Hydroxyapatite coating does not improve uncemented stem survival after total hip arthroplasty!

An analysis of 116,069 THAs in the Nordic Arthroplasty Register Association (NARA) database

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Submitted 2014-03-23. Accepted 2014-05-16

Background and purpose — **It is still being debated whether HA coating of uncemented stems used in total hip arthroplasty (THA) improves implant survival. We therefore investigated different uncemented stem brands, with and without HA coating, regarding early and long-term survival.**

Patients and methods — **We identified 152,410 THA procedures using uncemented stems that were performed between 1995 and 2011 and registered in the Nordic Arthroplasty Register Association (NARA) database. We excluded 19,446 procedures that used stem brands less than 500 times in each country, procedures performed due to diagnoses other than osteoarthritis or pediatric hip disease, and procedures with missing information on the type of coating. 22 stem brands remained (which were used in 116,069 procedures) for analysis of revision of any component. 79,192 procedures from Denmark, Norway, and Sweden were analyzed for the endpoint stem revision. Unadjusted survival rates were calculated according to Kaplan-Meier, and Cox proportional hazards models were fitted in order to calculate hazard ratios (HRs) for the risk of revision with 95% confidence intervals (CIs).**

Results — **Unadjusted 10-year survival with the endpoint revision of any component for any reason was 92.1% (CI: 91.8–92.4). Unadjusted 10-year survival with the endpoint stem revision due to aseptic loosening varied between the stem brands investigated and ranged from 96.7% (CI: 94.4–99.0) to 99.9% (CI: 99.6–100). Of the stem brands with the best survival, stems with and without HA coating were found. The presence of HA coating was not associated with statistically significant effects on the adjusted risk of stem revision due to aseptic loosening, with an HR of 0.8 (CI: 0.5–1.3; p = 0.4). The adjusted risk of revision due to infection was similar in the groups of THAs using HA-coated and non-HA-coated stems, with an HR of 0.9 (CI: 0.8–1.1; p = 0.6) for the presence of HA coating. The commonly used Bimetric stem (n = 25,329) was available both with and without HA coating, and the adjusted risk of stem revision due to aseptic loosening was similar for the 2 variants, with an HR of 0.9 (CI: 0.5–1.4; p = 0.5) for the HA-coated Bimetric stem.**

Interpretation — **Uncemented HA-coated stems had similar results to those of uncemented stems with porous coating or rough sand-blasted stems. The use of HA coating on stems available both with and without this surface treatment had no clinically relevant effect on their outcome, and we thus question whether HA coating adds any value to well-functioning stem designs.**

Hydroxyapatite (HA) is thought to improve early implant ingrowth and long-term stability in bone (Overgaard et al. 1997), and many stems intended for uncemented total hip arthroplasty (THA) are thus manufactured with HA coating. Several uncemented stems are only available with HA coating.

DOI 10.3109/17453674.2014.957088

Some HA-coated stems have excellent long-term outcomes in terms of the risk of revision, both for any reason and due to aseptic loosening (Capello et al. 2003, Shah et al. 2009). Registry data from Norway and Finland also indicate that certain HA-coated stems have excellent survivorship up to 10 years (Eskelinen et al. 2006, Hallan et al. 2007, Makela et al. 2008).

On the other hand, a number of studies on stem survival in the setting of randomized trials or smaller observational studies have failed to show beneficial effects of HA coating on clinical outcome and implant survival when compared to alternatives such as porous coating and sand-blasted rough surfaces (McPherson et al. 1995, Tanzer et al. 2001, Kim et al. 2003, Parvizi et al. 2004, Sanchez-Sotelo et al. 2004). Meta-analyses that have pooled data from randomized or cohort studies have come to the conclusion that there is "[…] no clinically beneficial effect to the addition of HA to porous coating alone in primary uncemented hip arthroplasty" (Gandhi et al. 2009, Li et al. 2013). In addition, a Danish registry analysis found that the use of HA coating does not reduce the risk of stem revision (Paulsen et al. 2007). Furthermore, a comparison of 4,772 uncemented Bimetric stems with or without HA coating implanted between 1992 and 2009 did not reveal any difference in survival between the 2 variants (Lazarinis et al. 2011).

HA was initially introduced as an implant coating to speed up and facilitate ongrowth and ingrowth of bone and thereby improve fixation, based on comprehensive preclinical and promising clinical documentation (Geesink et al. 1987, Bauer et al. 1991, Overgaard et al. 1997, Karrholm et al. 1998). Later on, concerns were raised due to findings of delamination and generation of HA particles originating from the coating with the potential to trigger osteolysis, acceleration of polyethylene wear, and subsequent implant loosening (Bloebaum and Dupont 1993, Morscher et al. 1998, Lazarinis et al. 2010). Today, there is renewed interest in HA coatings due to possible properties as a carrier for agents aimed at preventing infection (Ghani et al. 2012). Theoretical arguments for and against the use of HA coating can therefore be found. Given the renewed interest in uncemented stems—instigated by favorable outcomes after uncemented stem fixation in younger patients—the question of whether HA coating is beneficial or not is highly relevant (Eskelinen et al. 2006, Hooper et al. 2009, Swedish Hip Arthroplasty Register 2011). We therefore investigated uncemented stems with and without HA coating that are in frequent use in the Nordic countries, regarding early and long-term survival.

Patients and methods

Source of data

The Nordic Arthroplasty Register Association (NARA) dataset originally contained merged individual-based data from the Danish, Norwegian, and Swedish arthroplasty registries (Havelin et al. 2009), and Finland recently joined this collaboration (Havelin et al. 2011). Data from each contributing registry were transformed into a common dataset following a predetermined set of definitions, and all revisions were linked to the primary procedures. Prior to the merging of the national datasets, they were de-identified by deletion of personal identification numbers, and the common dataset was then processed in compliance with the national regulations governing research on registry data in each participating country.

Terminology

The term "revision" was defined as a new operation where 1 or more components of the primary THA prosthesis were exchanged, or where the entire prosthesis or parts of it were removed. Other types of reoperations where all implant parts were left in situ, e.g. closed reductions or incision and drainage, were not available from NARA data. Revisions were grouped further into revisions for any reason and revisions for specific reasons including aseptic loosening, infection, or periprosthetic fracture. Finally, in the subgroup of procedures performed in Denmark, Norway, or Sweden, detailed information on the procedures performed during revision surgery was available, enabling the analysis of stem revisions for specific reasons.

Diagnosis at index surgery was categorized into primary osteoarthritis (OA) or previous pediatric hip disease (defined as developmental dysplasia of the hip, Perthes' disease, or slipped femoral epiphysis), whereas procedures performed due to femoral neck fractures, inflammatory joint disease, and other diagnoses were excluded (see "Characteristics of the study population"). Age at the time of the index procedure was categorized into the age groups < 50, 50–59, 60–74, and ≥ 75 years.

Statistics

We adhered to the guidelines on the statistical analysis of registry data (Ranstam et al. 2011). Continuous data are described using means, medians, and ranges. 95% confidence intervals (CIs) are used to describe estimation uncertainty. Categorical data were summarized in cross tables and the chi-square test was used to investigate whether observed and expected frequencies differed significantly between groups of data. Follow-up started on the day of primary THA and ended on the day of revision, death, emigration, or December 31, 2011, whichever came first. Kaplan-Meier survival analysis was performed to calculate cumulative unadjusted component survival functions, with revision of any component or revision of the stem for any of the reasons given above as the endpoint. The log-rank test (Mantel-Cox) was used to investigate differences between groups. In order to calculate crude and adjusted hazard ratios (HRs) for relevant covariates, Cox regression models were fitted using the Efron method for handling ties. The risk of early revision for various reasons was investigated by calculating the risk of revision during the first 6 postoperative months only. Separate models were fitted for the covari-

Table 1. Procedures sorted according to stem brand in each country, after exclusion of stem brands used in less than 500 cases per country, and after exclusion of all diagnoses other than osteoarthritis or pediatric hip disease

	Denmark	Norway	Sweden	Finland	Total
Total	35,513	20,850	22,829	36,877	116,069
Bimetric	20,192	0	5,137	17,402	42,731
Corail	7,067	14,581	5,125	1,454	28,227
CLS	2,218	0	7,569	0	9,787
ABG	0	499	3,010	5,363	8,872
Synergy	714	0	0	2,564	3,278
Summit	0	0	0	3,166	3,166
Accolade	0	0	1,157	1,817	2,974
Filler	0	2,328	0	0	2,328
ML-Taper	0	0	0	2,214	2,214
Bicontact	1,580	0	0	0	1,580
Profemur	407	0	0	893	1,300
Anca-Fit	1,100	0	0	0	1,100
Omnifit	0	686	0	398	1,084
SCP	0	1,073	0	0	1,073
Hactiv	0	1,023	0	0	1,023
Symax	962	0	0	0	962
Anthology	0	0	0	898	898
Cone	0	0	831	0	831
Taperloc	0	0	0	708	708
Zweymuller	0	660	0	0	660
Versys	659	0	0	0	659
AML	614	0	0	0	614

Stem brands are ordered by total number in descending order.

Table 2. Presence or absence of HA coating on the 22 stem brands included

	no HA coating	HA coating	Total
Total	57,255	58,814	116,069
Bimetric	31,768	10,963	42,731
Corail	0	28,227	28,227
CLS	9,741	46	9,787
ABG	0	8,872	8,872
Synergy	3,278	0	3,278
Summit	3,166	0	3,166
Accolade	0	2,974	2,974
Filler	243	2,085	2,328
ML-Taper	2,214	0	2,214
Bicontact	1,580	0	1,580
Profemur	895	405	1,300
Anca-Fit	0	1,100	1,100
Omnifit	0	1,084	1,084
SCP	0	1,073	1,073
Hactiv	0	1,023	1,023
Symax	0	962	962
Anthology	898	0	898
Cone	831	0	831
Taperloc	708	0	708
Zweymuller	660	0	660
Versys	659	0	659
AML	614	0	614

Stems are ordered by total number in descending order. There were no missing data on HA coating.

ates HA coating, age, sex, diagnosis, and country of residence in order to calculate crude HRs with CI, and certain covariates were subsequently entered into Cox multiple regression models to enable calculation of adjusted HRs. In order to decide what covariates should be included in the models, directed acyclic graphs of possible causal relations were used (Shrier and Platt 2008). Model assumptions were investigated by calculating and plotting the correlation coefficient between transformed survival time and the scaled Schoenfeld residuals. When covariates did not meet model assumptions but were deemed to be relevant to outcome, adjusted multivariable models were fitted, stratified for these covariates (e.g. brand of stem). The level of significance was set at $p < 0.05$ in all analyses. We used R software version 3.0.2, including the "rms" and "Gmisc" packages (Harrell 2012, R Development Core Team 2012, Gordon 2013).

The analysis of both joints in bilaterally operated patients does not appear to lead to bias in registry studies of this size, and these were therefore included in the analysis (Robertsson and Ranstam 2003, Lie et al. 2004, Hailer et al. 2010). 22,069 of the 152,410 procedures eligible for the analyses presented here (15%) were based on bilateral observations.

Characteristics of the study population

Data on primary THA procedures using uncemented stems performed from 1995 through 2011 were pooled: 46,499 from Denmark, 27,748 from Norway, 28,244 from Sweden, and 49,919 from Finland, resulting in 152,410 procedures that were eligible for analysis. To reduce the influence of stem designs used in small numbers, we excluded all procedures involving a stem brand that had been used less than 500 times in each country. This left a total number of 135,515 THA procedures involving 22 different stem brands. We also excluded 19,446 THA procedures performed due to diagnoses other than osteoarthritis or pediatric hip disease, and those with erroneous or ambiguous information on the presence of HA coating. This left 116,069 THAs for the final analysis (Table 1).

The 116,069 procedures that were available for final analysis had been performed in 300 units. 94,309 stems were combined with uncemented cups, creating totally uncemented THA, 21,760 stems were combined with cemented cups, creating reversed hybrid THA. The number of cup brands was large, with more than 100 brands represented in the database. The 22 stem brands included in the analyses were categorized according to whether or not they had HA coating; 57,255 were not HA-coated and 58,814 were (Table 2).

Women were over-represented in the group of HA-coated stems ($p < 0.001$ for chi-square overall) (Table 3). Procedures performed in patients younger or older than the reference group (60–74 years) were over-represented in the group of HA-coated stems ($p < 0.001$ for chi-square overall) (Table 3). Procedures performed due to pediatric hip disease were more commonly performed using HA-coated stems ($p < 0.001$ for chi-square overall) (Table 3). The sex distributions and distri-

Table 3. Sex-, diagnosis-, and age distribution according to whether or not the stem had HA coating

	No HA coating n	%	HA coating n	%
Male	28,277	49	25,928	44
Female	28,978	51	32,886	56
Sum	57,255	100	58,814	100
OA	54,520	95	52,965	90
Pediatric	2,735	5	5,849	10
Sum	57,255	100	58,814	100
< 50	5,218	9	5,986	10
50–59	15,760	28	15,385	26
60–74	30,591	53	29,737	51
≥ 75	5,686	10	7,706	13
Total	57,255	100	58,814	100

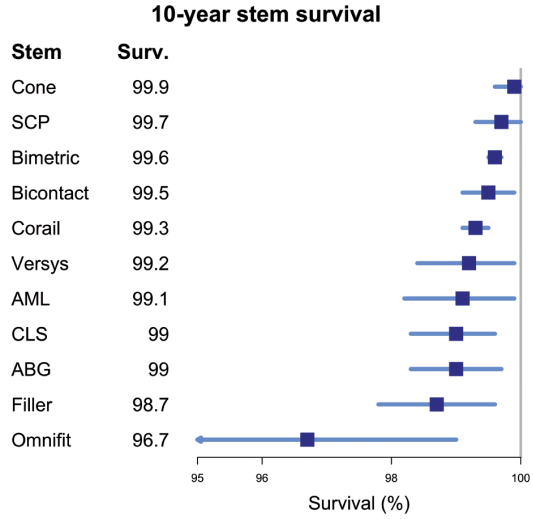

Figure 1. Unadjusted 10-year survival (with 95% CI) of the stem brands used in the Danish-Norwegian-Swedish subgroup, with stem revision for aseptic loosening as the endpoint. The 7 stem brands used in the Danish-Norwegian-Swedish subgroup that were not included in this analysis had fewer than 25 hips at risk after 10 years, and were therefore excluded. Stems are ordered by survival estimates, in descending order.

butions of diagnoses and age groups in the participating countries are given in Supplementary Table 4.

The risk of stem revision for various reasons was investigated in the subgroup of THAs performed in Denmark, Norway, and Sweden since the procedure "stem revision due to aseptic loosening" is not yet uniformly registered in Finland. This subgroup involved 79,192 procedures using 18 different brands of stem.

Results

Risk of revision of any component

The median observation time for the 116,069 THAs with the 22 selected uncemented stem brands was 3.6 (0–17) years. In this cohort, 5,223 THAs (4.5%) were revised with exchange of any component for any reason during the observation period. 1,631 revisions (1.4%) were done due to aseptic loosening of stem or cup or both, 629 (0.5%) were done due to infection, and 572 (0.5%) were done due to periprosthetic femoral fracture.

Unadjusted 10-year survival was 92.1% (CI: 91.8–92.4) with revision of any component for any reason as the endpoint. We then dichotomized the selected THAs into those using HA-coated stems and those using non-HA-coated stems. Unadjusted 10-year survival with the endpoint revision of any component for any reason was 92% (CI: 91.7–92.4) for the group of THAs without HA-coated stems (number at risk after 10 years: 6,676) and it was 92.1% (CI: 91.7–92.5) for those with HA-coated stems (number at risk after 10 years: 6,464) (p = 0.3).

Unadjusted 10-year survival due to infection was 99.3% (CI: 99.2–99.4) for all investigated THAs using stems without HA coating and it was 99.2% (CI: 99.0–99.3) for those using stems with HA coating (p = 0.002). After adjusting for age, sex, diagnosis, and country of residence as strata variables, we found that there was no statistically significant difference in the adjusted risk of revision due to infection between the group of THAs with HA-coated stems and that with non-HA-coated stems, with an HR of 0.9 (CI: 0.8–1.1) for the presence of HA coating versus non-HA coating (p = 0.6).

Risk of stem revision for various reasons

Median observation time for the subgroup of THAs performed in Denmark, Norway, and Sweden was 3.2 (0–17) years, which was therefore quite similar to the observation time for the entire study population. In this subgroup, 3,018 (3.8%) of all primary THAs underwent a revision procedure. 1,106 (1.4%) were stem revisions for any reason, and 273 (0.3%) were stem revisions performed because of aseptic loosening.

The unadjusted 10-year survival for this subgroup, with the endpoint revision of any component for any reason, was 92.8% (CI: 92.5–93.2). With the endpoint stem revision for any reason, it was 97.8% (CI: 97.6–98.0), and with the endpoint stem revision due to aseptic loosening, it was 99.3% (CI: 99.2–99.4). Unadjusted 10-year survival of non-HA-coated stems with the endpoint stem revision for any reason was 98.0% (CI: 97.7–98.2), and the corresponding survival rate for HA-coated stems was 97.7% (CI: 97.4–97.9) (p = 0.7). Unadjusted 10-year survival of non-HA-coated stems with the endpoint stem revision due to aseptic loosening was 99.4% (CI: 99.2–99.5), and the survival rate for HA-coated stems with the same endpoint was 99.3% (CI: 99.1–99.4) (p = 0.6). The numbers at risk at this time point were 2,503 for the non-HA-coated stems and 4,042 for the HA-coated stems.

Unadjusted 10-year stem survival with the endpoint revision due to aseptic loosening for the 11 stem brands that were available for 10-year analysis in the Danish-Norwegian-

Swedish subgroup is summarized in Figure 1 and in Supplementary Table 5. The 7 stem brands not included in this analysis had fewer than 25 hips at risk after 10 years, and they were therefore excluded. Both HA-coated and non-HA-coated stems were represented among the stems with the best 10-year survival. 10-year survival analyses stratified by age did not indicate that any age group benefited from having received HA-coated stems (Supplementary Table 6).

The endpoint stem revision for any reason was further investigated by fitting a multivariable Cox regression model including the covariates HA coating, age, sex, and diagnosis. Proportionality of hazards was not fulfilled for the covariate "stem brand" (e.g. Corail, Bimetric, Cone), and the regression model was thus stratified by this covariate. The presence of HA coating was not associated with statistically significant effects on the risk of stem revision for any reason in this regression model, with an HR of 1.0 (CI: 0.8–1.2) for HA-coated stems vs. non-HA-coated stems (p = 0.8).

The risk of stem revision for any reason within the first 6 months was investigated separately by fitting a multivariable model based on the covariates HA coating, age, and sex, stratified by diagnosis and stem brand. The presence of HA coating was not associated with statistically significant effects on the risk of stem revision for any reason within the first 6 months, with an HR of 0.9 (CI: 0.7–1.2) for HA-coated stems vs. non-HA-coated stems (p = 0.45).

Then a multivariable Cox regression model was fitted to calculate the adjusted risk of stem revision due to aseptic loosening. The regression model was again stratified for the covariate "stem brand". The presence of HA coating had no statistically significant effects on the adjusted risk of stem revision for aseptic loosening, with an HR of 0.8 (CI: 0.5–1.3) for HA-coated stems vs. non-HA-coated stems (p = 0.4).

Effects of HA coating on a commonly used stem

4 stem brands that had been used in the study population were available both with and without HA coating: the Bimetric, Profemur, Filler, and CLS stems. We investigated whether crude and adjusted stem survival differed for identical implants that were available with or without HA coating. In order to avoid bias created by small subgroups, we focused this specific analysis on the Bimetric stem, which was by far the most frequently used stem available both with and without HA coating (Table 1). We excluded Bimetric stems inserted in Finland because detailed information on stem revisions due to aseptic loosening was unavailable in that part of the cohort. This resulted in 25,321 Bimetric stems inserted either in Denmark or Sweden for final analysis (the Bimetric stem had not been used in Norway). Among these, 371 stems (1.5%) had been revised for any reason, and 74 stems (0.3%) had been revised due to aseptic loosening.

The unadjusted 10-year survival for the Bimetric stem with stem revision for any reason was 98.1 (CI: 97.9–98.4) for the non-HA-coated stem and 98.1 (CI: 97.7–98.5) for the HA-coated stem (p = 0.6). The adjusted revision risk for HA-coated Bimetric stems was similar to that for non-HA-coated stems, with an HR of 1.0 (CI: 0.8–1.2) for the HA-coated vs. the non-HA-coated Bimetric stem when considering the endpoint stem revision for any reason (p = 0.9).

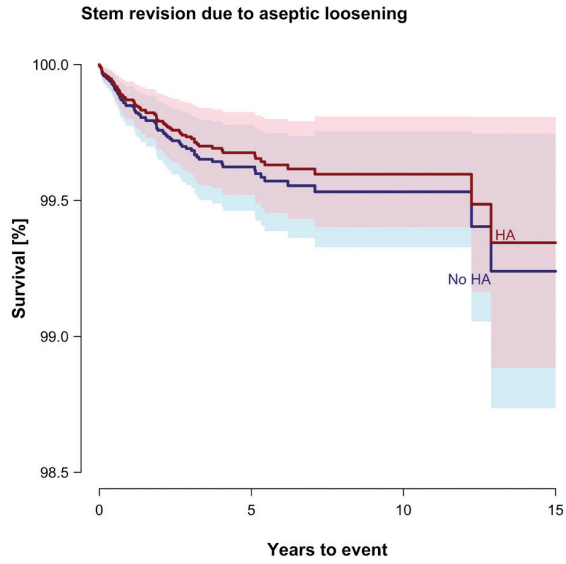

Figure 2. Survival of non-HA-coated and HA-coated Bimetric stems for females aged 60–74 with a diagnosis of osteoarthritis, with the endpoint stem revision for aseptic loosening in an adjusted Cox regression model.

With stem revision due to aseptic loosening as the endpoint, the unadjusted 10-year survival rates were 99.6 (CI: 99.4–99.7) for the non-HA-coated Bimetric stem and 99.7 (CI: 99.5–99.8) for the HA-coated stem (p = 0.4). We found that HA-coated Bimetric stems had an adjusted risk of revision due to aseptic loosening that was similar to that for non-HA-coated stems, with an HR of 0.9 (CI: 0.5–1.4; p = 0.5) (Figure 2).

Discussion

Is it the form or the finish?

We found no clinically relevant influence of HA coating on the risk of stem revision in our large material. This contrasts with the widely held belief that HA coating improves early stem fixation by faster bone ongrowth and—in the longer term—sealing of the effective joint space by bone ingrowth. A number of experimental studies on the ingrowth or stability of various implants in bone did indeed indicate that HA might be beneficial (Soballe et al. 1990, 1993a). The concept of HA coating of stems intended for uncemented THA gained additional support from (1) radiostereometric measurements of fixation showing reduced early migration of HA-coated implants (Soballe et al. 1993b), (2) a randomized study indicating that HA-coated stems were less prone to periprosthetic bone loss

(Tanzer et al. 2001), and (3) studies indicating improved bone remodeling around HA-coated implants (Dorr et al. 1998). However, the ultimate goal for HA-coated implants is the reduction of loosening of implants and thereby reduced revisions rates. The use of HA coating has not remained unopposed, since several studies (both observational and randomized) have found no advantage of HA-coated stems over stems with other coatings in terms of long-term survival (McPherson et al. 1995, Tanzer et al. 2001, Kim et al. 2003, Parvizi et al. 2004, Sanchez-Sotelo et al. 2004, Lazarinis et al. 2011). The drawback in some of these studies was the fact that the conclusions were based on outdated stem designs that were no longer in current use (Kärrholm et al. 1998).

We considered revision of any component for any reason and revision due to infection—and stem revision for any reason and stem revision due to aseptic loosening. The endpoints based on revision of any component were relevant, since delamination of HA from stems could have had a negative influence on cup survival, and the presence of HA coating on stems could hypothetically also have influenced the risk of infection. It is also reasonable to suspect that stems that were mated with poorly performing cups would suffer from this; patients who were revised because of a cup problem would be more likely to have their stem revised during the same revision procedure, either in order to facilitate cup removal or because the surgeon could identify a subclinical stem problem such as loosening or osteolysis during the revision procedure. Thus, a poor cup could have a negative effect on the stem results, so we studied the additional endpoints based on stem revisions in more detail. We also considered the endpoints stem revision due to aseptic loosening and stem revision for any reason (including the risk of revision within the first 6 months), since a failure to osseointegrate might have caused early revisions due to periprosthetic fracture.

The best-performing femoral implants included double-tapered designs such as the Bimetric stem and a tapered design with a circular cross section, as represented by the Wagner Cone stem. These observations are in accordance with previous investigations (Strom et al. 2006, Makela et al. 2008). The Zweymüller stem with its straight, tapered, rectangular cross-sectional design, the Omnifit stem, which is straight and tapered, and the ABG with its anatomical design and its smooth, sand-blasted surface had 10-year survival rates well above 90%, but all performed worse than the stems mentioned above. Again, this is in line with previous reports on the survival of these stems (Hallan et al. 2007).

The Bimetric stem was the most commonly inserted uncemented stem. This tapered titanium stem was associated with an excellent crude and adjusted 10-year survival, both considering stem revisions for any reason and those that were due to aseptic loosening. This finding is in line with previous reports (Davies et al. 2010), and revisions of THAs using the Bimetric stem are frequently associated with failure of the cup but not the stem component (Isaac et al. 2007). Low revision rates of the Bimetric stem have also been described in a Finnish registry study (Eskelinen et al. 2006). However, in a previous Swedish registry study, HA coating of Bimetric stems was not found to be associated with statistically significant effects on stem survival for any reason or due to aseptic loosening, which is in line with the present findings (Lazarinis et al. 2011).

Only the Bimetric stem had sufficient numbers of procedures done with and without HA coating, and the type of coating did not affect the fixation of this particular stem. We cannot, however, deduce from this finding that the coating had no effect on fixation of the other stems; some stem designs that had an HA coating could have had poorer or better results had the coating been removed from the implant, and implants with no HA coating could have performed differently with the addition of an HA coating. Moreover, not all HA-coated stems are similar, since the surface roughness and the thickness and crystallinity of the HA layer vary.

Thus, different design philosophies can successfully be applied to uncemented hip stem concepts, but seemingly minor differences in stem design and HA coating interact in a partially unknown way, which may influence the outcome. Lack of osseointegration of uncemented stems can increase the risk of early periprosthetic fracture and the risk of early loosening, and both of these phenomena—at least in part—would explain the decrease in cumulative survival of THAs during the first postoperative year. Periprosthetic fractures and early loosening are also reasons for cemented THAs doing better overall than uncemented THAs (Hailer et al. 2010, Makela et al. 2014).

Other risk factors for revision

Other factors with a possible influence on outcome were investigated in exploratory analyses. Analyses that were stratified by age group did not indicate that any group fared better or worse after having received HA-coated stems (Supplementary Table 6), and the same was true for women and men (data not shown). Inclusion of the type of cup fixation (cemented or uncemented) or the type of polyethylene (conventional or highly cross-linked) did not influence parameter estimates notably (data not shown), but this type of information was not available for the entire study population, and these exploratory findings must therefore be regarded with caution. Some other confounders that are known or suspected to influence outcome after THA, such as obesity, diabetes mellitus or other comorbidities, and intake of immunosuppressive or non-steroidal inflammatory drugs (Persson et al. 2005, Gilson et al. 2010, Bozic et al. 2012, Jamsen et al. 2012), were not registered in the database.

Strengths and limitations

The high number of THAs investigated was a strength in this study: 22 different uncemented stem brands in 4 different countries were included, with 7 of the stems used in at least 3 participating countries. The stem brands investigated are in current use, whereas historical designs were not evalu-

ated. Moreover, this large cohort allowed investigation of rare events such as stem revision due to aseptic loosening and due to infection. We therefore believe that our findings are representative of THA patients. It should be noted that absence of statistically significant differences between HA-coated and non-HA-coated stems is not necessarily evidence of their absence, but failure to detect statistically significant differences in this large material indicates that the clinical relevance of such putative differences is questionable.

One strength of the study was that we analyzed a large number of uncoated and HA-coated versions of the Bimetric prosthesis. A weakness of this comparison is that both the collared and the collarless versions of this stem brand were summarized under the term Bimetric, but subgrouping would have further reduced the available numbers of observations and events and inflated estimation uncertainty. On the other hand, no previous studies have indicated that there is any difference in survival between the 2 different stem variants. Other prostheses available both with and without HA coating (Filler, Profemur, and CLS) had not been used in sufficient numbers to allow valid comparisons, given the low number of stem revisions relative to the total number of procedures.

Limitations concerning completeness and coverage are inherent in observational studies based on registry materials. The NARA collaboration receives data from Denmark, Finland, Norway, and Sweden, and the respective registries have been repeatedly validated. The completeness of data in the 4 countries varies between 86% and 99% (Bergh et al. 2014). We tried to limit selection bias by only including stems that had been inserted at least 500 times in each participating country, thus avoiding bias introduced from low numbers of stems with either very good or very poor performance. Both high- and low-volume units were included in the analyses (data not shown), and this could have introduced bias if certain stems had predominated in one type of unit. However, we found no evidence that any of the stems investigated had been in used predominantly in units with either very high or very low volumes (data not shown). Detailed information on bearing surfaces is not available in the NARA database, which is a weakness of the study.

Conclusion

Excellent long-term survival can be found for both HA-coated and non-HA-coated stems, and for one specific stem brand that was available with and without HA coating, this surface treatment had no certain influence on the risk of stem revision. We therefore believe that HA coating of stem components is not associated with clinically relevant effects on the survival of THA stems, and we question the use of HA coatings on well-functioning stems.

Supplementary data

For Supplementary data, Tables 4–6, see www.actaorthop.org, identification number 7372.

NPH: study design, data analysis, and drafting and editing of the manuscript. SO, AE, AMF, GH, LH, FM, ABP, KTM, SLS, and JK: study design and editing of the manuscript.

We thank all the Danish, Finnish, Norwegian, and Swedish orthopedic surgeons and secretaries who contributed data.

No competing interests declared.

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