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Comparable mid-term revision rates of primary cemented and cementless total knee arthroplasties in 201,211 cases in the Dutch Arthroplasty Register (2007–2017)

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Abstract

Purpose Long-term failure of total knee arthroplasty (TKA) is mostly due to loosening of the prosthesis. In this study, the short- and mid-term revision rates of cemented vs cementless TKAs were investigated. Comparable short- and mid-term survival rates of both fixation methods were expected.

Methods Data on all cemented and cementless TKAs performed between 2007 and 2017 were retrieved from the Dutch Arthroplasty Register. The cumulative crude incidence of revision of cemented and cementless TKA was calculated. Death was considered a competing risk. Revision rates were compared using multivariable Cox proportional hazard regression analysis. The associations between fixation method and type of revision or reason for revision were tested using logistic regression analyses.

Results In total, 190,651 (94.8%) cemented and 10,560 (5.3%) cementless TKAs were evaluated. Both groups had comparable case characteristics. Cemented TKAs were inserted more often in cases with previous knee surgery compared to cementless TKAs (32% vs 27%). The cumulative incidence of revision after 9 years was 5.5% (CI 5.3–5.6%) for cemented and 5.8% (CI 5.2–6.4%) for cementless TKAs ($p = 0.2$). Cementless TKAs were more often revised due to loosening of the tibial (27% vs 18%; $p < 0.001$) or the femoral component (7% vs 5%; $p = 0.005$) than cemented TKAs. Cemented TKAs were more often revised due to infection (17% vs 9%; $p = 0.004$) than cementless TKAs.

Conclusion In conclusion, cemented and cementless TKAs have comparable short- and mid-term revision rates based on a nationwide register study.

Level of evidence III.

Keywords Total knee arthroplasty (TKA) · Total knee replacement · Cementation · Survival · Revision surgery

Introduction

Total knee arthroplasty (TKA) is performed in large numbers in the Netherlands; over 24,000 TKAs are placed annually, with the large majority (95%) being cemented [9]. Cemented TKA has the advantage of immediate stability of the implant and less chance of periprosthetic fractures [13]. Cementless fixation has the disadvantage of an increased risk for early migration of the prosthesis, especially migration of the tibial component in patients with osteoarthritis [2, 12]. However, cementless fixation has multiple theoretical advantages over cemented fixation, such as lower risk of embolism, better bone stock, shorter operation time and absence of cement debris [11, 12]. Furthermore, Carlsson et al. stated that cementless implants seem to settle firmly

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over time, whereas the cemented implants might continuously migrate [2].

Although cementless TKA shows more early migration than cemented TKA, previous studies have shown that after short-term follow-up, no significant differences in revision rates were found between cemented and cementless TKA in the general population with primary TKA [3, 18]. Also, a recent meta-analysis showed that there are no differences in mid-term implant survivorship and clinical outcomes between cementless and cemented fixation in primary TKA [22]. Although these studies show that short- and mid-term survival rates of both fixation methods are comparable, none of these studies used national register data, which makes the results of these studies less reliable. Moreover, the survival of cementless and cemented TKA in specific patient groups and differences in reason of revisions between both fixation methods remain unknown.

The aim of this study is to determine the short- and mid-term revision rate of cemented TKA compared to cementless TKA based on data from the population-based Dutch Arthroplasty Register (LROI). In addition, this study aims to compare the number of revisions (stratified by osteoarthritis (OA) vs non-OA, age and ASA-score), type of revision and reasons for revision between cemented and cementless fixation. This will help surgeons to make a well-informed decision. The first hypothesis is that short- and mid-term survival rates of cementless TKA and cemented TKA are comparable, both in OA and non-OA patients. The second hypothesis is that the reasons for revision and the types of revision differ between cementless and cemented TKA, namely more revisions due to loosening of the tibial component and more partial revisions are expected in cementless TKA than in cemented TKA.

Materials and methods

The Dutch arthroplasty register

The Dutch Arthroplasty Register is a nationwide population-based register, initiated by the Dutch Orthopedic Association (NOV), which contains information on joint arthroplasties performed in the Netherlands since 2007. In 2013, the completeness of primary TKA registration was 96% [19], which improved to 99% in more recent years [9].

Data collection

Patient characteristics and surgical details of all cemented and cementless primary TKA procedures registered in the Dutch Arthroplasty Register and performed between 2007 and 2017 were included ($n = 201{,}211$). Hybrid prostheses ($n = 10{,}986$) were excluded, as in the Netherlands hybrid prostheses are frequently used in patients with different patient characteristics than cemented and cementless prostheses. The overall mean age was 68.5 years with a standard deviation of 9.4 years. Sixty-five percent of all cases was female. The overall mean body mass index (BMI) was 29.7 kg/m^2 with a standard deviation of 5.1 kg/m^2. The overall physical condition was scored using the ASA score (I–IV). The ASA score was in 67.2 percent ASA II, 17.9 percent ASA I and in 14.9 percent ASA III.

Primary TKA was defined as the first implantation of a total knee prosthesis to replace the original joint. Knee revision arthroplasty was defined as any change (insertion, replacement or removal) of one or more components of the primary prosthesis. Revision procedures were categorized into major revision (revision of at least the femoral or tibial component) and minor revision (patella and/or insert revision only) [15]. The category "any type of revision" was reserved for combinations of major revisions and/or minor revisions, unknown types of revision and addition of the patella component. Addition of the patella component was evaluated separately. The moment of death of the deceased patients was obtained from Vektis, a national insurance database which records the vital status of all Dutch citizens [20].

Statistical data analysis

All statistical analyses were performed using SPSS version 24.0 (IBM Corp, Armonk, NY, USA). p values below 0.05 were considered statistically significant. In case of multiple testing, a Bonferroni correction was applied to avoid type I errors.

Case characteristics were stratified for cemented and cementless TKA. Continuous variables with Gaussian distribution are presented as mean and standard deviation (SD), otherwise as median and interquartile range (IQR) or number and percentage.

Survival time was calculated as the time from primary TKA to first revision arthroplasty for any reason, to the death of the patient, or to the end of the study follow-up (January 1, 2018). For the short-term (i.e. 3 years) and mid-term analyses (i.e. 9 years), all-cause cumulative crude incidence of revision of cemented and cementless TKA was calculated, where death was considered to be a competing risk [8, 21]. The median follow-up was 3.9 years (IQR: 1.9–6.4 years).

Adjusted revision rates of cemented and cementless TKA were compared using multivariable Cox proportional hazard regression analysis. Revision rates were adjusted for the confounders age at surgery, gender, ASA score, previous surgery and diagnosis at primary TKA [OA vs non-OA (i.e. rheumatoid arthritis (RA), posttraumatic, osteonecrosis, inflammatory arthritis, tumour (primary) and tumour (metastasis)]. BMI, Charnley score and smoking status were excluded from analysis because they have only been

registered since 2014. For all covariates added to the model, the proportional hazards assumption was inspected using log-minus-log curves.

Cases were stratified by diagnosis at primary TKA (OA vs non-OA) or age and ASA score to compare the numbers of revisions between patient groups. To test the association between the fixation method and the number of revisions stratified into major and minor revision in each group, logistic regression analyses were used.

The association between fixation method of TKA and type of revision was tested using logistic regression analyses. The association between fixation method and reasons for revision was also tested using logistic regression analyses and stratified into major and minor revisions. Each revision could have more than one selected reason.

Ethics, data sharing plan, funding and potential conflicts of interest

The data were registered confidentially with patient consent and in accordance with Dutch and EU data protection rules. Data were made accessible by application to the LROI. All available data were anonymous. This research received no specific grant from any funding agency. The authors have no conflicts of interest to declare.

Results

Case characteristics

A total of 201,211 TKAs were included, 94.8% of which ($n = 190{,}651$) were cemented and 5.2% ($n = 10{,}560$) were cementless. Cementless fixation was used in 64 of the 102 hospitals in the Netherlands registered in the Dutch Arthroplasty Register. Case characteristics and surgical details are presented in Table 1. BMI, Charnley score and smoking status were missing for 109,284 patients (54.3%). In the cemented group, the percentage of patients who had undergone previous knee surgery was higher than in the cementless group (30.8% vs 25.2%). In addition, the percentage of patients who received a patella component was higher in the cemented group than in the cementless group (22.1% vs 2.3%).

Table 1 Case characteristics and surgical details of all cases who underwent cemented or cementless TKA ($n = 201{,}211$)

	Cemented TKA ($n = 190{,}651$)	Cementless TKA ($n = 10{,}560$)
Age, years [mean (SD)]	68.5 (9.4)	68.4 (9.8)
Gender [*n* (%)]		
Female	124,985 (66.6)	6887 (65.2)
Side [*n* (%)]		
Left	89,968 (47.2)	4962 (47.0)
BMI, kg/m^2* [mean (SD)]	29.7 (5.1)	29.5 (4.9)
ASA score [*n* (%)]		
ASA I	33,105 (17.9)	1835 (18.0)
ASA II	123,957 (67.1)	7052 (69.2)
ASA III/IV	27,650 (15.0)	1306 (12.8)
Charnley score* [*n* (%)]		
A	37,622 (42.6)	1649 (46.0)
B1	30,271 (34.3)	1064 (29.7)
B2	17,710 (20.0)	726 (20.2)
C	2737 (3.1)	148 (4.1)
Smoking* [*n* (%)]		
Yes	7868 (9.4)	355 (10.2)
Diagnosis [*n* (%)]		
Osteoarthitis	181,549 (96.3)	10,084 (96.0)
Rheumatoid arthritis	2884 (1.5)	234 (2.2)
Other[a]	3801 (2.2)	157 (1.8)
Previous surgery[b] [*n* (%)]		
Yes	58,649 (30.8)	2662 (25.2)
Approach [*n* (%)]		
Medial parapatellar	177,773 (94.4)	10,049 (96.6)
Vastus (mid/sub)	8331 (4.4)	113 (1.1)
Lateral parapatellar	2321 (1.2)	239 (2.3)
Patella component [*n* (%)]		
Yes	40,870 (22.1)	235 (2.3)

Numbers do not add up to total due to missing values

TKA total knee arthroplasty, *BMI* body mass index

*Not registered before 2014

[a]Includes posttraumatic, osteonecrosis, inflammatory arthritis, tumour (primary) and tumour (metastasis)

[b]Includes meniscectomy, arthroscopy, osteotomy, osteosynthesis, ligament reconstruction, synovectomy and other previous surgery

Revision rates

Figure 1 shows the cumulative incidence of revision in TKA stratified by fixation technique. The cumulative incidence of revision within 3 years was 3.4% (CI 3.3–3.5%) for the cemented group and 3.7% (CI 3.3–4.1%) for the cementless group. Within 9 years, 5.5% (CI 5.3–5.6%) of the cemented TKAs and 5.8% (CI 5.2–6.4%) of the cementless TKAs were revised. In the crude model as well as after adjustments, this difference was not statistically significant (Table 2).

In both the OA and the non-OA group, cases with a cementless primary TKA were more likely to undergo a major revision than cases with a cemented TKA [OR 1.4 (CI 1.2–1.6; $p = 0.001$) and OR 1.8 (CI 1.1–2.9; $p = 0.015$), respectively, Table 3]. Also, in the group of 60 to 69 years old with an ASA score of I or II, cases with a cementless TKA were more likely to undergo a major revision than

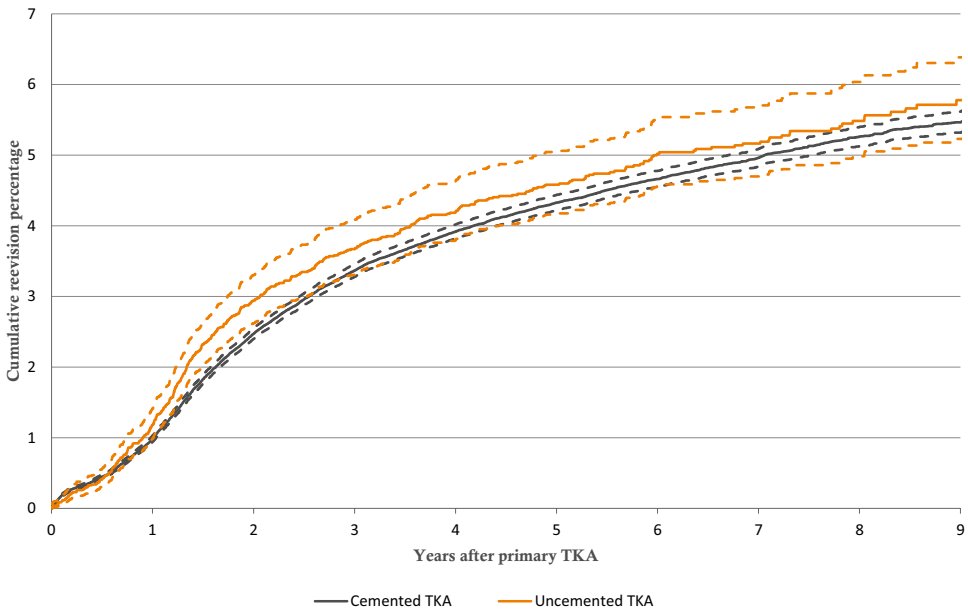

Fig. 1 Cumulative incidence of revision of cemented ($n=190,651$) and cementless ($n=10,560$) TKAs ($n=201,211$). TKA: total knee arthroplasty. Dotted lines represent the 95% confidence interval

Table 2 Crude and multivariable survival analyses of cemented and cementless TKAs ($n=201,211$)

	Revised (n)/total (n)	Follow-up, years [median (IQR)]	3-Year cumulative incidence of revision (%)	9-Year cumulative incidence of revision (%)	Crude model HR (95% CI)	Adjusted model* HR (95% CI)
Cemented TKA	6903/190,651	3.85 (1.84–6.29)	3.4	5.5	1.0	1.0
Cementless TKA	453/10,560	5.03 (2.28–7.37)	3.7	5.8	1.07 (0.97–1.18)	1.06 (0.96–1.17)

TKA total knee arthroplasty, *IQR* interquartile range, *HR* hazard ratio, *CI* confidence interval

*Adjusted for age, gender, ASA score, diagnosis (osteoarthritis or non-osteoarthritis) and previous operations to the affected knee

Table 3 Number of revisions in cemented and cementless TKAs stratified by diagnosis

	Cemented TKA		Cementless TKA		OR (95% CI)	p value
	n	Revisions [n (%)]	n	Revisions [n (%)]		
Minor[a]						
OA	181,549	1780 (1.0)	10,084	103 (1.0)	1.04 (0.85–1.27)	0.69
Non-OA	9102	128 (1.4)	476	10 (2.1)	1.50 (0.79–2.88)	0.22
Major[b]						
OA	181,549	3141 (1.7)	10,084	243 (2.4)	1.40 (1.23–1.60)	0.001
Non-OA	9102	204 (2.2)	476	19 (4.0)	1.81 (1.12–2.93)	0.015

[a]Only insert and/or patella exchange (excluding patella addition)

[b]Partial revision (at least revision tibia or femur), total revision or removal prosthesis (incl. spacer)

cases with a cemented TKA [OR 1.3 (CI 1.1–1.6; $p=0.002$); Table 4].

Revision characteristics

Nine years after surgery, 6903 (3.6%) of the cemented TKAs and 453 (4.3%) of the cementless TKAs were revised. More partial revisions (i.e. revision of at least the tibial or femoral component) were performed in cementless TKAs than in cemented TKAs [25.4% vs 14.9%; OR 2.1 (CI 1.7–2.5), $p<0.001$]. More total revisions were performed in cementless TKAs than in cemented TKAs, namely 30.3% and 29.2%, respectively [OR 1.3 (CI 1.0–1.5), $p=0.01$; Table 5].

The three most common reasons for a minor revision in cemented and cementless TKA were instability, infection and patellar pain. The numbers of revisions due to instability, infection or patellar pain did not differ significantly between cemented and cementless TKA after Bonferroni

Table 4 Number of revisions in cemented and cementless TKAs stratified by age and ASA score

	Cemented TKA		Cementless TKA		OR (95% CI)	*p* value
	n	Revisions [*n* (%)]	*n*	Revisions [*n* (%)]		
Minor[a]						
ASA I–II						
< 60 years	29,733	586 (2.0)	1773	38 (2.1)	0.97 (0.70–1.35)	0.88
60–69 years	90,392	793 (0.9)	4942	47 (1.0)	0.99 (0.74–1.34)	0.99
≥ 70 years	42,626	249 (0.6)	2528	14 (0.6)	0.89 (0.52–1.54)	0.70
ASA III–IV						
< 60 years	3007	51 (1.7)	140	3 (2.1)	1.16 (0.36–3.72)	0.80
60–69 years	13,520	152 (1.1)	612	9 (1.5)	1.24 (0.63–2.44)	0.52
≥ 70 years	11,068	75 (0.7)	549	2 (0.4)	0.52 (0.12–2.11)	0.35
Major[b]						
ASA I-II						
< 60 years	29,733	926 (3.1)	1773	65 (3.7)	1.01 (0.78–1.30)	0.93
60–69 years	90,392	1552 (1.7)	4942	126 (2.5)	1.32 (1.10–1.58)	0.002
≥ 70 years	42,626	436 (1.0)	2528	35 (1.4)	1.26 (0.89–1.78)	0.18
ASA III–IV						
< 60 years	3007	80 (2.7)	140	7 (5.0)	1.65 (0.76–3.58)	0.20
60–69 years	13,520	261 (1.9)	612	19 (3.1)	1.46 (0.91–2.33)	0.11
≥ 70 years	11,068	85 (0.8)	549	8 (1.5)	1.83 (0.88–3.78)	0.10

p values < 0.004 were considered statistically significant after Bonferroni correction

[a]Only insert and/or patella exchange (excluding patella addition)

[b]Partial revision (at least revision tibia or femur), total revision or removal prosthesis (incl. spacer)

Table 5 Type of revision of cemented and cementless TKAs (*n* = 7356)

	Cemented TKA (*n* = 6903) [*n* (%)]	Cementless TKA (*n* = 453) [*n* (%)]	OR (95% CI)	*p* value
Total revision	1970 (29.2)	136 (30.3)	1.25 (1.05–1.49)	0.012
Removal prosthesis (incl. spacer)	367 (5.4)	12 (2.7)	0.59 (0.33–1.05)	0.069
Partial revision, at least revision tibia or femur	1008 (14.9)	114 (25.4)	2.05 (1.69–2.49)	< 0.001
Partial revision, only insert or patella	1908 (28.2)	113 (25.2)	1.07 (0.88–1.30)	0.49
Partial revision unknown which component	52 (0.8)	2 (0.4)	0.69 (0.17–2.85)	0.61
Only patella addition	1453 (21.5)	72 (16.0)	0.89 (0.71–1.13)	0.35

correction ($p > 0.001$). Minor revisions due to arthrofibrosis were significantly less common in cemented TKA than in cementless TKA (4.7% vs 14.2%, $p < 0.001$).

The three most common reasons for a major revision in cemented and cementless TKA were loosening of the tibial component, instability and malalignment. The numbers of revisions due to loosening of the tibial component, instability or malalignment did not differ significantly between cemented and cementless TKA after Bonferroni correction ($p > 0.001$). Major revisions due to infection were significantly more common in cemented TKA than in cementless TKA after applying a Bonferroni correction (18.2% vs 9.2%; $p < 0.001$; Table 6).

Discussion

The most important finding of this study was the comparable revision rates of cemented and cementless TKA after 9 years based on data from the population-based Dutch Arthroplasty Register. These results are comparable to the meta-analysis of Zhou et al. which showed no significant differences in implant survival and clinical efficacy between cemented and cementless fixation [22]. The results of the present study also confirm the results of Cherian et al. [3] who stated that short-term survival is comparable between cemented and cementless TKA. The

Table 6 Reasons for minor or major revisions of cemented and cementless TKAs

Reason for revision	Minor revision[a]				Major revision[b]			
	Cemented TKA ($n = 1908$) [n (%)]	Cementless TKA ($n = 113$) [n (%)]	OR (95% CI)	p value	Cemented TKA ($n = 3345$) [n (%)]	Cementless TKA ($n = 262$) [n (%)]	OR (95% CI)	p value
Patellar pain	430 (22.5)	24 (21.2)	0.94 (0.59–1.50)	0.80	312 (9.3)	19 (7.3)	0.76 (0.47–1.23)	0.26
Instability	709 (37.2)	46 (40.7)	1.19 (0.80–1.76)	0.39	922 (27.6)	71 (27.1)	0.74 (0.73–1.30)	0.86
Loosening of tibial component	21 (1.1)	3 (2.7)	2.48 (0.73–8.46)	0.13	1223 (36.6)	116 (44.3)	1.39 (1.07–1.79)	0.013
Infection	530 (27.8)	16 (14.2)	0.43 (0.25–0.74)	0.002	610 (18.2)	24 (9.2)	0.45 (0.29–0.69)	< 0.001
Malalignment	55 (2.9)	5 (4.4)	1.58 (0.62–4.03)	0.33	889 (26.6)	66 (25.2)	0.93 (0.69–1.24)	0.61
Loosening of femur component	9 (0.5)	2 (1.8)	3.85 (0.82–18.04)	0.066	340 (10.2)	31 (11.8)	1.18 (0.80–1.75)	0.40
Arthrofibrosis	90 (4.7)	16 (14.2)	3.39 (0.91–6.00)	< 0.001	131 (3.9)	11 (4.2)	1.07 (0.57–2.01)	0.83
Revision after knee removal	16 (0.8)	0 (0.0)	n.a.	n.a.	202 (6.0)	11 (4.2)	0.68 (3.7–1.27)	0.22
Patellar dislocation	48 (2.5)	3 (2.7)	1.07 (0.33–3.49)	0.91	81 (2.4)	0 (0.0)	n.a.	n.a.
Insert wear	94 (4.9)	8 (7.1)	1.47 (0.70–3.11)	0.31	68 (2.0)	5 (1.9)	0.94 (0.38–2.35)	0.89
Periprosthetic fracture	9 (0.5)	1 (0.9)	1.9 (0.24–15.2)	0.54	130 (3.9)	10 (3.8)	0.98 (0.51-1.89)	0.95
Loosening of patella component	47 (2.5)	1 (0.9)	0.36 (0.05–2.62)	0.29	22 (0.7)	4 (1.5)	2.34 (0.80–6.84)	0.11
Progression of osteoarthritis	8 (1.4)	0 (0.0)	n.a.	n.a.	14 (0.4)	0 (0.0)	n.a.	n.a.
Other	277 (14.5)	24 (21.2)	1.62 (1.01–2.59)	0.044	311 (9.3)	33 (12.6)	1.41 (0.96–2.06)	0.081

Numbers do not add up to total due to multiple reasons for one revision

TKA total knee arthroplasty, *OR* odds ratio, *CI* confidence interval, *n.a.* not applicable

p values < 0.001 were considered statistically significant after Bonferroni correction

[a]Only insert and/or patella exchange (excluding patella addition)

[b]Partial revision (at least revision tibia or femur), total revision or removal prosthesis (incl. spacer)

results of the present study are also in accordance with the findings of Van der List et al. [17] who described a 5-, 10- and 15-year survival of cementless TKA of 97.7%, 95.4% and 93.0%, respectively. In contrast to previous studies, the present register study included more cases and the data were nearly complete, which makes the present study more accurate. However, long-term revision rates should still be evaluated.

Stratification by age and ASA score showed comparable revision numbers in cemented and cementless TKAs for each group. No significant difference in the number of revisions was found between the two types of fixation in older patients with a high ASA score and younger patients with a low ASA score. This suggests that there is no need to reserve the cementless TKA especially for younger and healthier patients. Kim et al. and Franceschetti et al. found no significant differences in terms of clinical, functional and radiological outcomes between cemented and cementless TKA in patients younger than 55 and 60 years, respectively [5, 7]. These studies showed good results of the young patients with cementless TKA, but did not compare young patients with old patients. The result of the present study might be explained by good ingrowth of the hydroxyapatite-coated implants in both elderly and young patients, as found by

Dixon et al. [5]. Furthermore, our study showed that both in OA and in non-OA cases, major revisions were required more frequently in cementless TKA than in cemented TKA, which suggests that a cemented TKA could be better in both OA cases as well as in non-OA cases. This result might be due to the low number of cases with non-OA and the low number of revisions in both groups.

In both cemented and cementless TKA, the most frequent reason for revision is loosening of the tibial or femoral component. The results of the present study show that cementless TKAs were more often revised due to loosening of the tibial component or loosening of the femoral component than cemented TKAs. This finding may be explained by an RSA study with Interax TKAs by Pijls et al., which found a three-time higher revision rate due to aseptic loosening for uncoated uncemented tibial components than for cemented tibial components [12]. A recent radiostereometric analysis (RSA) study by Van Hamersveld et al. showed that the tibial component of a cementless total knee prosthesis coated with peri-apatite (PA) showed more overall migration than the tibial cemented component of a cemented total knee prosthesis [18]. However, post hoc analysis showed that this difference was caused by the migration of PA-coated components in the first 3 months. After these 3 months, a stable migration pattern was observed. Clinically, there was no significant difference in outcome between the groups after short-term follow-up [18]. Nakama et al. confirmed the outcome of Van Hamersveld et al. in a review, but even found that the risk of future aseptic loosening with cementless fixation was approximately half that of cemented fixation according to the arthroplasty instability classification [10]. Besides PA-coated or HA-coated cementless TKA, there are also newer designs of cementless TKA fixation, such as porous tantalum, which have better surface characteristics. Hu et al. [6] showed in their meta-analysis that the survival of cementless porous tantalum monoblock tibia component seems similar to the survival of the conventional cemented modular tibia component at 5-year follow-up. This could indicate that newer designs like cementless porous tantalum components have better surface characteristics than PA or HA components. Long-term survival of these prosthesis' designs has not been described yet.

Besides the relevance of good implantation to prevent varus, valgus and stress shielding, another possible explanation for more revision due to loosening of the tibial component or the femoral component in cementless TKAs than cemented TKAs could be the stem design [2]. The shape of the stem needs to be different in cementless TKA than in cemented TKA. In addition, the length of the stem could be the problem. Scott et al. [14] showed that a longer stem could be used in cementless TKA with the advantages of resistance to shear reduced tibial lift-off and increased stability by reducing micro-motion. However, longer stems may have disadvantages, including stress shielding along the length of the stem, which is associated with an increase in bone loss, reduction in bone density and a theoretical risk of subsidence and loosening, periprosthetic fracture and end-of-stem pain. Furthermore, lengthening the stem of the primary cementless tibial plateau could make any revision more difficult. Lengthening, size, material and coating of the stem could be among the many factors that contribute to the migration of the prosthesis, besides the relevance of patient characteristics, such as thickness of the cortical bone and bone density.

The results of the present study showed a significantly higher number of revisions due to infection in cemented TKAs (27.8%) than in cementless TKAs (14.2%). This is in contrast to a previous study by Anis et al. [1] who analysed the 2-year overall infection rate in cemented and cementless TKAs and found no significant difference. Possible confounders of the results of the present study are not only operation time, hospital, experience of the surgeon, but also type of cement, cementation time and case characteristics. Furthermore, infections are only registered in the Dutch Arthroplasty Register if they lead to revision of one of the components. If cases undergo a debridement, antibiotics and implant retention (DAIR) procedure without revision of one of the components, the infection is not registered. Moreover, the definition of infection is arbitrary. Infections in this register-based study were not confirmed with microbiology results.

The increased infection rate in cemented TKAs found in this study may have been due to the chemical composition of the cement. Cordero et al. [4] already described in 1996 that PMMA cement usually appears to be the implant material most prone to causing infection, while titanium (Ti) and cobalt–chromium (CoCr) are the materials least likely to cause infection. Furthermore, Turhan [16] stated that the incidence of deep infections in cemented TKA was not reduced by the use of antibiotic-loaded bone cement. This suggests that it could be possible that bone ingrowth of porous cementless TKAs enables better access of the body's inflammatory system than using a second matrix such as antibiotic-loaded bone cement. However, more studies should be performed to gain more insight into the underlying causes of infections in cemented and cementless TKAs.

The strength of this study is the large number of registry data used from the Dutch Arthroplasty Register with a completeness of nearly 100% [9, 21]. Because TKAs have a good survival and a relatively low revision rate, only large register studies can accurately evaluate the effect of fixation type on the revision rate. Furthermore, almost all revisions performed in the Netherlands are registered. This makes the results on revision characteristics reliable. Finally, cementless TKAs are performed in 64 out of 102 hospitals in the

Netherlands, which ensures objective results reflecting the entire population.

Nevertheless, register data also have their drawbacks since data have not been collected prospectively and the number of variables that have been registered is limited. While the present register study provides possible explanations for the differences between cemented and cementless TKAs in terms of reason for revision and type of revision, these explanations will have to be verified by prospective cohort studies such as randomized controlled trials.

A limitation of this study is the exclusion of the possible confounders BMI, Charnley score and smoking in the analyses, as these data are unknown for more than half of the patients. Furthermore, no corrections were made for possible confounders such as operating surgeon, treatment hospital and other characteristics that could indicate the health care team's experience in the chosen fixation method, as these data were not available. Also, no corrections were made for type of implant. However, the annual report of the LROI shows that the five most frequently registered knee prostheses were used in 86.8% of the primary TKAs. The annual report shows that the revision percentages of different types of prosthesis used in cemented primary TKAs do not differ [9]. Therefore, no large effect on the results was expected.

Conclusion

Based on population-based register data from the Netherlands, cemented and cementless TKAs showed comparable short-term and mid-term revision rates, which confirms that cemented and cementless fixation both are safe and effective fixation methods in TKA. Based on the findings in this study, there is no preferred fixation technique for OA and non-OA cases, elderly or cases with a high ASA score. As the long-term survival of TKAs is still unknown, the choice of fixation method remains dependent on the surgeon's preference and experience.

Author contributions All authors contributed substantially to the manuscript. CQ, TD, HV and RD contributed to the design of the study. CQ, AS and LS collected the data. CQ, AS, LS and JP performed the data analysis and statistical analysis. CQ, SB, JP and RD interpreted and discussed the results. CQ, SB, TD, JP and HV drafted the manuscript. All authors critically revised the manuscript and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest No authors have conflicts of interest.

Ethical approval Ethical approval has been evaluated by the LROI.

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