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Influence of the type of stem and its fixation on revision and immediate postoperative mortality in elective total hip arthroplasty

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Aims

Despite higher rates of revision after total hip arthroplasty (THA) being reported for uncemented stems in patients aged > 75 years, they are frequently used in this age group. Increased mortality after cemented fixation is often used as a justification, but recent data do not confirm this association. The aim of this study was to investigate the influence of the design of the stem and the type of fixation on the rate of revision and immediate postoperative mortality, focusing on the age and sex of the patients.

Methods

A total of 333,144 patients with primary osteoarthritis (OA) of the hip who underwent elective THA between November 2012 and September 2022, using uncemented acetabular components without reconstruction shells, from the German arthroplasty registry were included in the study. The revision rates three years postoperatively for four types of stem (uncemented, uncemented with collar, uncemented short, and cemented) were compared within four age groups: < 60 years (Young), between 61 and 70 years (Mid-I), between 71 and 80 years (Mid-II), and aged > 80 years (Old). A noninferiority analysis was performed on the most frequently used designs of stem.

Results

The design of the stem was found to have no significant influence on the rate of revision for either sex in the Young group. Uncemented collared stems had a significantly lower rate of revision compared with the other types of stem for females in the Mid-I group. There was a significantly higher rate of revision for uncemented stems in females in the Mid-II group compared with all other types of stem, while in males the rate for uncemented stems was only significantly higher than the rate for cemented stems. Cemented stems had a significantly lower revision rate compared with uncemented and short stems for both sexes in the Old cohort, as did females with collared stems. The rate of immediate postoperative mortality was similar for all types of stem in the Old age group, as were the American Society of Anesthesiologists grades.

Conclusion

In patients aged > 80 years, uncemented and short stems had significantly higher revision rates compared with cemented and collared stems, especially in females. The design of the stem and type of fixation have to be analyzed in more detail than only considering cemented and uncemented fixation, in order to further improve the success of THA.

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Introduction

Despite the success of total hip arthroplasty (THA),[1] the rate of revision surgery remains high. The German arthroplasty registry (EPRD) reported that 18,145 revision THAs were undertaken in 2022 with periprosthetic joint infection (PJI), implant loosening, and periprosthetic fracture as the main indications.[2] The influence of the method of fixation and the design features of the components on the risk of revision have to be analyzed in

Table I. The distribution of the patients into the different type of stem groups. Most patients were in the Mid-II age cohort (37%) and most stems were in the uncemented group (68%).

Group	Admission, n (%)	Uncemented, %			Collar, %			Short, %			Cemented, %			3 yrs, n (%)
		All	Male	Female	All	Male	Female	All	Male	Female	All	Male	Female	
All ages	333,144 (100)	68	72.4	65.5	3	2.8	3.0	11	12.7	9.6	18	12.0	21.8	172,937 (100)
Young	64,827 (19)	75	74.2	75.0	3	2.8	3.2	21	20.8	20.4	2	2.2	1.3	34,210 (20)
Mid-I	101,739 (31)	78	79.2	77.6	3	2.9	3.2	13	14.6	12.7	5	3.3	6.5	52,800 (31)
Mid-II	123,063 (37)	65	71.0	61.9	3	2.8	3.0	6	7.3	5.5	26	19.0	29.6	67,262 (39)
Old	43,515 (13)	44	51.7	40.8	3	2.8	2.6	3	4.3	2.7	50	41.2	53.9	18,665 (11)

detail in an attempt ot improve the rate of success of THA. The use of cemented stems is suggested in older patients to reduce the rate of revision, especially for those due to periprosthetic fracture.[3] Uncemented stems, however, continue to be used in elderly patients and this use is increasing.[3,4] The slightly increased rate of mortality after cemented THA compared with uncemented THA reported in registry studies is the justification for this ‘uncemented paradox’, although it is not clear whether there is a causal relationship or whether this merely represents a confounding factor.[3–7] The increased intramedullary pressure during cementing increases the rate of thromboembolic events, especially pulmonary embolism.[8-10] Recent reports have not confirmed differences in early postoperative mortality between patients undergoing cemented and uncemented THA,[11-15] possibly as a result of improved cementing techniques and faster postoperative mobilization.[16,17] The increased rate of mortality might simply reflect the patients’ individual risk of thromboembolism.

Uncemented collared and short stems have gained popularity, especially in Germany. Collared stems provide increased primary stability and a reduced risk of subsidence and early periprosthetic fracture.[18,19] The indications for their use have been extended from younger to elderly patients.[20]

The aim of this study was to investigate the influence of stem design and the method of fixation on the revision rate, and immediate postoperative mortality rate, focusing on the patients' age and sex, based on the data available in the EPRD.

Methods

Patients from the EPRD database with primary osteoarthritis (OA) undergoing elective THA using uncemented acetabular components, excluding those with reconstruction shells, were included in the analysis without risk stratification. As the EPRD cooperates with health insurance policies and the medical industry, mortality and morbidity (using the American Society of Anesthesiologists physical status classification (ASA)),[21] in combination with detailed implant specification, were available for all patients including the ASA for operations undertaken after 2020. There were 477,292 THAs in the registry. Those undertaken for trauma (19,083) and those in patients without primary OA (International Classification of Diseases (ICD) codes M16.0 and M16.1)[22] (95,279), those with cemented acetabular components (19,782) and support shells (four), were excluded, leaving 333,144 THAs in the study. Stems were categorized into four groups: uncemented without collar and short (uncemented; 136 different types), uncemented with collar (collar; eight), uncemented short (short; 18), and cemented (98). The revision rates of these groups were analyzed for four age cohorts: age at admission of < 60 years (Young), between 61 and 70 years (Mid-I), between 71 and 80 years (Mid-II), and > 80 years (Old; Table I).

Statistical analysis. Revision was defined as removal or exchange of one or all components and used as the endpoint for the analysis. Patient-specific data included sex, age, BMI, and ASA grade. Differences in the means of these variables were tested using independent-samples *t*-tests. Cumulative revision rates were determined using Kaplan-Meier estimations with the patient’s death, or the time of analysis of the data at the end of the period of follow-up, as censoring events. The cumulative revision rates for different types of stem up to three years after surgery were compared using pairwise log-rank tests. The Bonferroni-Holm method was applied for adjustment of multiple testing.[23] Immediate postoperative mortality was analyzed for the day of the surgery (including the following day) and for the whole hospital stay using chi-squared tests. All analyses were performed for all patients together and separately for males and females. The revision rates up to seven years postoperatively are shown for all subgroups with > 50 observations to illustrate the further development. No statistical analysis was performed for these data due to the greatly varying sizes of the groups.

Stems used in at least three different hospitals with > 300 THAs under surveillance three years after surgery (or design variants of these stems), were analyzed aditionally with non-inferiority analyses in the Mid-I, Mid-II, and Old age cohorts. The reference stem for each age cohort was determined as the stem with > 1,000 THAs under surveillance three years after surgery and the lowest revision rate as described by Deere et al.[24] Two non-inferiority limits were set at a 20% and 100% increase in revision rate. Corrected p-values < 0.05 were considered significant. R v. 3.6.1 with the survival package (R Foundation for Statistical Computing, Austria) was used.

Results

The type of stem used varied greatly between the age cohorts (Table I). In the Young cohort, 21% of the patients received a short stem and only 2% a cemented stem. An uncemented stem was still used in 50% of the Old cohort. The characteristics of the patients changed with increasing age. The mean BMI decreased from 29.9 kg/m^2 (standard error (SE) 0.10) in the Young cohort to 26.7 kg/m^2 (SE 0.07) in the Old cohort. The mean ASA grade increased from 2.0 (SE 0.01) in the Young to 2.4 (SE 0.07) in the Old cohort. The mean ASA grade for patients with a cemented stem was slightly higher than for those with an uncemented stem, in all age cohorts (between 0.01 and 0.22; $p < 0.001$) except the Old cohort. This trend was

Table II. Revision rates three years after surgery.

Group	Patients, n	Revision (95% CI)	Male, %	Revision (95% CI)	Female, %	Revision (95% CI)
Cemented						
Young	655	2.9 (2.0 to 4.2)	65	2.5 (1.5 to 4.1)	35	3.5 (2.1 to 5.9)
Mid-I	2,844	2.6 (2.2 to 3.1)	26	3.2 (2.4 to 4.4)	74	2.4 (1.9 to 3.0)
Mid-II	17,433	2.5 (2.3 to 2.7)	25	3.1 (2.7 to 3.5)	75	2.3 (2.1 to 2.5)
Old	9,032	2.5 (2.3 to 2.7)	24	2.5 (2.1 to 3.0)	76	2.5 (2.2 to 2.7)
All ages	29,964	2.5 (2.4 to 2.7)		2.9 (2.6 to 3.2)		2.4 (2.2 to 2.5)
Collar						
Young	697	2.5 (1.8 to 3.5)	47	1.8 (1.1 to 3.0)	53	3.2 (2.1 to 4.8)
Mid-I	1,230	1.3 (0.9 to 1.9)	37	1.8 (1.1 to 2.8)	63	1.1 (0.7 to 1.7)
Mid-II	1,558	2.4 (1.9 to 3.0)	30	3.3 (2.3 to 4.7)	70	1.9 (1.4 to 2.6)
Old	411	2.4 (1.6 to 3.6)	31	3.1 (1.7 to 5.5)	69	2.1 (1.2 to 3.6)
All ages	3,896	2.1 (1.8 to 2.4)		2.4 (1.9 to 3.0)		1.9 (2.5 to 1.3)
Short						
Young	6,488	2.8 (2.5 to 3.1)	50	3.0 (2.6 to 3.5)	50	2.6 (2.2 to 3.0)
Mid-I	6,237	2.2 (2.0 to 2.5)	42	2.8 (2.4 to 3.3)	58	1.8 (1.5 to 2.2)
Mid-II	3,321	2.5 (2.2 to 2.9)	39	3.0 (2.4 to 3.7)	61	2.2 (1.8 to 2.7)
Old	468	4.3 (3.3 to 5.6)	38	4.5 (3.0 to 6.8)	62	4.1 (2.9 to 5.8)
All ages	16,514	2.6 (2.4 to 2.8)		3.0 (2.7 to 3.3)		2.3 (2.1 to 2.5)
Uncemented						
Young	26,370	3.2 (3.0 to 3.4)	49	3.4 (3.2 to 3.6)	51	3.0 (2.8 to 3.2)
Mid-I	42,489	2.9 (2.8 to 3.1)	40	3.1 (2.9 to 3.3)	60	2.8 (2.7 to 3.0)
Mid-II	44,950	3.7 (3.5 to 3.8)	36	3.9 (3.7 to 4.1)	64	3.6 (3.4 to 3.7)
Old	8,754	4.6 (4.3 to 4.9)	34	4.6 (4.1 to 5.1)	66	4.6 (4.3 to 5.1)
All ages	122,563	3.3 (3.3 to 3.5)		3.5 (3.4 to 3.7)		3.3 (3.2 to 3.4)

CI, confidence interval.

Fig. 1

Pairwise comparison of the revision rates (RR) up to three years after surgery by cohort for the four types of stem for all the patients together and each sex separately. The p-value indicates whether the RR between the two stem groups indicated by the coloured boxes in a line differ significantly (the RR of the green group is significantly lower than the red group). There were no differences in the Young cohort in any group (Cem: cemented).

pronounced in comparison to patients with collared and short stems (collared 0.08 to 0.32; $p < 0.001$; short: between 0.03 and 0.23; $p < 0.001$, all independent-samples *t*-test).

There was considerable variation in the rate of revision according to the type of stem between sexes and age cohorts (Table II). The type of stem did not influence the rate of revision in the Young cohort for either sex or when combining all the patients (Figure 1). For the Mid-I age cohort, only male patients did not show an influence of the type of stem. All patients together, and female patients in this age cohort, had a lower rate of revision for collared stems compared with the other three types, while short stems performed better than uncemented

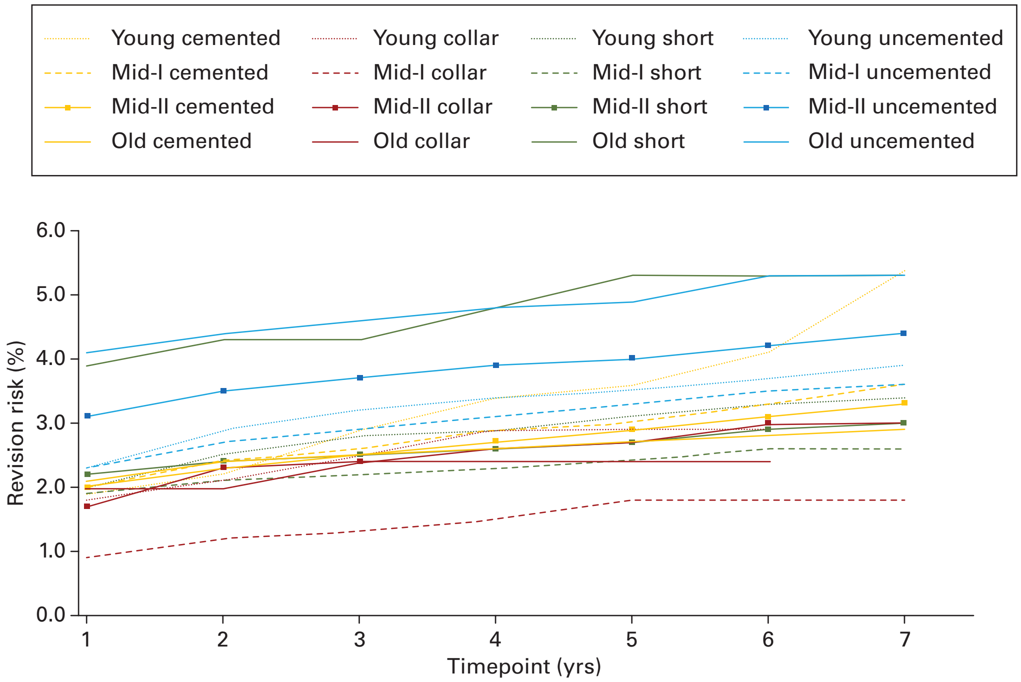

Fig. 2

Revision rates for the different stem groups for the different age cohorts for all patients together up to seven years postoperatively.

Table III. Mortality rates immediately postoperatively (day of surgery or the following day) and during the whole hospital stay for all patients and those aged > 80 years.

Time of death	Uncemented		Collar		Short		Cemented		p-value*
	n	Mortality, n (%)	n	Mortality, n (%)	n	Mortality, n (%)	n	Mortality, n (%)	
Immediate postoperatively									
All patients	227,088	11 (0.00)	9,820	1 (0.01)	35,936	2 (0.01)	60,274	12 (0.02)	0.003
> 80 yrs	19,212	2 (0.01)	1,145	0 (0)	1,379	0 (0)	21,770	7 (0.03)	0.410
Hospital									
All patients	226,909	190 (0.08)	9,815	6 (0.06)	35,926	12 (0.03)	60,159	127 (0.21)	< 0.001
> 80 yrs	19,150	64 (0.33)	1,144	1 (0.09)	1,378	1 (0.07)	21,703	74 (0.34)	0.177

*Chi-squared test; comparison between stem groups.

stems. For the Mid-II cohort, all patients together and females had a higher rate of revision for uncemented stems compared with the other three types of stem, whereas male patients only showed a difference between cemented and uncemented stems. For the Old cohort, cemented stems had a significantly lower rate of revision compared with uncemented and short stems for both sexes and all patients together. Female patients in the Old cohort also had a lower rate of revision for collared stems compared with short and uncemented stems.

The overall rate of revision in males was higher compared with females for all types of stem and age cohorts (Table II). The exceptions were cemented and collared stems in the Young cohort, with a higher rate of revision in females.

The trends in the rates of revision up to seven years postoperatively show a persistently lower rate for collared stems in the four age cohorts and a higher rate for uncemented stems (Figure 2). Short and cemented stems had similar results with a medium rate of revision, with two exceptions: the revision rate for cemented stems in the Young cohort increased considerably in the mid term, and short stems in the Old cohort had an increased rate throughout.

The reference stem in the Mid-I cohort was the Corail AMT stem with a collar (Supplementary Figure a). Nine other stems were inconclusive, indicating that the large standard errors overlap with the results of the reference stem, 22 stems were inferior by 20%, and one stem was inferior by 100%, which means that its rate of revision was twice as high.

In the Mid-II cohort, the Mueller straight cemented stem was the reference stem (Supplementary Figure b). Two other designs were not inferior, 23 stems were inconclusive, and 16 were inferior by 20%. Of the ten best performing stems in this analysis, six were cemented, two were short, one had a collar, and one was uncemented.

In the Old cohort, the Mueller Straight cemented stem was the reference stem (Figure 3), 15 stems were inconclusive, and six stems were inferior by 20%. Of the 12 best performing

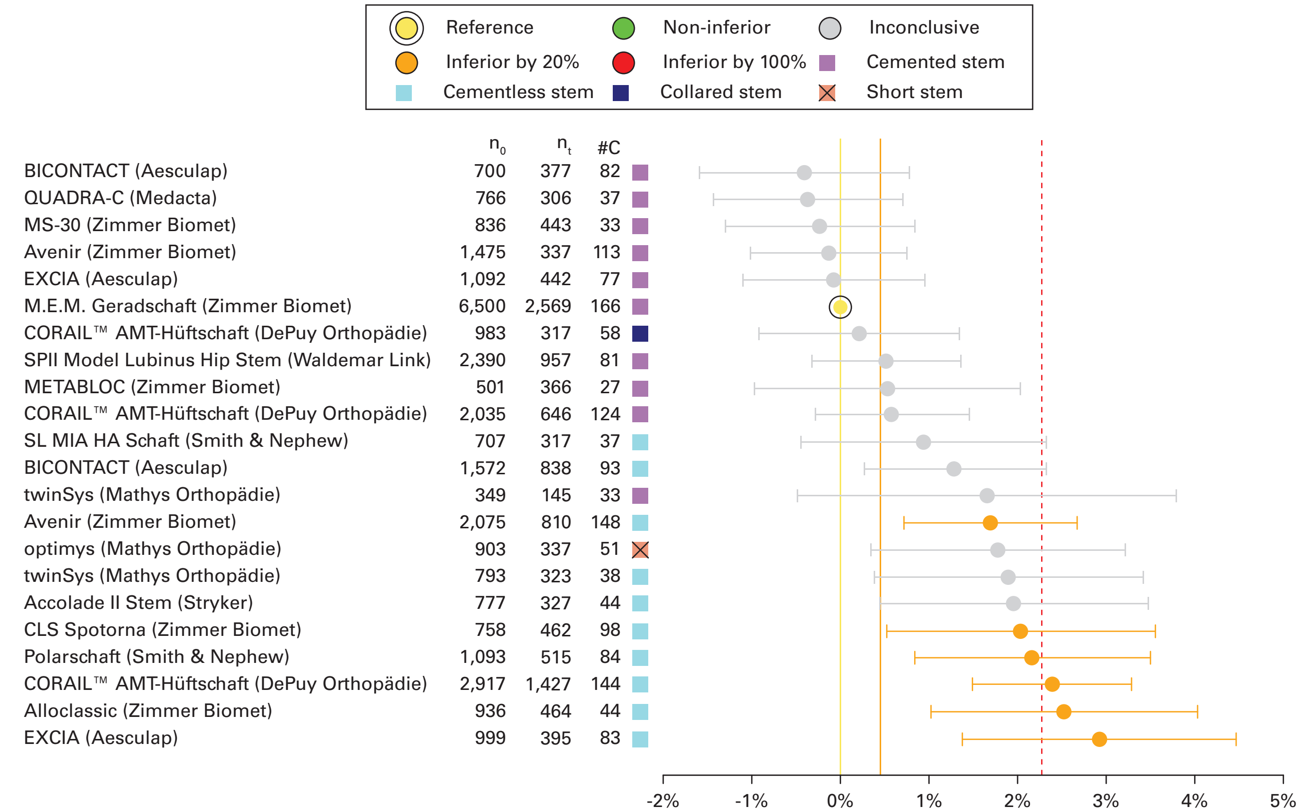

Fig. 3

Non-inferiority graph of the revision rate at three years for the "Old" age cohort. The coloured squares indicate the type of stem. The error whiskers indicate 2-times standard error of the mean (n_0: number of implanted stems; n_3: number of stems under surveillance after three years; #C: number of hospitals using the stem).

Table IV. Early rate of mortality in hospital comparing hospitals with different philosophies about the type of fixation in primary total hip arthroplasty.

Time of death	Percentage of THAs with cemented fixation in the respective hospital								p-value*
	< 25%		25% to 50%		51% to 75%		> 75%		
	n	Mortality, n (%)	n	Mortality, n (%)	n	Mortality, n (%)	n	Mortality, n (%)	
Hospital									
All patients	57,071	114 (0.2)	30,067	61 (0.2)	22,144	39 (0.18)	25,855	49 (0.19)	0.895
> 80 yrs	13,033	32 (0.25)	7,368	30 (0.41)	7,636	23 (0.3)	13,198	46 (0.35)	0.215

*Chi-squared test; comparison between the hospitals with different shares of cemented fixation.
THA, total hip arthroplasty.

stems, nine were cemented, one had a collar, and two were uncemented.

The rates of mortality immediately postoperatively and while in hospital were very low (Table III). The median hospital stay for the whole group was eight days (interquartile range (IQR) 6 to 9) and for the Old cohort also eight days (IQR 7 to 11). There were no significant differences in mortality between the stem groups in the Old patient cohort but for the whole group in which the rate of mortality in the cemented stem group was significantly higher. The rate of immediate postoperative mortality was much lower than the mortality during the stay in hospital, especially for the Old cohort. The frequency with which a hospital used cemented fixation was not significantly related to the rate of mortality while in hospital (Table IV).

Discussion

This registry study highlights the fact that a comparison between uncemented and cemented fixation in THA in general, without considering variations in the design of the components, might not be sufficient to answer the highly age- and sex-dependent question: how should the stem be fixed?

The quality of bone plays an important role for the success of THA.[25] This might explain why the type of stem did not influence the rate of revision in the Young cohort three years postoperatively. Cemented stems in young patients with a clear increase in the rate of revision in mid term were an exception, probably due to the selection of the patients, which is partly highlighted by the slightly higher ASA grades in those who were aged < 80 years. The choice of stem in male patients overall seemed less important than in female patients. In female patients aged > 60 years, cemented and collared stems outperformed uncemented stems, mostly due to a reduced rate of periprosthetic fracture. A similar benefit was seen for short stems until the age of 80 years, with a less clear explanation (Table II).[26]

The noninferiority analysis showed large variations in rate of revision of the different types of stem, indicating that a low rate of revision can be obtained with different designs. The reduced rate of revision using collared stems has been reported in other studies without elaborating on the effect of sex or age.[18,19,27,28] Our findings emphasize the importance especially for female patients in all age cohorts, as the use of a collar was associated with a clear reduction in the rate of revision (Table II). Other studies have also shown good long-term results of certain uncemented designs of stem in the elderly, which is also reflected in the non-inferiority analysis of the Old cohort. This highlights the importance of individual patient selection and surgical procedure for a more differentiated choice of stem.[29,30]

The question of whether collared stems can achieve the same rates of revision as cemented stems cannot fully be answered from this study, due to a possible bias in the selection of patients, slight differences in ASA grades between the groups, and the small numbers in some subgroups. There were, however, signs of a reduced rate of revision compared with uncemented stems without a collar, which are still frequently used in older patients.

A recent study showed that the mortality rates in patients aged > 90 years undergoing THA were lower than those in a corresponding age group of the general population, emphasizing the safety of THA.[31] Other studies confirmed similar early mortality rates for cemented and uncemented designs of stem, especially if the cohort of patients is adjusted for covariates.[15,32] The increased rates of mortality for cemented designs of stem, which have been described in the past, might be the result of a bias in the selection of patients and persistent confounding factors, rather than the type of fixation. This is probably also reflected in our study by the higher mortality while in hospital for all patients except the Old group. The increased length of hospital stay can be explained by the lack of early rehabilitation structures in the outpatient setting in Germany. The average daily hospital costs are significantly lower than in other G15 countries; furthermore, a minimum length of stay of a patient (depending on diagnosis and procedure) is part of the contract with the health insurance providers.

The study had limitations. The rate of revision as the primary endpoint, as typically used in registry studies, is open to selection bias, especially in the elderly in whom there is a general increased risk during surgery, making revision less likely. The collared stem group consists mostly of one design and adaptations of it. As such, the beneficial effect of the collar cannot be generalized to other uncemented designs. The results for the whole population are biased by the results for the female patients due to the larger percentage of females who were treated. For the future, it is debatable whether the results for females and males should be reported separately, rather than being combined. Another limitation is the overall small number of short and collared stems, and of cemented stems in young patients. Furthermore, only short- to mid-term outcomes were evaluated. Periprosthetic fractures with certain uncemented stems are also described in the long term. This has to be recognized, since only results up to three years were analyzed.[33] The decision to concentrate on the results at three years seems justified, considering the rather consistent trends up to seven years (with the exception of cemented stems in the Young cohort).

Registries are strong tools to document the overall success of treatments administered by different surgeons, but care has to be taken to formulate suggestions based on registry results, especially due to patient selection bias and differences in data coding between hospitals. Conclusions regarding rates of mortalityt due to cementing should be reviewed carefully, especially since the differences are small and risk stratification difficult.[7] The benefit of cemented fixation on the rate of revision in patients aged > 70 years reported in other studies was also shown in this analysis. A similar benefit was found for collared uncemented stems, especially for females. Patients aged > 70 years with medical morbidities who are at high risk of thromboembolism might benefit from this finding. However, we did not find an increase in the immediate postoperative rate of mortality in this cohort of patients. Short uncemented stems should not be used in patients aged > 80 years, while they seem to perform well in younger patients. Within each design of stem, some stems perform better than others, as indicated by the non-inferiority analysis.[34]

Take home message

- The selection of stem fixation should consider stem design beyond purely cemented and uncemented regarding sex and age of the patient, to further improve the outcome of primary total hip arthroplasty.
- Design variants such as collared or short uncemented stems should be considered separately.
- A collar on an uncemented stem can act as a safety belt and reduce the periprosthetic fracture rate.
- The good results of short uncemented stems are confirmed, but their use should be restricted to patients aged under 80 years.

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