44–46,48–50,52,54,56,57,60,61,64,65,67–74]. The methodological quality of randomized clinical trials scored 8.0 out of 11 points (range: five to 10), which corresponds to 73% of the maximum score. Logically, none of the studies had blinding of the surgeon for the type of implant and excluding this question would result in 80% of maximum score. For comparative studies, methodological quality of studies scored 18.7 out of 24 points (range: 16 to 22), which corresponds to 78% of the maximum score. For non-comparative studies, methodological quality scored 10.3 out of 16 points (range: seven to 12), corresponding to 65% of the maximum score.

3.3. Revision rates

Revision rates of all individual UKA and TKA cohort studies with the length of follow-up are displayed in Figure 2. ARR of all individual studies are displayed in Figure 3 with the length of follow-up. No correlation between ARR and follow-up time was noted for TKA ($p = 0.407$) or UKA ($p = 0.864$).

In cohort studies, a total of 10,309 cementless TKA procedures were reported with a mean age of 67 years and 37% males. In this group, 318 failures were reported, yielding a revision rate of 3.1% at 6.6-year follow-up and an ARR of 0.46% per year. This ARR corresponds to an extrapolated five-, 10- and 15-year survivorship of cementless TKAs of 97.7%, 95.4% and 93.0%, respectively. In registries, a total of 4576 failures were reported in 128,979 cementless TKA procedures, yielding a revision rate of 3.5% at 4.1-year follow-up and an ARR of 0.87% per year, which corresponds to an extrapolated five-, 10- and 15-year survivorship of 95.7%, 91.3% and 87.0%, respectively (Table 1 and Figure 4).

For UKA, a total of 2218 cementless UKA procedures were reported with a mean age of 66 years and 53% males. In this group, 62 failures were reported, yielding a revision rate of 2.9% at 4.1-year follow-up and an ARR of 0.71% per year, which corresponds to an extrapolated five-, 10- and 15-year survivorship of 96.4%, 92.9% and 89.3%, respectively. In the registry of New Zealand, an ARR of 0.67% per year was reported in 1970 UKA procedures, yielding a revision rate of 2.2% at 3.2-year follow-up and an extrapolated five-, 10- and 15-year survivorship of 96.6%, 93.3% and 89.9%, respectively (Table 1 and Figure 4).

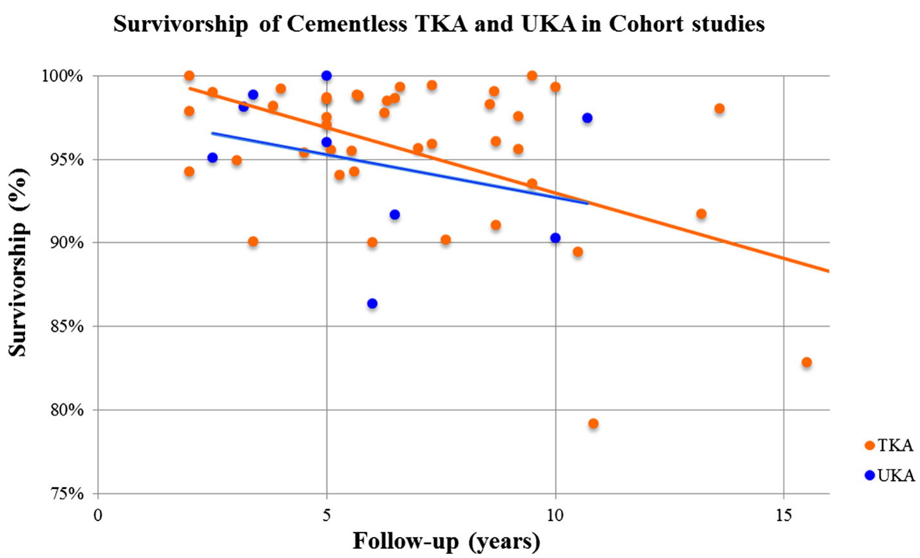

Figure 2. This graph shows the survivorship of UKA and TKA as was found in the individual studies with trendlines.

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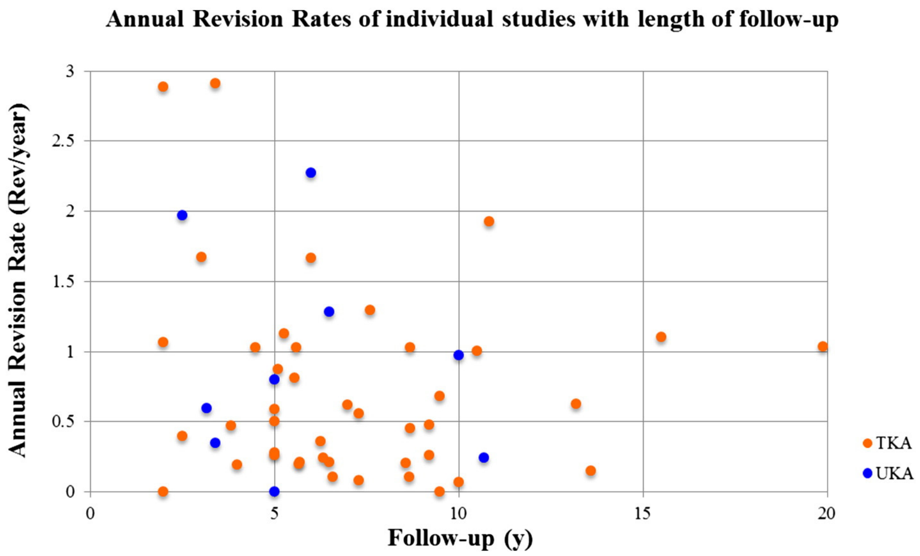

Figure 3. Annual revision rates of the individual studies are shown with length of follow-up of these studies. It can be noted that no correlation between the annual revision rate and length of follow-up was seen.

3.4. Cementless fixation methods

For TKA, majority of patients received porous titanium TKA (4789 patients) or HA-coated TKA (3943 patients). ARR for porous titanium TKA was 0.48 with extrapolated five-, 10- and 15-year survivorship of 97.6%, 95.2% and 92.7%, while ARR for HA-coated TKA was 0.35 with extrapolated five-, 10- and 15-year survivorship of 98.2%, 96.5% and 94.7%. However, number of patients with porous titanium plus HA, and trabecular metal were small (Table 2).

For UKA, a total of 1814 patients received UKA with porous titanium and a HA coating, of which 37 patients failed, yielding an ARR of 0.60 and an extrapolated survivorship at five-, 10- and 15-year of 97.0%, 94.0% and 90.9%. Although the ARR was lower compared to only HA coating (1.13), the number of patients in this group was too low for comparison (Table 2).

3.5. Failure modes

Failure modes of cementless TKA were reported for 244 cases and most common failure modes were aseptic loosening (25%), infection (16%) and instability (nine percent). Most common failure modes for cementless UKA in 56 cases were progression of OA (32%), bearing dislocation (25%) and aseptic loosening (13%) (Table 3).

3.6. Functional outcomes

Functional outcome scores were reported in 2008 patients who underwent cementless UKA and 8603 patients who underwent cementless TKA. Overall percentage of maximum score for all patients undergoing cementless UKA and TKA was equivalent (84.3% and 84.5%, respectively). It was further noted that the KSS Function score was higher following UKA (86.9%) when compared to TKA (80.5%) (Table 4 and Figure 5).

4. Discussion

The main findings of this study were that the extrapolated five-, 10- and 15-year survivorship of cementless TKAs in cohort studies were 97.7%, 95.4% and 93.0%, respectively, while these were 96.4%, 92.9% and 89.3% for cementless UKA, respectively.

Table 1
Annual revision rates and survivorship of cementless UKA and TKA, stratified by cohort studies and registries.

Type	Source	Studies (n)	Knees (n)	Failed (n)	Mean FU (y)	OCY (y)	ARR	Range	Extrapolated survivorship		
									5 years	10 years	15 years
UKA	Cohorts	9	2128	62	4.1	8724	0.71	0.00–2.29	96.4%	92.9%	89.3%
	Registries	1	1970	43	3.2	6400	0.67		96.6%	93.3%	89.9%
TKA	Cohorts	43	10,309	318	6.6	68,408	0.46	0.00–2.91	97.7%	95.4%	93.0%
	Registries	4	128,979	4576	4.1	527,641	0.87	0.65–0.91	95.7%	91.3%	87.0%

UKA indicates unicompartmental knee arthroplasty; TKA, total knee arthroplasty; OCY, observed component years; ARR, annual revision rates.

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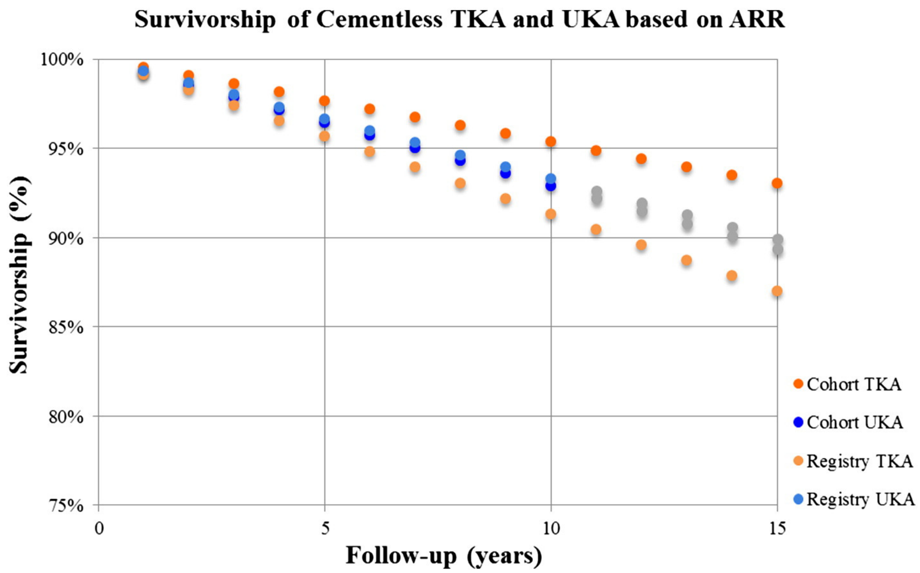

Figure 4. Extrapolated survivorship of UKA and TKA in cohort studies and registries are shown. Extrapolated survivorship is based on the annual revision rates in the studies and registries.

Most common failure modes were aseptic loosening (25%), infection (16%) and instability (nine percent) for cementless TKA and were OA progression (32%), bearing dislocation (25%) and aseptic loosening (13%) for cementless UKA. Finally, functional outcomes of cementless TKA and UKA were equivalent to 84.3% and 84.5% of the maximum possible scores, respectively. KSS Function score was higher following uncemented UKA than TKA (86.9% vs. 80.7%).

In this systematic review, excellent survivorship of cementless TKA and UKA at five-, 10- and 15-year follow-ups was noted. To our knowledge, one systematic review has also assessed survivorship of cementless TKA. Mont et al. found 10-year survivorship of cementless TKA of 95.6%, which is similar to the survivorship of this current study (95.4%) [5]. This study furthermore concluded that the 20-year survivorship of cementless TKA was 76%, although this was based on one study that performed TKA surgery between 1984 and 1986 and had 20-year follow-up of 24 patients [65]. In this current study, ARR was used to assess revision rates of cementless UKA and TKA. Given the fact that no correlation between length of follow-up and ARR was seen up to 15 years follow-up (Figure 3), it was possible to use this method for extrapolating the data to this length of follow-up. This not only made it possible to base this extrapolated survivorship on revision data of 10,000 knees rather than one study, but also to only include more recent studies and thus provide a more up to date overview of cementless survivorship of prosthesis that are used these days.

In our results, it was noted that TKA survivorship in cohort studies was higher than registry studies. This can be explained by the fact that most cohort studies are high-volume centers whereas registries contain both high and low volume centers. As several studies have shown that better outcomes and lesser complications are seen in high-volume centers [77–79], it is often expected that cohort studies report higher survivorship than registries. Another explanation is that publication bias can be present in cohort studies, which is less likely in registries [23]. For UKA, survivorship in cohort studies and the registry were nearly equivalent, which can be explained by the fact that only one registry could be included in this study.

Table 2
Annual revision rates and survivorship of cementless UKA and TKA in cohort studies, stratified by type of cementless fixation.

Type	Cementless fixation method	Studies (n)	Knees (n)	Failed (n)	Mean FU (y)	OCY (y)	ARR	Range	Extrapolated survivorship		
									5 yrs	10 yrs	15 yrs
UKA	Porous titanium with HA	5	1814	37	3.4	6126	0.60	0.00–1.97	97.0%	94.0%	90.9%
	HA coating	2	192	17	7.8	1500	1.13	0.97–1.28	94.3%	88.7%	83.0%
	Unspecified/various	2	122	8	9.0	1099	0.73	0.24–2.27	96.4%	93.4%	89.1%
TKA	Porous titanium	22	4789	153	6.6	31,596	0.48	0.00–2.88	97.6%	95.2%	92.7%
	HA coating	8	3943	92	6.6	26,011	0.35	0.11–1.03	98.2%	96.5%	94.7%
	Porous titanium with HA	3	291	26	7.9	2292	1.13	1.00–1.29	94.3%	88.7%	83.0%
	Trabecular metal	7	520	23	5.4	2819	0.82	0.00–2.91	95.9%	91.8%	87.8%
	Unspecified/various	3	766	24	7.4	5689	0.42	0.26–1.68	97.9%	95.8%	93.7%

UKA indicates unicompartmental knee arthroplasty; TKA, total knee arthroplasty; OCY, observed component years; ARR, annual revision rates; HA, hydroxyapatite coating; yrs., years.

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Table 3
Failure modes in cementless UKA and TKA.

Failure mode	TKA N = 244	UKA N = 56
Aseptic loosening	25%	13%
Infection	16%	7%
Instability	11%	0%
Polyethylene wear	9%	2%
Periprosthetic fracture	7%	9%
Tibial subsidence	7%	0%
Malpositioning	6%	0%
Patellar problems[a]	5%	0%
Pain	3%	5%
Bearing fracture	3%	7%
Bearing dislocation	2%	25%
OA progression	0%	32%
Other[b]	6%	0%
Total	100%	100%

UKA indicates unicompartmental knee arthroplasty; TKA, total knee arthroplasty; OA, osteoarthritis.
[a] Indicates patellar resurfacing and patellar button revisions.
[b] Other causes include arthrofibrosis, stiffness, other and unknown causes.

TKA survivorship is known to be higher when compared to UKA survivorship. This is often contributed to the possibility of OA progression in UKA, the lower surgical threshold for revision in UKA and the relatively surgical inexperience with UKA [7,9,80]. Interestingly, however, New Zealand registry data showed that ARR following UKA was lower compared to TKA (0.67 vs. 0.82) [4]. Liddle et al. have suggested that cementless designs may be more beneficial for UKA than for TKA [7]. They stated that UKA aims to restore normal ligament tension with minimal implant constraint and thus aims to restore the normal ligament-driven kinematics of the knee. Because the ligaments remain intact with UKA, they state that all the force on the components remain compressive, which is thought to be ideal for cementless fixation [7]. With TKA, however, the soft tissues and most ligaments are removed, which requires a constrained tibiofemoral articulation and this may lead to shear forces at the bone–implant interface and subsequent failure [7]. The authors suggested in this study that cementless designs could therefore be more beneficial in UKA in comparison to TKA.

When comparing survivorship of cementless TKA and UKA in this study with studies reporting survivorship of cemented TKA and UKA in the literature, it might indeed be suggested that UKA could benefit more from cementless designs than TKA. Mont et al. compared survivorship of cemented and cementless TKA in cohort studies and indeed found no differences between cemented (95.3%) and cementless (95.6%) TKA survivorship [5]. When comparing the extrapolated survivorship of cementless UKA in this current study (92.9%) with a recent systematic review of cemented medial UKA (91.7%) in cohort studies with 47,256 patients [6], however, it seems that there may be a benefit for cementless designs in UKA. However, because this survivorship is extrapolated and because it is difficult to compare outcomes of two different studies, it is not possible to draw strong conclusions. Therefore, more studies are necessary to confirm the observations made in the New Zealand registry and in these systematic reviews, and to confirm if the suggested differences made by Liddle et al. [7] in kinematics will result in more benefit of cementless designs in UKA.

Table 4
Percentage of maximum scores of different patient-reported outcome scores are displayed at different follow-up intervals.

FU (y)	UKA studies	No. of knees	KSSC	KSSF	Oxford	HSS	WOMAC	UKA total	TKA studies	No. of knees	KSSC	KSSF	Oxford	HSS	WOMAC	TKA total
2									[38,41,43]	127	92.3	92.0	89.6	89.0	87.8	90.1
3	[26,60,94]	1634	84.3	86.1	85.8			**85.5**	[47,69]	297	95.0	82.0				**88.5**
4									[34,46]	1190		85.0		82.0		83.5
5	[49,59]	180	78.8	92.0	85.2			**85.3**	[17,32,40,57,64,73]	556	86.5	81.9		83.9	80.3	**83.6**
6	[31]	44				76.8		**76.8**	[35,53,61,63,68]	738	87.6	79.9				**84.2**
7									[55]	342	87.7	93.2				**90.4**
8									[48]	112				84.0		84.0
9									[27,28,44,51,74]	900	89.4	76.7		90.1		84.8
10	[42]	72			79.9		72.2	**75.7**	[33,36,39,50,71,95]	3799	90.1	83.0		91.8	72.1	**85.6**
11	[67]	78	98.0	83.4				**90.7**	[45,58]	143	87.2	63.6				**75.4**
13									[30]	206	89.0	80.0				84.5
14									[62]	50	97.7	88.1			62.9	82.9
>15									[65,72]	143	91.0	76.3	78.0			81.8
Total (%)		2008	86.4	86.9	84.5	76.8	72.2	84.3	Total (%)	8603	89.2	80.5	83.8	87.3	76.7	84.5

FU (y) indicates follow-up in years; KSSC, Knee Society Clinical Score; KSSF, Knee Society Functional Score; HSS, Hospital for Special Surgery Score; WOMAC, Western Ontario and McMaster Universities Arthritis Index; Mn., mean.

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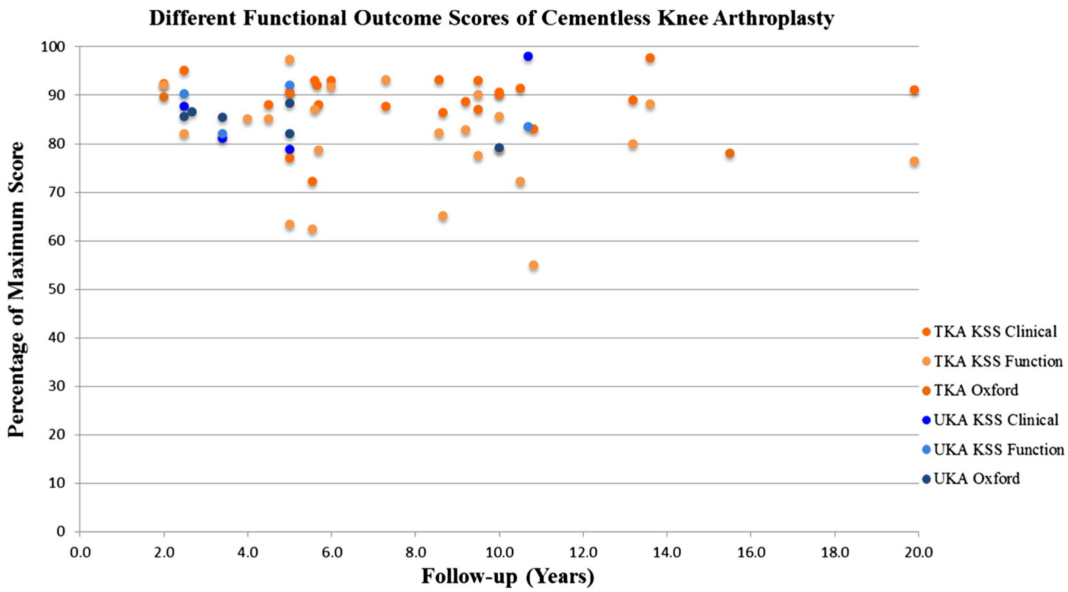

Figure 5. The functional outcome scores of the most commonly used outcome measurements are shown for UKA and TKA. Scores were converted to the percentage of the maximum score.

Reviewing the outcomes of different types of cementless fixation, it was noted that most studies used porous titanium with HA coating for UKA implants. However, as the number of patients treated with HA coating was not large enough for comparison between different fixation groups, it can only be stated that the results in the porous titanium with HA were good with an ARR of 0.60. For TKA, however, many patients were treated with either porous titanium (4789 patients) or HA coating (3943 patients) in cohort studies. Interestingly, it was noted that patients treated with HA coating had lower ARR when compared to porous titanium. Only two randomized trials have been performed comparing HA versus no HA coating and titanium versus non-titanium TKA [81,82]. Pijls et al. compared component migration in HA-coated versus non-HA-coated TKA [81]. They found that at 10-year follow-up mean migration for HA-coated TKA was 1.66 mm and for non-HA-coated TKA 2.25 mm, and concluded that HA reduced migration of cementless TKA. On the other hand, van Hove et al. compared titanium with non-titanium coating at five-year follow-up and they did not find any differences in revision rates, outcomes, or pain between both designs [82]. Although there are only two randomized studies, these findings may explain the difference in ARR between titanium porous TKA and HA TKA. However, more studies are clearly needed to further explore the differences in ARR between HA-coating and porous titanium TKA.

One of the reasons for using cementless designs is the high incidence of aseptic loosening in cemented UKA [9] and TKA [8] at the implant–cement or cement–bone interface [83]. When comparing failure modes of UKA and TKA in the literature with the failure modes in this current study, some differences can be noted. In this current study, modes of failure of cementless TKA were aseptic loosening (25%), infection (16%) and instability (nine percent), which is similar to recently reported failure modes of cemented TKA with aseptic loosening (31%), infection (19%) and instability (16%) [8]. For UKA, however, most common failure modes in this current study were progression of OA (32%), bearing dislocation (25%) and aseptic loosening (13%), while these have reported to be aseptic loosening (36%), OA progression (20%) and pain (11%) in predominantly cemented UKA procedures [9]. Intuitively, OA progression should not be different in cementless and cemented designs, since this is thought to be caused by inappropriate patient selection and postoperative malalignment [9,84,85], while aseptic loosening can be influenced by prosthesis design and fixation method [8,9,83]. Reviewing these numbers, it seems that with cementless designs there is relatively less aseptic loosening when compared to cemented designs in UKA [9], which could also be explained by the kinematic difference between UKA and TKA. Furthermore, OA progression as most common failure mode indicates that further improvement in cementless UKA survivorship could be expected with further improving patient selection and more strict control of postoperative lower leg alignment [84,86,87], possibly using navigation or robotic assistance [88–90]. Although it is difficult to compare the outcomes of this study with findings in the literature due to different methods and surgical techniques, the findings in our study and the literature suggest that there are differences in failure modes in cementless and cemented UKA. Future comparative studies are therefore needed to further assess these differences.

Reviewing the functional outcomes following cementless UKA and TKA, it can be concluded that excellent outcomes are reported for both procedures. A difference in percentage of maximum score was noted for KSS Function score, which was higher following UKA procedures. Although several studies have compared functional outcomes of UKA and TKA, no studies, to the best of our knowledge, have compared cementless UKA and TKA. Therefore, it is only possible to compare these findings with cemented studies [91–93]. Manzotti et al. compared KSS scores in UKA and TKA patients at four-year follow-up in a matched-cohort and found similar findings as in our study [92]. While preoperatively no differences existed between both cohorts, they found equivalent KSS Clinical scores but superior KSS Function scores in the UKA group. Similarly, Lyons et al. performed a

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database comparison between 5606 TKA procedures and 279 UKA procedures at seven-year follow-up [91]. They also noted equivalent KSS Clinical scores but superior KSS Function scores in the UKA group when compared to the TKA group. Finally, Zuiderbaan et al. assessed joint awareness during activities following UKA and TKA and also noted less joint awareness during activities in UKA compared to TKA [93]. Despite these small differences in KSS Function between UKA and TKA, excellent functional outcomes are reported following both arthroplasty treatments with 84% of the maximum score in more than 2000 patients in each cohort.

To the best of our knowledge, this is the first systematic review that reported survivorship, annual revision rates, failure modes and functional outcomes of cementless TKA and UKA. Furthermore, this is the first study that only used recently published studies and therefore aimed to give an up to date status of cementless knee arthroplasties. Limitations are, however, also present in this study. First of all, this is a systematic review with pooled analysis and this study is therefore limited by the quality of included studies. Many studies were level IV evidence studies and since no studies directly compared cementless TKA with cementless UKA, no statistical comparison between both could be performed. The main goal of this study, however, was to give an overview of modern-day cementless UKA and TKA outcomes rather than comparing these. Secondly, long-term survivorship outcomes can only be extrapolated since long-term outcome studies of more modern cementless designs are lacking. In this study ARR was used to extrapolate long-term outcomes up to 15 years since several studies reported outcomes to this follow-up interval [62,65,72], but further extrapolation to 20 years was not performed. Using ARR for extrapolation has the advantage of including all recent studies with modern implant designs for analysis, as opposed to drawing conclusions of long-term outcomes on one or two studies that performed knee replacement procedures in the 1980s and early 1990s [5,65]. Finally, the number of UKA patients and failures in the cohort studies was small. As the registry of New Zealand has shown, registries can have an important role in reporting outcomes of less commonly performed procedures, such as UKA. Future registries should report UKA outcomes and stratify the outcomes by cemented and cementless designs.

In conclusion, this systematic review showed that the extrapolated five-, 10- and 15-year survivorship of cementless TKAs were 97.7%, 95.4% and 93.0%, respectively, and for cementless UKA 96.4%, 92.9% and 89.3%, respectively, and that overall functional outcomes for both procedures were excellent with 84% of the maximum score. Differences in failure modes were observed between both procedures with aseptic loosening being the most common failure mode in cementless TKA (25%), while OA progression (32%) was more common than aseptic loosening (13%) in cementless UKA.

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