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Fixation, sex, and age: highest risk of revision for uncemented stems in elderly women — data from 66,995 primary total hip arthroplasties in the Norwegian Arthroplasty Register

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Cemented THAs have been reported to have better overall implant survival than uncemented THAs (Hailer et al. 2010, Mäkelä et al. 2014). Still, there has been a worldwide increase in the use of uncemented THAs, including in elderly patients (Troelsen et al. 2013, Mäkelä et al. 2014). Cemented THAs have been reported to be prone to aseptic loosening, mostly in younger patients, and in the long term, whereas THAs with uncemented components have been prone to revisions due to femoral fractures, dislocations, and infections, often early postoperatively (Pedersen et al. 2014). Differences in prosthesis survival between all-cemented and all-uncemented THAs seem to have evened out during the last decade, and reverse hybrid (uncemented stem and cemented cup) and hybrid fixation (cemented stem and uncemented cup) have shown good results in primary THA (Troelsen et al. 2013, Wyatt et al. 2014, Wangen et al. 2017). In most reports, the outcomes were stratified by age, with results in favor of cemented THAs in the oldest patients. Sex is considered less frequently. There may be need for a more differentiated approach to what mode of fixation would be beneficial for individual patients. One needs to look at all the different reasons for revision in the same cohort. In addition, to eliminate the impact of “poor prostheses” and make the assessment relevant, one should compare the findings in a “best-case” scenario, investigating only commonly used, contemporary and well-documented prostheses.

We compared prosthesis survival for primary all-cemented, all-uncemented, reverse hybrid (uncemented stem and cemented cup), and hybrid (cemented stem and uncemented cup) THAs relative to sex and age. We assessed the risk of revision for different causes, and assessed whether there were groups of patients in whom certain modes of THA fixation were superior or inferior.
Patients and methods

Since its inception in 1987, the Norwegian Arthroplasty Register (NAR) has registered detailed information on primary THAs and THA revisions in Norway. Among the data collected is the patient’s identity, date of operation, indication for primary THA, type of implant, method of fixation, and other surgery-related factors. In addition, information on patient-related factors like sex, age, and comorbidities is registered. The unique identification number of each Norwegian links the primary THA to any subsequent revisions, and the National Population Register, which provides information on death or emigration. The definition of revision is removal or exchange of the whole prosthesis or part(s) of the prosthesis. The surgeon fills in the register form immediately after surgery, and this is mailed and entered electronically at the NAR. The present study is based on validated data from the NAR, with 97% completeness of reporting of primary THAs, 88% reporting of revisions, and 100% coverage of Norwegian hospitals (Furnes et al. 2019).

For this study, we assessed the fixation mode of commonly used, contemporary, and well-documented implants in cases with complete information on patient characteristics. A THA was considered commonly used when both the cup and stem had been used in more than 1,000 THAs, and contemporary when the cup and stem were still in use or used in at least 10 years of the study period. A THA was considered well documented if it had a documented 10-year survival of more than 90%. Whether the THAs were well documented were evaluated through: (1) Results in the NAR, (2) evaluation of the British Orthopaedic Device Evaluation Panel, and lastly (3) results in other arthroplasty registers with sufficient length of follow-up (i.e., Nordic, England and Wales, Australia). 10-year documentation was evaluated at the time of the analyses. Implants with documented poor performance were excluded.

Comorbidity according to the ASA classification has been registered in the NAR since 2005. In addition, the use of highly cross-linked polyethylene (XLPE) was established at that time. Therefore, the period of inclusion and observation for the present study was from January 1, 2005 to December 31, 2017. From this time period, the NAR contained data on 97,840 primary THAs. 30,845 THAs were excluded due to infrequent use, poor performance, terminated use, lack of 10-year documentation, or due to missing information on essential variables. In the end, 66,995 primary THAs in 55,935 patients were eligible for analyses (Table 1 and Figure 1).

Statistics

We performed Kaplan–Meier (KM) survival analyses in addition to adjusted survival analyses by Cox regression models. Time of revision due to any cause or revision due to aseptic loosening, deep infection, periprosthetic fracture, dislocation, or other reasons were the endpoints in the analyses.

All THAs were followed until their first revision, until the date of death or emigration of the patient, or until censoring at December 31, 2017. Patients were censored at time of death or emigration by linkage to the National Population Register. Adjusted hazard rate ratios, as a measure of relative risk (RR), were estimated for types of fixation, overall, for each sex, and in 3 age groups. In the Cox analyses, we adjusted for sex, age, ASA class, indication for primary THA, surgical approach, articulation, and head size of the prosthesis. Further, we adjusted for year of primary surgery to minimize the effect of time-dependent confounding.

Table 1. Included commonly used, contemporary, and well-documented stems and cups employed in THA in Norway 2005-2017

| THA fixation | Stem | Cup |
|-------------|------|-----|
| Cemented    | Exeter¹, Spectron EF², Lubinus SP²³, Charnley Modular⁴ | Exeter¹, Elite⁴, IP/SP1²³, Contemporary¹, Marathon⁴, Exeter X3 Rimfit¹ |
| Uncemented  | Coral¹, Filler², Hactiv⁶ | Reflection uncemented², Trilogy², Igloo², Trident¹, Pinnacle¹, R³² |
| Reverse hybrid | Coral¹, Filler², Hactiv⁶ | Exeter¹, Elite⁴, IP/SP1²³, Contemporary¹, Marathon⁴, Exeter X3 Rimfit¹ |
| Hybrid      | Exeter¹, Spectron EF², Lubinus SP²³, Charnley Modular⁴ | Reflection uncemented², Trilogy², Trident¹, Pinnacle¹, R³² |

¹ Stryker, ² Smith & Nephew, ³ Waldemar LINK, ⁴ DePuy, ⁵ Biotechni, ⁶ Evolutis, ⁷ Zimmer Biomet.

Figure 1. Flowchart of inclusion and exclusion of THAs. * There may be more than 1 missing variable per THA.
The analyses were performed in accordance with the guidelines for statistical analyses of arthroplasty register data (Ranstam et al. 2011). The proportional hazard assumptions of the Cox survival analyses were not completely fulfilled between the 4 modes of fixation when tested by smoothed Schoenfeld residuals (Figures 3 and 5). This resulted in assessment of the risk of revision 0–1 year, 1–3 years, and 3–10 years postoperatively and in the age groups less than 55, 55–75, and over 75 years.

In earlier register studies from the NAR we found that potential overestimation of incidence of revision through the effect of competing risks (death and revision) is negligible. The competing risk analyses (Fine & Grey) will therefore give similar results to the Cox analyses (Ranstam and Robertsson 2017). Based on this we chose to include results only from KM and Cox analyses. Bilateral THAs are dependent observations, but the influence of bilaterality has been found to have negligible influence on outcome (Lie et al. 2004, Ranstam et al. 2011). Hence, patients with bilateral THAs were included, and considered independent.

95% confidence intervals (CI) were calculated for survival rates and RRs. We used the IBM SPSS 24.0 (IBM Corp, Armonk, NY, USA) and R statistical software (R Centre for Statistical Computing, Vienna, Austria) packages for analyses, and the study was performed in accordance with the STROBE and RECORD statements.

**Ethics, data sharing plan, funding, and potential conflicts of interests**

The registration of data and the study was performed confidentially on patient consent and according to Norwegian and EU data protection rules. Data may be accessible upon application to the NAR. The study was fully financed by the NAR, and no conflict of interest is declared.

### Results

65% of the THA patients were women, mean age was 68 years (12–97), and mean ASA class was 2.0. Median follow-up was 4.6 years (interquartile range: 2.1–7.2). The group of cemented THAs had the longest follow-up. In general, patients with uncemented THAs were younger and slightly healthier than those with cemented THAs, with reverse hybrid and hybrid THA patients as intermediate groups (Tables 2 and 3). 66% of the cemented stems were polished taper slip (forced closed) stems.

Among the included 66,995 primary THAs, 2,210 (3.3%) were revised. The 10-year KM survival and adjusted implant survival was 94–95% for all 4 modes of fixation (Figure 2, Table 4, see Supplementary data). However, compared with cemented THAs, uncemented THAs had a 40% higher risk of revision. Reverse hybrid and hybrid THA had a similar risk of revision to cemented (Figure 2, Table 4, see Supplementary data).

**Fixation and sex**

Men had a higher risk of revision (RR 1.6; CI 1.4–1.7) than women (Figure 2). The risk of revision after uncemented THA was higher in both men and women, whereas reverse hybrid and hybrid THAs had similar overall revision risks compared with cemented THAs within each sex (Figure 2, Table 4, see Supplementary data).

**Fixation, sex, and age**

In women the risk of revision after uncemented THA, compared with cemented, increased with age (Figure 3, Table 4, see Supplementary data). In addition, the risk of revision after reverse hybrid THA, compared with cemented THA, was increased in women older than 75 years (Figure 3, Table 4, see Supplementary data).

In men, the risk of revision after uncemented THA was increased compared with cemented (Figure 3, Table 4, see Supplementary data). However, in contrast to women, the results for uncemented and reverse hybrid THAs were similar to cemented THAs in men over 55 years of age (Figures 2 and 3, Table 4, see Supplementary data). Nevertheless, there was a trend of increased risk of revision for uncemented, compared with cemented, THAs for men over 75 years of age (Figures 2 and 3, Table 4, see Supplementary data).

**Fixation, sex, and causes of revision**

Deep infection (1.2 %) was the most common cause of revision, followed by dislocation (0.7%), aseptic loosening (0.7%), periprosthetic fractures (0.4%), and other causes of revision (pain, wear, breakage of components, osteolysis, anisomelia, etc.) (0.4%). 93% of the periprosthetic fractures involved the femur and 7% the acetabulum.

In men, the risk of revision due to infection was slightly lower after reverse hybrid THA, compared with cemented (Table 5,
Table 3. Distribution of patient and surgery related factors by mode of fixation

| Risk factors                        | Number of THAs | Number revised | Cemented (%) | Uncemented (%) | Reverse hybrid (%) | Hybrid (%) |
|-------------------------------------|----------------|----------------|--------------|----------------|--------------------|-----------|
|                                     | n = 66,995    | n = 2,210      |              |                |                    |           |
| Sex                                 |                |                |              |                |                    |           |
| Male                                | 23,235         | 989            | 30           | 39             | 36                 | 36        |
| Female                              | 43,760         | 1,221          | 70           | 61             | 64                 | 64        |
| Age                                 |                |                |              |                |                    |           |
| < 45                                | 2,055          | 75             | 0.3          | 8              | 3                  | 2         |
| 45–54                               | 5,455          | 196            | 2            | 16             | 9                  | 10        |
| 55–64                               | 15,707         | 505            | 14           | 31             | 29                 | 27        |
| 65–74                               | 24,484         | 784            | 39           | 33             | 37                 | 29        |
| 75–84                               | 16,462         | 548            | 40           | 12             | 19                 | 27        |
| ≥ 85                                | 2,832          | 102            | 7            | 1              | 3                  | 6         |
| ASA class                           |                |                |              |                |                    |           |
| 1                                   | 12,501         | 368            | 13           | 25             | 20                 | 16        |
| 2                                   | 41,924         | 1,336          | 62           | 62             | 63                 | 68        |
| 3                                   | 12,339         | 495            | 24           | 13             | 17                 | 16        |
| 4                                   | 231            | 11             | 0.5          | 0.3            | 0.2                | 0.3       |
| Indication for primary THA          |                |                |              |                |                    |           |
| Osteoarthritis                      | 52,305         | 1,698          | 80           | 72             | 80                 | 71        |
| Inflammatory hip disease            | 1,495          | 49             | 2            | 2              | 2                  | 1         |
| Acute hip fracture                  | 1,981          | 73             | 4            | 2              | 2                  | 3         |
| Complication after hip fracture     | 2,978          | 143            | 6            | 3              | 4                  | 3         |
| Complication after childhood hip    | 6,169          | 169            | 5            | 17             | 7                  | 22        |
| Osteonecrosis of the femoral head   | 1,683          | 93             | 3            | 3              | 3                  | 3         |
| Other diagnosis                     | 384            | 17             | 0.6          | 0.8            | 0.4                | 0.3       |
| Surgical approach                   |                |                |              |                |                    |           |
| Anterior                            | 3,390          | 98             | 0            | 9              | 8                  | 0         |
| Anterolateral                       | 6,906          | 240            | 5            | 3              | 23                 | 1         |
| Lateral                             | 28,469         | 1,028          | 54           | 22             | 46                 | 8         |
| Posterolateral                      | 28,230         | 844            | 41           | 66             | 23                 | 92        |
| Articulation                        |                |                |              |                |                    |           |
| Metal-poly                          | 14,583         | 626            | 51           | 0.2            | 6                  | 1         |
| Metal-XLPE                          | 29,827         | 857            | 44           | 31             | 51                 | 85        |
| Ceramic-poly                        | 2,505          | 87             | 1            | 2              | 9                  | 2         |
| Ceramic-XLPE                        | 16,920         | 544            | 4            | 48             | 34                 | 10        |
| Ceramic-ceramic                     | 3,160          | 96             | 0            | 19             | 0                  | 2         |
| Head size, mm                       |                |                |              |                |                    |           |
| 28                                  | 31,559         | 1,219          | 65           | 14             | 53                 | 18        |
| 32                                  | 31,557         | 875            | 33           | 71             | 46                 | 52        |
| 36                                  | 3,879          | 116            | 2            | 15             | 1                  | 30        |

Figure 2. Adjusted implant survival curves with any revision as endpoint, for the 4 types of THA fixation in all THAs, THA in males, and THA in females, adjusted for age, sex (in all THAs only), ASA class, indication for primary THA, surgical approach, articulation, head size of the prosthesis, and year of primary surgery.
men and women (Table 6, see Supplementary data). During the first year postoperatively, compared with cemented THAs, reverse hybrid THAs also had a higher risk of aseptic loosening in both sexes (Table 6, see Supplementary data). In women, the risk of revision due to periprosthetic fracture after uncemented THA was increased 19-fold in the first year postoperatively, compared with cemented THAs (Table 6, see Supplementary data). In contrast to men, women had an 11 times increased risk of revision due to periprosthetic fracture after reverse hybrid THAs (Table 6, see Supplementary data) in the first year postoperatively.

Between 1 and 3 years, the risk of revision was lower for uncemented, reverse hybrid, and hybrid THAs compared with cemented THAs, in both men and women, mainly due to increased risk of aseptic loosening after cemented THAs (Figure 5, Table 6, see Supplementary data).

From 3 to 10 years postoperatively all 4 modes of fixations had similar overall risk of revision (Figure 5, Table 6, see Supplementary data). However, both men and women had a lower risk of revision due to aseptic loosening after uncemented THA (Table 6, see Supplementary data). Women, in contrast to men, had grossly increased risk of revision due to periprosthetic fracture 3 to 10 years after all THAs involving uncemented components, compared with cemented THAs (Table 6, see Supplementary data).

![Figure 3](image-url) Graphical representation of the relationship between age at primary THA and the log relative risk (RR) for revision due to all causes for uncemented and reverse hybrid compared with cemented THAs, for women and men with 95% confidence intervals. The horizontal green line shows the reference hazard rate ratio (RR = 1) of cemented THAs. The vertical lines indicate 55 and 75 years of age. We adjusted for ASA class, indication for primary THA, surgical approach, articulation, head size of the prosthesis, and year of primary surgery in the analyses. Hybrid THAs are omitted due to low numbers.

![Figure 4](image-url) Adjusted implant survival curves for different causes of revision for 3 types of THA fixation in women and men, adjusted for age, ASA class, indication for primary THA, surgical approach, articulation, head size of the prosthesis, and year of primary surgery. Hybrid THAs are omitted due to low numbers.
Discussion

We found good overall survival for common, contemporary, well-documented primary THAs regardless of fixation method: cemented, uncemented, reverse hybrid, or hybrid fixation. However, uncemented THAs had a slightly higher overall risk of revision compared with cemented THAs. This difference was mainly caused by an increased risk of periprosthetic fracture and dislocation after uncemented THA, in particular when used in elderly women. Reverse hybrid and hybrid THAs had similar overall results to cemented THAs, except for a reverse hybrid in women over the age of 75 years, where the risk of revision was higher.

Traditionally, uncemented THAs have been found, as in our study, to have higher revision rates than cemented THAs (Hailer et al. 2010, Mäkelä et al. 2014, Kandala et al. 2015). Despite this knowledge, there has been a paradoxical increase in the use of uncemented THA (Troelsen et al. 2013, Mäkelä et al. 2014). Recent development of wear-resistant articulating surfaces (i.e., XLPE), together with manufacturers’ marketing skills, may have induced this optimism in uncemented fixation among surgeons (Wechter et al. 2013, Giebaly et al. 2016). At least according to earlier findings from our register, the main problem with earlier generations of uncemented implants was wear and wear-related problems (osteolysis, loosening) (Havelin et al. 2000, 2002, Hallan et al. 2010). There is an increasing bulk of evidence that these issues are less of a problem with modern designs (Broomfield et al. 2017, Devane et al. 2017). Yet another possible reason for the increased usage of uncemented THAs may be inferior results of some commonly used cemented implants (Espehaug et al. 2009, Hallan et al. 2012). We assessed contemporary THAs, in a “best-case” scenario, comprising all patients in a national cohort. We still found inferior results for uncemented THAs, compared with cemented and reverse

Table 5. Risks of revision due to different causes, for men and women, for the 4 groups of fixation, adjusted for age, ASA class, indication for primary THA, surgical approach, articulation, head size of prosthesis, and year of primary surgery

|                      | THAs in men | THAs in women |
|----------------------|-------------|---------------|
|                      | THAs Revisions Relative risk (CI) THAs Revisions Relative risk (CI) |
| Aseptic loosening    |             |               |
| Cemented             | 7,756       | 83            | 17,922       | 118            | 1 |
| Uncemented           | 6,296       | 39            | 0.9 (0.5–1.6) | 9,710          | 39 | 0.5 (0.3–0.8) |
| Reverse hybrid       | 8,466       | 69            | 0.9 (0.6–1.5) | 14,846         | 99 | 1.0 (0.7–1.4) |
| Hybrid               | 717         | 2             | 0.5 (0.1–2.1) | 1,282          | 1  | 0.2 (0.0–1.2) |
| Infection            |             |               |
| Cemented             | 7,756       | 156           | 17,922       | 193            | 1 |
| Uncemented           | 6,296       | 106           | 1.1 (0.8–1.6) | 9,710          | 66 | 1.3 (0.9–1.9) |
| Reverse hybrid       | 8,466       | 126           | 0.7 (0.5–0.9) | 14,846         | 99 | 0.9 (0.7–1.2) |
| Hybrid               | 717         | 9             | 0.8 (0.4–1.6) | 1,282          | 13 | 1.5 (0.8–2.8) |
| Periprosthetic fracture |            |               |
| Cemented             | 7,756       | 33            | 17,922       | 23             | 1 |
| Uncemented           | 6,296       | 26            | 1.8 (0.9–3.6) | 9,710          | 41 | 12.3 (6.2–24) |
| Reverse hybrid       | 8,466       | 33            | 1.4 (0.7–2.6) | 14,846         | 81 | 9.9 (5.6–18) |
| Hybrid               | 717         | 0             | 1,282        | 4              | 7.4 (2.3–24) |
| Dislocation          |             |               |
| Cemented             | 7,756       | 84            | 17,922       | 156            | 1 |
| Uncemented           | 6,296       | 71            | 2.6 (1.6–4.4) | 9,710          | 65 | 1.8 (1.1–2.8) |
| Reverse hybrid       | 8,466       | 31            | 0.6 (0.4–1.0) | 14,846         | 50 | 0.7 (0.4–1.0) |
| Hybrid               | 717         | 5             | 1.1 (0.4–3.0) | 1,282          | 6  | 1.2 (0.5–2.9) |
| Other                |             |               |
| Cemented             | 7,756       | 24            | 17,922       | 48             | 1 |
| Uncemented           | 6,296       | 39            | 1.4 (0.6–3.0) | 9,710          | 43 | 12 (0.6–2.2) |
| Reverse hybrid       | 8,466       | 50            | 1.5 (0.8–2.9) | 14,846         | 53 | 0.9 (0.6–1.6) |
| Hybrid               | 717         | 3             | 1.6 (0.4–5.9) | 1,282          | 3  | 1.0 (0.3–3.5) |

Figure 5. Graphical representation of the relationship between year postoperatively and the log relative risk (RR) for revision due to all causes for uncemented, reverse hybrid, and hybrid THAs, compared with cemented THAs, with 95% confidence intervals. The horizontal green line shows the reference hazard rate ratio (RR = 1) of cemented THAs. The vertical lines indicate 1 and 3 years postoperatively. We adjusted for sex, age, ASA class, indication for primary THA, surgical approach, articulation, head size of the prosthesis, and year of primary surgery in the analyses.
hybrid THAs. The differences in implant survival were small, but sex and age influenced the results.

Periprosthetic fractures was the revision cause with the most pronounced differences between the sexes. Thus, this is the strongest finding in our study, and has been found by others (Abdel et al. 2016, Wangen et al. 2017, Chatziagorou et al. 2019). Periprosthetic fractures were found to be strongly associated with uncemented and reverse hybrid THAs, and mostly so in women. The fractures were mainly located around the femoral stem. The risk of revision due to periprosthetic fracture was higher in women from the age of 55 and increasing with age. In addition, the risk of revision due to periprosthetic fractures associated with uncemented stems continued to be high up to 10 years postoperatively. This was in contrast to men, where there was only a trend of increased risk of revision due to periprosthetic fracture after 75 years of age, and only early postoperatively. The use of uncemented components in patients with deteriorating bone stock should probably be avoided, since impaction of components may result in fissures due to fragile cortical bone (Piarulli et al. 2013, Sidler-Maier and Waddell 2015, Abdel et al. 2016, Hasegawa et al. 2017, Dammerer et al. 2019). The poorer results after uncemented stems in elderly patients are supported by literature on both THA and hemiarthroplasty (Gjertsen et al. 2012, Mäkelä et al. 2014, Wangen et al. 2017). Womens’ grossly increased risk of periprosthetic fractures with uncemented stems, both early postoperatively and 3–10 years postoperatively, may be due to bone density loss (Alm et al. 2009, Sköldenberg et al. 2014). One of the cemented femoral stems included in our study was the polished taper slipped Exeter™ prosthesis. This implant has a long and successful record of accomplishment. However, polished taper slip (force closed) prostheses have been reported to have an increased risk of periprosthetic fracture (Thien et al. 2014, Palan et al. 2016, Kristensen et al. 2018, Chatziagorou et al. 2019). The Exeter stem (polished taper slip) was used in 66% of the THAs with cemented stems in the present study and inferior outcome with one stem design or brand could potentially affect the whole group. The increased risk of periprosthetic fractures after uncemented THA could therefore have been even more pronounced if other designs of cemented stems were used to a larger degree (Thien et al. 2014). Also on the acetabular side, uncemented components have been associated with periprosthetic fracture (Hasegawa et al. 2017, Dammerer et al. 2019).

The 2nd most common cause of revision was dislocation. Both men and women had an increased risk of revision due to dislocation after uncemented THA, compared with cemented THA, in the first year postoperatively. This was despite the fact that a 28 mm prostheses head was more common in cemented THAs. In addition, there was higher risk of early aseptic loosening for THAs involving uncemented stems. This may indicate problems with initial stability and orientation of components for uncemented THAs, and in particular stems. Bone stock quality and geometry of the implant may have influenced these findings (Ogino et al. 2008, Finnila et al. 2016). The variation in the orientation of the components, especially the cup, may be larger with uncemented implants (Nishii et al. 2015, Sukathrien et al. 2018). Wedge shaped femoral stems, commonly used in Norway, tend to dictate the version of the stem to a large degree (Al-Dirini et al. 2019). Thus, any mal-positioning of the cup cannot always be sufficiently adjusted for with the stem. Also, the uncemented stem may subside in the femur more often than cemented ones (Selvaratnam et al. 2015). It may be that these factors lead to suboptimal position of the THA components, and thus to a higher risk of revision due to dislocation. The finding that hybrid and reverse hybrid THAs did not have increased risk of revision due to dislocation may indicate that there is an additive effect on the risk of dislocation when both components are uncemented.

Infection was the most common cause of revision after primary THA. This may partly reflect an increased risk of revision due to infection as reported in other studies (Dale et al. 2012).

Aseptic loosening was the 3rd most common cause of revision. This may confirm that our “best-case” selection included implants with good longevity regarding fixation, as intended. However, it also reflects the relatively short follow-up (median follow-up 4.6 years). A dilemma in evolution of arthroplasty is the conflict of interest between innovation and documentation of longevity. This is also illustrated by the contradiction in the inclusion criteria of the present study: contemporary and well documented. The differences between implants and fixation techniques may only be evident beyond 10–15 years postoperatively. In order to study contemporary THAs, we had a relatively short follow-up. Longer follow-up may change the results, particularly concerning revisions due to aseptic loosening, which is still the most common late cause of revision in studies with long term follow-up (Hailer et al. 2010). The follow-up was also slightly different for the 4 fixation groups as there had been a shift towards increased use of uncemented and reverse hybrid THAs with time. However, we had no indications on improved results for uncemented THAs, compared with cemented, at 10-year follow-up.

**Strengths and limitations**

We had the benefit of detailed information on patient- and surgery-related confounders. By way of example, the NAR uses catalogue numbers to identify implants and cements, securing near 100% coding accuracy. Accordingly, we were able to adjust for important differences between the patient groups. Because revisions are relatively rare, it may only be possible to study specific causes of revision in large databases such as national arthroplasty registers. We included a large number of common, contemporary, and well-documented THAs and detailed information on causes of revision and exact survival times. Because the results were based on data from a nationwide THA population, the results should also have good external validity.
Some selection bias and unknown confounding may, however, have affected our results. Patients who received uncemented THAs were in general younger and healthier than those who received cemented THAs. Hospitals with a preference for one type of fixation may have differences in case mix compared with hospitals choosing another fixation for the majority of their patients, differences that were not adjusted for in the analyses. We found that reverse hybrid THAs had a lower risk of revision due to infection, compared with cemented THAs, which could be the result of such bias. However, considering the number of cases, coverage of hospitals, completeness of the data, the strict inclusion criteria, and the fact that we adjusted for several clinically important risk factors in the analyses, we expect the selection bias and unknown confounding to be minor, and the study to be without major systematic errors.

The NAR does not include radiographs nor information on bone stock quality. Assumptions on periprosthetic fractures and fixation relative to elderly women were therefore based on epidemiological and not individual data.

In conclusion, longevity of primary THAs was good for cemented, uncemented, reverse hybrid, and hybrid THAs when common, contemporary, well-documented implants were used. However, uncemented THAs had a higher risk of revision, mainly due to more periprosthetic fractures and dislocations. Uncemented fixation should be considered as best avoided in women aged 55–75 years and avoided in women over the age of 75. The increased risk of revision due to periprosthetic fractures associated with uncemented components in elderly women, as found in our study, has resulted in a quality project in Norway where surgeons are advised to use only cemented stems in women over the age of 75.

Supplementary data

Tables 4 and 6 are available as supplementary data in the online version of this article, http://dx.doi.org/10.1080/17453674.2019.1682851

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Acta Orthopaedica 2019; 90 (x): x–x

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