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Association between fixation technique and revision risk in total hip arthroplasty patients younger than 55 years of age. Results from the Nordic Arthroplasty Register Association

A.B. Pedersen †*, F. Mehnert †, L.I. Havelin ‡§, O. Furnes ‡§, P. Herberts ||, J. Kärrholm ||, G. Garellick ||, K. Mäkela ¶#, A. Eskelinen #††, S. Overgaard ‡‡§§

† *Competence Centre for Clinical Epidemiology and Biostatistics, North, Department of Clinical Epidemiology, Aarhus University Hospital, Aarhus, Denmark*
‡ *The Norwegian Arthroplasty Register, Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen, Norway*
§ *Department of Clinical Medicine, University of Bergen, Bergen, Norway*
|| *The Swedish Hip Arthroplasty Register, Department of Orthopaedics, Institute of Surgical Sciences, Sahlgrenska University Hospital, University of Gothenburg, Mölndal, Sweden*
¶ *Department of Orthopaedics and Traumatology, Turku University Hospital, Turku, Finland*
# *The Finnish Arthroplasty Register, Finland*
†† *The Coxa Hospital for Joint Replacement, Tampere, Finland*
‡‡ *Department of Orthopaedic Surgery, Traumatology and Clinical Institute, Odense University Hospital, Odense, Denmark*
§§ *Danish Hip Arthroplasty Register, Department of Clinical Epidemiology, Aarhus University Hospital, Aarhus, Denmark*

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SUMMARY

Objectives: To evaluate implant survival following primary total hip replacement (THR) in younger patients. To describe the diversity in use of cup-stem implant combinations.
Design: 29,558 primary THRs osteoarthritis (OA) patients younger than 55 years of age performed from 1995 through 2011 were identified using the Nordic Arthroplasty Registry Association database. We estimated adjusted relative risk (aRR) of revision with 95% confidence interval (CI) using Cox regression.
Results: In general, no difference was observed between uncemented and cemented implants in terms of risk of any revision. Hybrid implants were associated with higher risk of any revision (aRR = 1.3, CI: 1.1–1.5). Uncemented implants led to a reduced risk of revision due to aseptic loosening (aRR = 0.5, CI: 0.5–0.6), whereas the risk was similar for hybrid and cemented implants. Compared with cemented implants, both uncemented and hybrid implants led to elevated risk of revision due to other causes, as well as elevated risk of revision due to any reason within 2 years. 183 different uncemented cup-stem implant combinations were registered in Denmark, of these, 172 were used in less than 100 operations which is similar to Norway, Sweden and Finland.
Conclusions: Uncemented implants perform better in relation to long-term risk of aseptic loosening, whereas both uncemented and hybrid rather than cemented implants in patients younger than 55 years had more short-term revisions because problems due to dislocation, periprosthetic fracture and infection has not yet been completely solved. The vast majority of cup-stem combinations were used in very few operations.

Introduction

Previous literature has shown the short-term and long-term risk of revision following primary total hip replacement (THR) to be higher in younger than in older patients[1–3]. These findings could be explained by significant decrease in body-weight and physical activity with age[4,5]. In addition, secondary osteoarthritis (OA), common indication for THR in younger patients is associated with an elevated risk of revision during the first 6 postoperative months[1,6–

* Address correspondence and reprint requests to: A.B. Pedersen, Department of Clinical Epidemiology, Aarhus University Hospital, Olof Palmes Alle 43-45, 8200 Aarhus N, Denmark. Tel: 45-8716-8208; Fax: 45-8716-7215.
E-mail addresses: abp@dce.au.dk (A.B. Pedersen), fm@dce.au.dk (F. Mehnert), leif.ivar.havelin@helse-bergen.no (L.I. Havelin), ove.furnes@helse-bergen.no (O. Furnes), peter.herberts@vgregion.se (P. Herberts), johan.karrholm@vgregion.se (J. Kärrholm), Goran.Garellick@registercentrum.se (G. Garellick), Keijo.Makela@tyks.fi (K. Mäkela), antti.eskelinen@fimnet.fi (A. Eskelinen), Soeren.Overgaard@rsyd.dk (S. Overgaard).

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[8] but also 10 years after primary THR. However, after adjustment for fixation technique no difference in implant survival was found between these two groups[6]. In general, most studies[3,9] report an association between uncemented fixation and higher risk of revision. However, good results in terms of implant survival have been reported for uncemented implants in younger patients in some[10,11], but not all studies[12]. Still, it is unknown whether the change in design and materials over the last many years have influenced the risk of revision of uncemented implants, which have more often than cemented implants been subject to these changes. For instance, metal-on-metal bearing couples, which are known to have an increased risk of early revision[13], have almost solely been used in uncemented implants. Large between-country variation in implants use[14] has been reported previously in NARA settings. Data from Australian hip and knee registry showed that only about 23% of the new introduced hip and knee implants were used in more than 100 procedures[15] in total, indicating further that the introduction of new implants is associated with worse outcome[15,16].

As only 5% of THRs are performed in patients younger than 55 years of age, it is difficult to get a sample size with adequate power from a single center or even from a single national arthroplasty registry. In 2007, The Nordic Arthroplasty Register Association (NARA) was established including selected variables, which population-based Danish, Norwegian, and Swedish hip registries could deliver. In 2010, the Finnish Hip Register joined NARA. The NARA database opened up new possibilities of studying the results of prosthetic concepts on a much larger scale than within any of the national registries.

The aim of this study was to evaluate the association between type of fixation and risk of revision following primary THR in patients younger than 55 years of age using the large population-based NARA dataset. In addition, we aimed to describe the diversity in use of cup-stem implant combinations.

Methods

Study settings

We conducted a population-based follow-up study, based on data from prospective, nationwide hip arthroplasty registries in Sweden, Norway, Denmark and Finland. These four registries contain data on primary THRs and revisions performed in Sweden, Norway, Denmark and Finland since 1979, 1987, 1995 and 1980, respectively. The registries are all validated and contain more than 90% of all THRs performed in each country[17–19]. All orthopedic departments in the respective countries, including private hospitals, provide pre- and peri-operative data on primary THR and revision procedures to these registries. All Swedish, Norwegian, Danish and Finnish citizens are assigned a unique civil registration number, permitting unambiguous linkage between hip registries and civil registration systems in each country, enabling tracking of patients who died, or emigrated.

The steering committees of the respective registries established the NARA in order to combine data in one Nordic hip arthroplasty database[14].

Study population

The study included only patients younger than 55 years of age at the time of primary THR ($n = 58{,}493$). THR on patients less than 35 years of age ($n = 4150$) were excluded due to their low number and special reasons for requiring THR. Since previous studies found large discrepancy related to biology, treatment and prognosis[1,20] between THR patients operated due to primary and secondary OA, we only focused on primary OA (thus $n = 20{,}769$ THRs due to secondary OA was excluded). This also enhanced the possibility of comparing results with previous studies. Hip resurfacing procedures ($n = 4016$) were also excluded from our study due to prognosis which is different from the prognosis of conventional THR[21]. After the exclusions, we identified 29,558 primary THRs performed between 1 January 1995 and 31 December 2011, including 3974 patients with bilateral surgery. Although assumption about independent observations is not fulfilled when bilateral observations are included in the analysis and this may theoretically have influence on the validity of the results, we choose to do so since this has not been shown to be a practical problem for analyses of arthroplasty register data[22,23].

Study outcome

The outcome measure was time to revision. Revision was defined as a new surgical intervention involving partial or complete exchange or removal of the implant. Data on primary THR and subsequent revision were accurately linked by the patient's unique civil registration number and the laterality of the hip registered in the country specific hip registries. Thus, the NARA database includes information on all first time revisions performed on the each identified primary THR patients irrespective of laterality during the follow-up period. We analyzed the risk of revision due to four reasons (1) any reason, (2) aseptic loosening, (3) other causes than aseptic loosening, and (4) any cause within 2 years of primary THR.

Statistical analyses

Age, sex, fixation technique, and calendar year of primary THR surgery were included in the analyses as possible risk factors. Follow-up began on the day of primary THR and ended on the day of first revision, on the day of death, emigration, or 31 December 2011, whichever came first. Kaplan–Meier (KM) analyses were used to estimate the cumulative implant survival probabilities with standard error (SE) for survival. A Cox proportional hazards analysis was used to assess the risk of revision by computing hazard ratios (HR) as a measure of relative risks (RR) for revision with 95% Confidence Interval (CI). We compared uncemented, hybrid and inverse hybrid implant with cemented implants as reference group during the entire period 1995–2011 in relation to four outcomes previously described. We repeated these analyses for each of the following time periods, 1995–1999, 2000–2003, 2004–2007 and 2008–2011. In addition, we compared fixation techniques calculating the 5 years revision risk for patients with full 5 years follow up and 10 years revision risk accordingly. Since the fixation technique did not fulfill the proportional hazard assumption, we split the follow-up period into 1 year intervals. Separate sub-analyses were carried out for sub-study population 2002–2011 ($n = 19{,}282$). The reason for doing so was to be able to account for femoral head size and different bearing surfaces as a confounding variable, as it has only been available in the NARA since 2002. We also presented the most commonly used cup-stem combinations separately for each type of fixation. As for the uncemented most common cup-stem combinations, we included those used in more than 3% of patients receiving uncemented implants. The corresponding percentage for other types of fixation was 4%. All analyses were performed using SAS version 9.1.3. (SAS Institute Inc, Cary, NC).

Results

Description of study population

Characteristics of the study population 1995–2011 are presented in Table I, including the distribution of causes for revision

Table I
Characteristics of the study population 1995–2011

Characteristics		All patients $n = 29,558$
Sex	Female	14,167 (47.9%)
	Male	15,391 (52.1%)
Age, years	35–45	4078 (13.8%)
	46–55	25,480 (86.2%)
Year of primary THR surgery	1995–1999	6690 (22.6%)
	2000–2003	6735 (22.8%)
	2004–2007	7123 (24.1%)
	2008–2011	9010 (30.5%)
Fixation technique	Cemented	6824 (23.1%)
	Uncemented	16,407 (55.5%)
	Hybrid	3068 (10.4%)
	Inverse hybrid	3259 (11.0%)
Distribution of causes of revision during the entire follow-up period ($n = 2413$)	Aseptic loosening	1290 (53.4%)
	Unspecified	415 (17.2%)
	Dislocation	288 (11.9%)
	Deep infection	219 (9.1%)
	Periprosthetic fracture	91 (3.8%)
	Pain only	78 (3.2%)
Distribution of causes of revision within 2 years of follow-up period ($n = 590$)	Dislocation	150 (25.4%)
	Aseptic loosening	136 (23.0%)
	Deep infection	119 (20.2%)
	Unspecified	105 (17.8%)
	Periprosthetic fracture	52 (8.8%)
	Pain only	28 (4.7%)

during the entire follow-up period (most common cause was aseptic loosening, followed by unspecified causes and dislocation), as well as within 2 years of primary THR (most common cause was dislocation, followed by aseptic loosening and deep infection). During the entire follow-up period, 8.2% (2413) of the primary THRs were revised due to any reason, whereas 4.4% (1290) and 3.8% (1123) were revised due to aseptic loosening and due to other reasons than aseptic loosening, respectively. 2.0% (590) of primary THRs were revised within the first 2 years due to any reason (Table I).

Sub-study population 2002–2011 comprise of the following femoral head size: ≤28 mm (55%), 28–36 mm (29%), >36 mm (19%) and missing data (1%). About 60% of uncemented and 11% of cemented implants were inserted with femoral head size ≥28 mm. In total, following bearing surfaces were used: Metal-on-metal (14%), Metal-on-poly (45%), Ceramic-on-poly (20%), other surfaces (13%) and missing data (8%). For uncemented implants, the distribution was as following: 18%, 36%, 16% and 17%, whereas for cemented was 2%, 71%, 21% and 2%.

Fixation technique

During the entire study period of 1995–2011, we found no major difference between uncemented and cemented fixation in terms of risk of any revision (Fig. 1(A)). However, we found that uncemented implants were associated with a reduced risk of revision due to aseptic loosening (RR = 0.5, CI: 0.5–0.6), but an elevated risk of

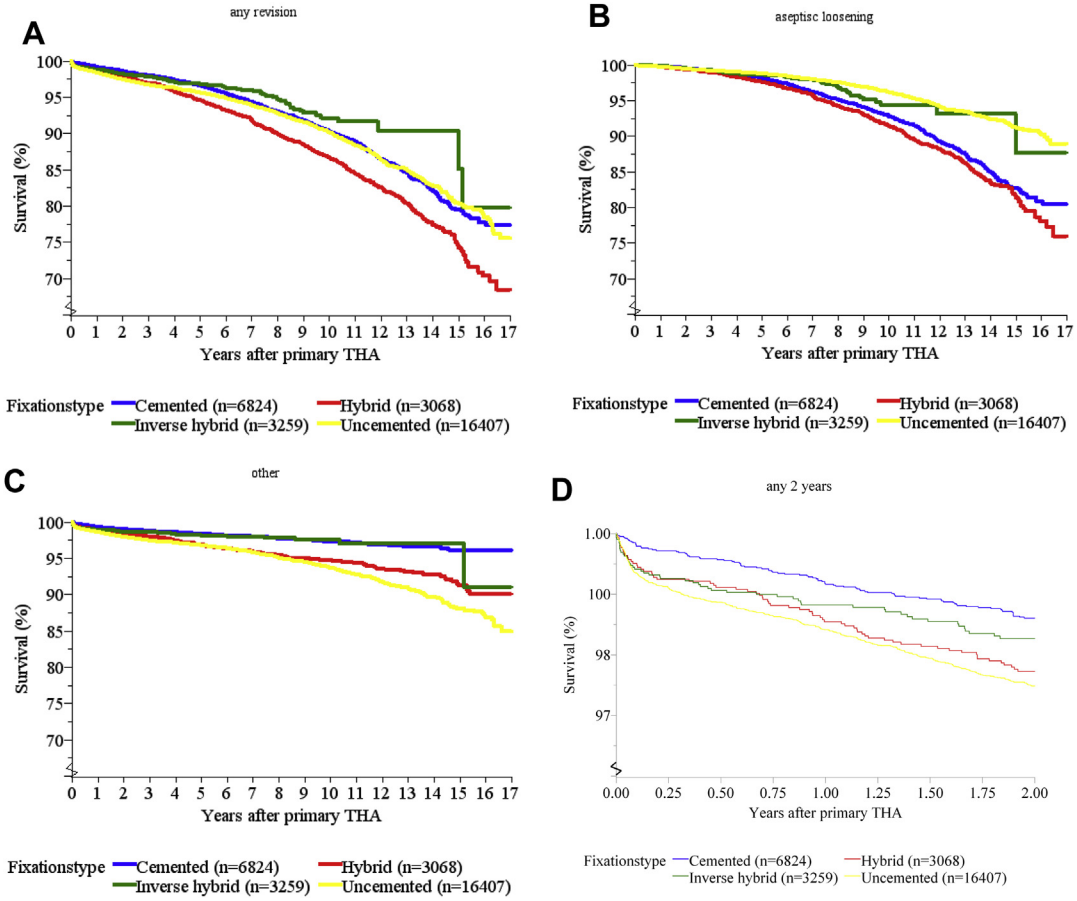

Fig. 1. A. KM survival according to fixation technique and any revision as an endpoint. B. KM survival according to fixation technique and revision due to aseptic loosening as an endpoint. C. KM survival according to fixation technique and revision due to other causes than aseptic loosening as an endpoint. D. KM survival according to fixation technique and revision due to any cause within 2 years of primary surgery as an endpoint.

revision due to other causes than aseptic loosening of 2.6 (CI: 2.2–3.2) compared to cemented implants (Table II) (Fig. 1(B,C)). In addition, risk of revision due to any cause within 2 years of surgery was almost twice as high for uncemented compared to cemented implants (RR = 1.8, CI: 1.4–2.3) (Fig. 1(D)). Hybrid fixation technique was associated with 34% (CI: 1.2–1.5) higher risk of any revision compared with the cemented technique during the period 1995–2011. No difference was observed between hybrid and cemented implants in relation to revision due to aseptic loosening, but hybrid implants led to an increased risk of revision of 2.1 (CI: 1.7–2.6) due to other causes than aseptic loosening compared with cemented implants (Table II). In addition, hybrid implants led to 65% higher risk of revision due to any cause within 2 years of surgery compared with cemented implants (CI: 1.2–2.3). We observed a tendency towards lower risk of any revision and revision due to aseptic loosening for inverse hybrid implants compared with cemented implants, but higher risk of other revisions (Table II).

The estimates did not differ between female and males, either between age groups 35–45 and 46–55 years of age.

Adjustment for the femoral head size and bearing surfaces, in addition to age, gender and calendar year of surgery in the separate analyses for the patients operated between 2002 and 2011 weakened the associations, but did not change substantially risk estimates when comparing fixation technique in relation to different revision outcomes (data not shown).

Supplementary appendix Table 1 present by gender and age groups the adjusted RR estimates with 95% CI for uncemented, hybrid and inverse hybrid implant with cemented implant as the reference group. The estimates did not deviate from the overall estimates for fixation techniques.

Fixation technique – time trend analyses

Results regarding fixation technique varied slightly through the four time periods. No difference was seen in the risk of any revision between uncemented and cemented implants when analyzing the data separately for each of the four different time periods [Fig. 2(A)]. Lower risk of revision due to aseptic loosening, increased risk of revision due to other causes than aseptic loosening, and increased risk of revision due to any cause within 2 years of primary surgery for uncemented compared with cemented implants was only evident in the periods 1995–1999, 2000–2003, 2004–2007, but not in the period 2008–2011 [Fig. 2(B–D)]. Comparing hybrid with cemented implants, any risk of revision was higher for hybrid implants in patients operated in the time periods 1995–1999 (RR = 1.3, CI: 1.1–1.5), 2000–2003 (RR = 1.3, CI: 1.0–1.7) and 2004–2007 (RR = 2.1, CI: 1.3–3.3), whereas it decreased in the period 2008–2011 (RR = 0.6, CI: 0.2–1.7) [Fig. 2(A)].

We presented crude KM survival data after 2, 10 and 16 years for different implants in relation to any revision, revision due to aseptic loosening and revision due to other causes than aseptic loosening in Table III. Supplementary appendix Table 2 present RR estimates for fixation technique according to follow-up period divided into 1 year intervals, indicating the same pattern regarding risk for revisions as observed in the four time periods.

Additional analyses of the 5 year and 10 years risk of any revision, revision due to aseptic loosening and revision due to other causes than aseptic loosening among patients with complete 5 and 10 years follow up are presented in Table IV. Again, uncemented implants had the same or increased risk of any revision compared with cemented implants, reduced risk of revision due to aseptic loosening and increased risk of revision due to other causes. Revision risk for hybrid and inverse hybrid implants compared with cemented has not changed substantially from the estimates presented in Table II.

Implant brands

Four types of uncemented implants were accounting for 30% of all uncemented THRs (thus, 3675 patients received the four most common uncemented implants, whereas 11,021 patients received other uncemented implants) (Table V). Likewise, 4041 (61%), 720 (27%) and 1043 (36%) patients received the four most common cemented, hybrid and inverse hybrid cup-stem implants, respectively. During the entire study period 1995–2011, 183 different uncemented cup-stem combinations were registered in Denmark and 94% were used in less than 100 operations. Similarly, in Norway, Sweden and Finland, 95%, 91%, and 94% uncemented combinations were used in less than 100 operations during the entire study period. The similar picture was seen for cemented cup-stem combinations in all four countries.

60 combinations were used in less than 100 operations. Likewise, in Norway, Sweden and Finland, 65 out of 69, 95 out of 106, and 73 out of 74 cemented combinations were used in less than 100 operations during the entire study period.

Discussion

Study population

More than half of our study population received uncemented implants, with between-countries variations from 37% to 84%. This is in agreement with the latest review of annual report data from seven international hip replacement registries, showing a current prevalence of uncemented implants among all THR patients of between 15% and 82%[24]. Uncemented implants, in particular the modern second-generation type, have been the first choice of implant for younger patients, whereas cemented implants were more commonly used in older patients[25–29]. Some countries, however, including Australia, Denmark, Finland and Canada predominantly use uncemented implants irrespective of patient age[25,28,30]. The increase in use of uncemented implants has been reported in all age groups, including older patients, despite reports showing that survival of cemented implants is clearly better than

Table II
Risk of revision according to fixation technique. *n* = number of revisions (%) among all primary THR operations in each category

Fixation technique		Any revision		Revision aseptic loosening		Revision other causes[†]		Revision due to any cause within 2 years	
		n (%)	HR (95% CI)[*]	*n* (%)	HR (95% CI)	*n* (%)	HR (95% CI)	*n* (%)	HR (95% CI)
Overall	Cemented	692 (10.1%)	**1.0 (ref.)**	526 (7.7%)	**1.0 (ref.)**	166 (2.4%)	**1.0 (ref.)**	92 (1.3%)	**1.0 (ref.)**
	Uncemented	1139 (6.9%)	1.0 (1.0–1.2)	403 (2.5%)	0.5 (0.5–0.6)	736 (4.5%)	2.6 (2.2–3.1)	379 (2.3%)	1.8 (1.4–2.3)
	Hybrid	47 4 (15.4%)	1.3 (1.2–1.5)	307 (10.0%)	1.1 (0.9–1.3)	167 (5.4%)	2.1 (1.7–2.6)	68 (2.2%)	1.7 (1.2–2.3)
	Inverse hybrid	108 (3.3%)	0.8 (0.7–1.0)	54 (1.7%)	0.8 (0.6–1.0)	54 (1.7%)	1.3 (1.0–1.8)	51 (1.6%)	1.2 (0.8–1.7)

[*] HR with 95% CI, mutually adjusted for gender, age, year of surgery.
[†] Revision other causes includes all revisions except revisions due to aseptic loosening during the entire follow-up period.

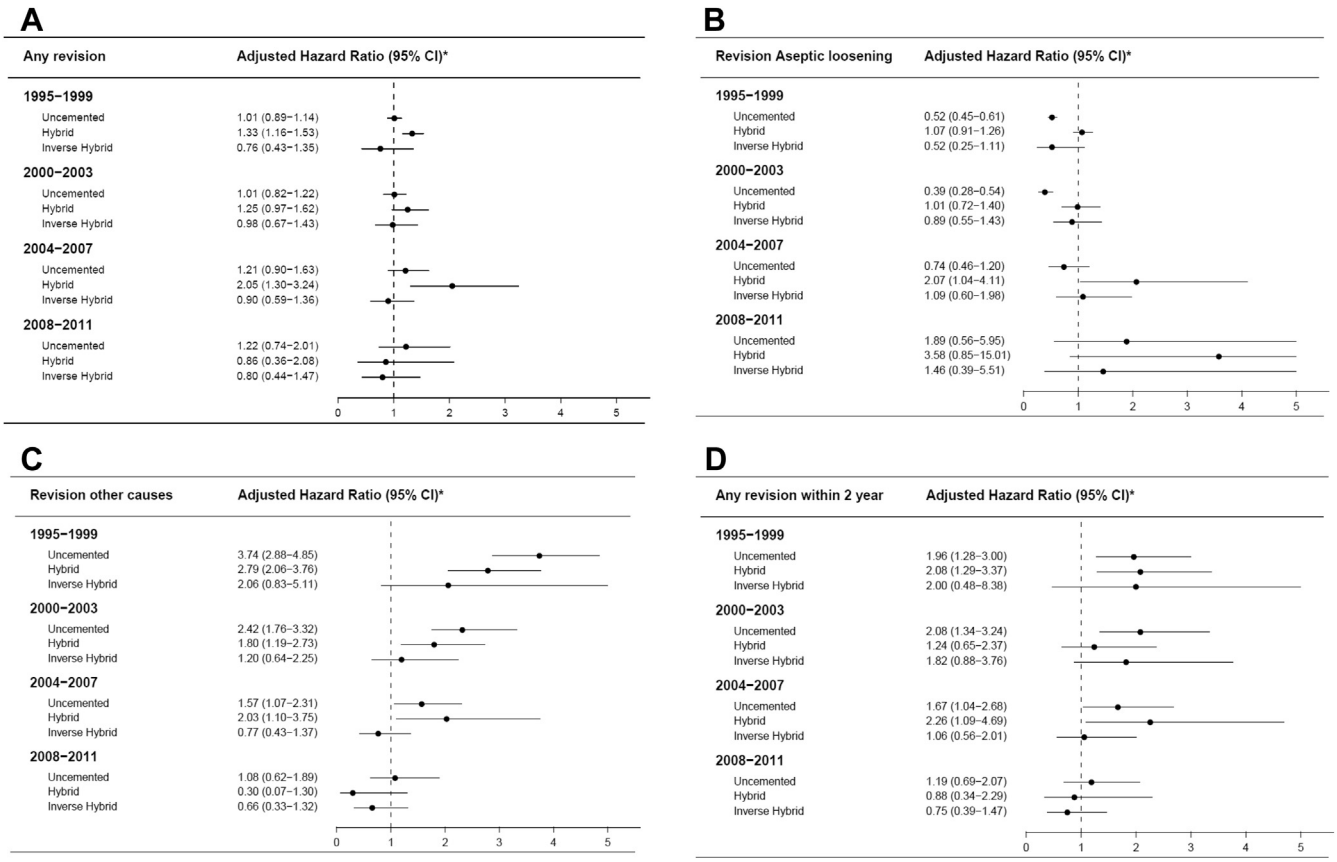

Fig. 2. A: Association between fixation technique and risk of any revision, time trend analyses. HR with 95% CI adjusted for sex and age. Reference: Cemented implants. B: Association between fixation technique and risk of revision due to aseptic loosening, time trend analyses. HR with 95% CI adjusted for sex and age. Reference: Cemented implants. C: Association between fixation technique and risk of revision due to other causes, time trend analyses. HR with 95% CI adjusted for sex and age. Reference: Cemented implants. D: Association between fixation technique and risk of any revision within 2 years of surgery, time trend analyses. HR with 95% CI adjusted for sex and age. Reference: Cemented implants.

uncemented implants among patients older than 75 years of age[12] and patients older than 65 years of age[31]. The recommendation on use of fixation technique should be further guided by the mortality risk which was found to be different between cemented and uncemented implants[32].

Fixation technique

Our analyses show that the risk of any revision related to uncemented implants was comparable to that of cemented implants, which confirms the recent findings from several registries including those of New Zealand, Sweden, Finland, England, Norway and Denmark[11,12,26,28,33,34]. Some of the uncemented implants introduced in Norway before 2000 were found to have higher overall risk of revision than cemented implants[33] and were consequently removed from the market. A systematic review and meta-analysis of nine randomized trials, including a total of 930 THRs with a mean age of 60 years also confirmed that there is no major difference between uncemented and cemented implants in relation to risk of any revision[35]. Results from the Australian Hip Registry[36] show also no difference between uncemented and cemented implants in relation to any revision, which change to

Table III
Unadjusted KM survival at 2, 10 and 16 years according fixation technique and different outcomes following primary THR operations 1995–2011

Fixation technique		2 years follow up		10 years follow up		16 years follow up	
		Survival	SE	Survival	SE	Survival	SE
Any revision	Cemented	98.6%	0.14	90.2%	0.43	77.4%	1.13
	Uncemented	97.5%	0.13	90.2%	0.35	75.6%	1.42
	Hybrid	97.7%	0.27	86.6%	0.69	68.5%	2.12
	Inverse hybrid	98.3%	0.24	92.2%	1.01	79.8%	7.22
Revision Aseptic loosening	Cemented	99.6%	0.43	92.8%	0.38	80.5%	1.13
	Uncemented	99.5%	0.06	96.2%	0.24	89.0%	1.03
	Hybrid	99.3%	0.15	91.4%	0.59	75.9%	2.17
	Inverse hybrid	99.5%	0.13	94.4%	0.97	87.7%	5.52
Revision other causes	Cemented	99.0%	0.12	97.3%	0.23	96.1%	0.39
	Uncemented	98.0%	0.11	93.7%	0.28	85.0%	1.26
	Hybrid	98.4%	0.23	94.8%	0.44	90.1%	1.08
	Inverse hybrid	98.7%	0.21	97.6%	0.41	91.0%	5.91

Table IV
Five and 10 years risk of revision by fixation techniques for among patients with complete 5 years follow up and those with complete 10 years follow up

Calendar year	Fixation technique	HR (95%-CI) any revision 5 years	HR (95%-CI) aseptic loosening 5 years	HR (95%-CI) other causes 5 years	HR (95%-CI) any revision 10 years	HR (95%-CI) aseptic loosening 10 years	HR (95%-CI) other causes 10 years
1995–2001	Cemented	**1.00 (reference)**	**1.00 (reference)**	**1.00 (reference)**	**1.00 (reference)**	**1.00 (reference)**	**1.00 (reference)**
	Uncemented	1.22 (0.97–1.54)	0.57 (0.40–0.82)	2.29 (1.63–3.21)	1.07 (0.93–1.23)	0.55 (0.45–0.66)	2.74 (2.14–3.51)
	Hybrid	1.68 (1.30–2.17)	1.16 (0.80–1.66)	2.53 (1.73–3.70)	1.42 (1.21–1.67)	1.16 (0.95–1.40)	2.28 (1.70–3.05)
	Inverse hybrid	0.88 (0.43–1.81)	0.35 (0.09–1.44)	1.76 (0.75–4.12)	0.68 (0.42–1.09)	0.59 (0.33–1.06)	0.96 (0.42–2.21)
1995–2006	Cemented	**1.00 (reference)**	**1.00 (reference)**	**1.00 (reference)**	–	–	–
	Uncemented	1.35 (1.13–1.61)	0.64 (0.48–0.84)	2.22 (1.74–2.84)	–	–	–
	Hybrid	1.74 (1.40–2.16)	1.30 (0.94–1.79)	2.28 (1.68–3.09)	–	–	–
	Inverse hybrid	1.01 (0.73–1.41)	0.72 (0.43–1.21)	1.37 (0.88–2.13)	–	–	–

HR adjusted for age and gender.

significantly lower risk of revision in uncemented implants after exclusion of large head size. Adjusting for head size, we were not able to achieve the same results. Uncemented implants were introduced in order to solve the problem of aseptic loosening of cemented implants[37] as well as wear of the acetabular bearing side[38], particularly in younger patients. Our study document both 5 and 10 years lower risk of revision due to aseptic loosening for uncemented vs cemented implants, which is in agreement with previous findings[11,28,34]. The risk estimates for the period 2008–2011 presented in Fig. 2(B) in relation to aseptic loosening are affected by high uncertainty (since the aseptic loosening occurs after a longer follow-up period) and should be interpreted with caution.

Uncemented implants may be more resistant to aseptic loosening but are more susceptible to revisions due to other causes, including dislocations, fractures and infections. The differences in the femoral head size and bearing surfaces used between cemented and uncemented implants could not entire explain the association we found. On the other hand, the potential difference in the use of cross-linked poly liner with documented low revision rate due to wear[39] between fixation types may affect our results. Unfortunately, information on highly cross-linked polyethylene use was not available in our dataset. The analyses from New Zealand showed a higher revision rate for uncemented vs cemented implants among all THR patients more than 90 days postoperatively due to dislocations, pain, periprosthetic femoral fractures and other causes, except deep infections[11]. Separate data on younger patients were not available in their study. Another study from Finland on patients less than 55 years of age found more dislocations, fractures and revisions due to other reasons in uncemented than cemented THRs[34], in addition to higher wear of the polyethylene liner among modular uncemented cups. A study based on Swedish data from the period 1992–2007 found an increased fracture risk around uncemented stems compared to cemented stems[12]. The increase in early revision risk due to dislocations, fractures and deep infections has been observed in many countries[26–28]. Several risk factors for dislocation have been identified including small femoral head size[40,41] and posterior surgical approach[42]. Further research is warranted to increase our understanding of the risk factors for dislocations, fractures and deep infections. However, integration of clinical expertise and evidence-based medicine including national hip registry data into the decision-making process for patient care to optimize clinical outcome remains a challenge. However, our findings presented in Fig. 2(D) of no major difference in the risk of revision due to any cause within 2 years of surgery in the latest time period when comparing different fixation types might be promising. Still, there is a lot of work to be done to overcome short-term problems of uncemented implants. A recent study, however, found that uncemented implants are still associated with low cost effectiveness when comparing improvement in health related outcomes[43].

Despite longer tradition of use of hybrid implant, a New Zealand study among younger patients found comparable survival of hybrid implants and cemented implants in relation to revision due to aseptic loosening[11], which is similar to our results. The results are also found in the Australian hip registry[36]. Hybrid implants were also in our study more susceptible to revision causes other than aseptic loosening, may be because of problems related to the uncemented cup component. The problem is not only short-term, since analyses among patients with complete 5 and 10 years follow up pointed up in the same direction. The slightly higher revision risk of on inverse hybrid compared with cemented was also related to other revision than aseptic loosening. This finding accords with previous reports of increased risk of early periprosthetic fractures and infections using inverse hybrid implants[44,45].

Table V
The most commonly used cup-stem implant combinations within each fixation technique of THR

Fixation technique	Cup – stem	Manufacturer	N (%)
Uncemented	Trilogy – Bimetric	Zimmer-Biomet	1352 (8.2%)
	Mallory-Head-Bimetric	Biomet	507 (3.1%)
	Pinnacle-Corail	DePuy	749 (4.6%)
	Trilogy – Spotorno	Zimmer-NMS	1105 (6.7%)
	Other		11,676 (71.2%)
	Total		16,407
Cemented	Lubinus – Lubinus SP II	Link	1782 (27.1%)
	Charnley – Charnley	DePuy	1023 (14.9%)
	Exeter – Exeter	Stryker	986 (15.0%)
	Reflection – Spectron	Smith & Nephew	270 (4.0%)
	Other		2759 (40.4%)
	Total		6824
Hybrid	Trilogy – Spectron EF	Zimmer-Smith & Nephew	139 (4.5%)
	Mallory Head – Exeter	Biomet – Stryker	185 (6.1%)
	Trilogy – Lubinus SP II	Zimmer-Link	258 (8.4%)
	Trilogy – Exeter	Zimmer-Stryker	155 (5.0%)
	Other		2204 (71.8%)
	Total		3068
Inverse Hybrid	Elite – Corail	DePuy – DePuy	317 (9.7%)
	Elite – ABG	DePuy-Stryker	217 (6.7%)
	Reflection – Corail	Smith & Nephew-DePuy	146 (4.5%)
	Marathon – Corail	DePuy	376 (11.5%)
	Other		2202 (67.6%)
	Total		3259

Implants brands

Another interesting but concerning finding in our study is the fact that about 70% of the THR patients received more than 100 different uncemented cup-stem implant combinations rather than one of the most common combinations presented in Table III. It is

worrisome that the majority of combinations available on the market have only been used in less than 100 operations during the 17 years long study period. Other registries reported that more than 70% of their new introduced implants was used in less than 100 cases which is a problem since about 30% of these implants had higher revision rate compared to well established implants in the same class and none of the implants performed better[15,16]. Low number of observations and few revisions hampers conclusive analyses of single combinations. The clinicians are familiar with parts of the health technology assessment process in the context of the introduction of new drugs and the phases I to IV of drug trial development[46]. However, the assessment of novel surgical devices has not quite reached the level of pharmacological trials. More than two decades ago, stepwise introduction of new hip implants was introduced with growing acceptance, including clinical trials, radiostereometry, digitized radiography and a national hip registry[47]. One may argue that implants used in a small number of operations are in phase IV of a stepwise introduction. In addition, the introduction of new implants involves aspects not known in drug trials, such as surgeons needing to acquire new practical skills and go through a "learning curve", efficacy vs effectiveness issues, and cost-benefit assessments of implants. The number of different surgeons using specific implants and surgeon volume is variables further needed to fully understand the size of the problem. However, it has been shown previously that low hospital volume affect more survival of uncemented than cemented implants[48] which might be an extra argument for using cemented implants since they are not so prone to technical error. The high number of implant combinations on the market makes novelty of new implants questionable. The validity of implant brands and combinations reported to NARA is not fully known as only three of the four registries in NARA are using the catalog numbers to identify the implants. This system, when fully implemented would in future enable uniformly identification and comparison of implant within- and between countries.

Methodological considerations

We used the NARA dataset, which includes registry data from four Scandinavian countries with well-documented registration completeness and data validity[17–19]. By using the NARA database we were able to obtain a sufficient number of patients to get reliable risk estimates for revision. Still, we were not able to perform detailed analyses on different implant brands and combinations. Although we performed multivariate analyses controlling for some confounders we cannot entirely exclude the impact of bias on our estimates. For example, we did not have information on surgeon volume which might explain some of our findings in relation to higher early revision rates of uncemented and hybrid implants. However, this information has merely been available in previous studies on the same subject. Although patient and surgeon preferences may be related to age and sex[49], we have no reason to believe that these preferences are related to fixation technique in this young patient population. The assumption of proportional hazard was not fulfilled in Cox regression analyses for fixation technique which we partly dealt with splitting the follow-up period. However we still reported the overall RR estimates being very well aware that our risk estimates might be biased in order to be able to compare our results with the results from other registries using the same method.

In conclusion, in this large population-based study on younger THR patients, risk of any revision was similar for uncemented and cemented implants whereas it was higher for hybrid implants. Uncemented implants perform better in relation to long-term risk of aseptic loosening, whereas both uncemented and hybrid rather than cemented implants in patients younger than 55 years had more short-term revisions because problems due to dislocation, periprosthetic fracture and infection has not yet been completely solved. The vast majority of implant combinations were used in very few operations.

Contributions

ABP, JK, LIH, OF, GG and SO conceived the study idea and developed it in collaboration with the other co-authors. All authors contributed to the design of the study. FM and ABP collected the data. ABP reviewed the literature. ABP, FM, LIH, OF, AE and JK directed the analyses, which were carried out by FM. All authors participated in the discussion and interpretation of the results. ABP organized the writing and wrote the initial draft. All authors critically revised the manuscript for intellectual content and approved the final version before submission. ABP and FM take responsibility for the integrity of the data and the accuracy of the data analyses.

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Competing interests

All authors have completed the ICMJE form for disclosure of potential conflicts of interest at http://jama.jamanetwork.com/data/ifora-forms/icmje-author_form.pdf (available on request from the corresponding author) and declare that[1] no authors have received support from any company for the submitted work. The Department of Clinical Epidemiology at Aarhus University Hospital is involved, however, in studies with funding from various companies as research grants to (and administered by) Aarhus University. None of these studies have any relation to the present study[2]; ABP, FM, LIH, OF, PH, JK, KM, and SO have no financial relationships with any company that might have an interest in the submitted work in the previous three years. GG is a board member of the Swedish Hip Arthroplasty Register and has received a speaker's fee from Biomet and Link. AE has received a speaker's fee from DePuy. None of these funding sources had a role in the design, conduct, analysis, or reporting of the submitted work[3]; their spouses, partners, or children have no financial relationships that may be relevant to the submitted work[4]; no authors have non-financial interests that may be related to the submitted work.

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.joca.2014.03.005

References

1. Johnsen SP, Sorensen HT, Lucht U, Soballe K, Overgaard S, Pedersen AB. Patient-related predictors of implant failure after primary total hip replacement in the initial, short- and long-terms. A nationwide Danish follow-up study including 36,984 patients. J Bone Joint Surg Br 2006 October;88(10):1303–8.
2. Katz JN, Wright EA, Wright J, Malchau H, Mahomed NN, Stedman M, *et al.* Twelve-year risk of revision after primary

total hip replacement in the U.S. Medicare population. J Bone Joint Surg Am 2012 October 17;94(20):1825–32.
3. Prokopetz JJ, Losina E, Bliss RL, Wright J, Baron JA, Katz JN. Risk factors for revision of primary total hip arthroplasty: a systematic review. BMC Musculoskelet Disord 2012;13:251.
4. Bijnen FC, Feskens EJ, Caspersen CJ, Mosterd WL, Kromhout D. Age, period, and cohort effects on physical activity among elderly men during 10 years of follow-up: the Zutphen Elderly Study. J Gerontol A Biol Sci Med Sci 1998 May;53(3):M235–41.
5. Dey DK, Rothenberg E, Sundh V, Bosaeus I, Steen B. Height and body weight in the elderly. I. A 25-year longitudinal study of a population aged 70 to 95 years. Eur J Clin Nutr 1999 December;53(12):905–14.
6. Engesaeter LB, Engesaeter IO, Fenstad AM, Havelin LI, Karrholm J, Garellick G, *et al*. Low revision rate after total hip arthroplasty in patients with pediatric hip diseases. Acta Orthop 2012 October;83(5):436–41.
7. Furnes O, Lie SA, Espehaug B, Vollset SE, Engesaeter LB, Havelin LI. Hip disease and the prognosis of total hip replacements. A review of 53,698 primary total hip replacements reported to the Norwegian Arthroplasty Register 1987-99. J Bone Joint Surg Br 2001 May;83(4):579–86.
8. Thillemann TM, Pedersen AB, Johnsen SP, Soballe K. Implant survival after primary total hip arthroplasty due to childhood hip disorders: results from the Danish Hip Arthroplasty Registry. Acta Orthop 2008 December;79(6):769–76.
9. Corbett KL, Losina E, Nti AA, Prokopetz JJ, Katz JN. Population-based rates of revision of primary total hip arthroplasty: a systematic review. PLoS One 2010;5(10):e13520.
10. Eskelinen A, Remes V, Helenius I, Pulkkinen P, Nevalainen J, Paavolainen P. Total hip arthroplasty for primary osteoarthrosis in younger patients in the Finnish arthroplasty register. 4,661 primary replacements followed for 0–22 years. Acta Orthop 2005 February;76(1):28–41.
11. Hooper GJ, Rothwell AG, Stringer M, Frampton C. Revision following cemented and uncemented primary total hip replacement: a seven-year analysis from the New Zealand Joint Registry. J Bone Joint Surg Br 2009 April;91(4):451–8.
12. Hailer NP, Garellick G, Karrholm J. Uncemented and cemented primary total hip arthroplasty in the Swedish Hip Arthroplasty Register. Acta Orthop 2010 February;81(1):34–41.
13. Smith AJ, Dieppe P, Vernon K, Porter M, Blom AW. Failure rates of stemmed metal-on-metal hip replacements: analysis of data from the National Joint Registry of England and Wales. Lancet 2012 March 31;379(9822):1199–204.
14. Havelin LI, Fenstad AM, Salomonsson R, Mehnert F, Furnes O, Overgaard S, *et al*. The Nordic Arthroplasty Register Association: a unique collaboration between 3 national hip arthroplasty registries with 280,201 THRs. Acta Orthop 2009 August;80(4):393–401.
15. Anand R, Graves SE, de Steiger RN, Davidson DC, Ryan P, Miller LN, *et al*. What is the benefit of introducing new hip and knee prostheses? J Bone Joint Surg Am 2011 December 21;93(Suppl 3):51–4.
16. Kmietowicz Z. Patients who have new types of hip and knee replacement are more likely to need revision. BMJ 2008;337:a1520.
17. Espehaug B, Furnes O, Havelin LI, Engesaeter LB, Vollset SE, Kindseth O. Registration completeness in the Norwegian Arthroplasty Register. Acta Orthop 2006 February;77(1):49–56.
18. Pedersen A, Johnsen S, Overgaard S, Soballe K, Sorensen H, Lucht U. Registration in the Danish Hip Arthroplasty Registry: completeness of total hip arthroplasties and positive predictive value of registered diagnosis and postoperative complications. Acta Orthop Scand 2004 August;75(4):434–41.
19. Soderman P. On the validity of the results from the Swedish National Total Hip Arthroplasty register. Acta Orthop Scand Suppl 2000 December;71(296):1–33.
20. Gjertsen JE, Engesaeter LB, Furnes O, Havelin LI, Steindal K, Vinje T, *et al*. The Norwegian Hip Fracture Register: experiences after the first 2 years and 15,576 reported operations. Acta Orthop 2008 October;79(5):583–93.
21. Johanson PE, Fenstad AM, Furnes O, Garellick G, Havelin LI, Overgaard S, *et al*. Inferior outcome after hip resurfacing arthroplasty than after conventional arthroplasty. Evidence from the Nordic Arthroplasty Register Association (NARA) database, 1995 to 2007. Acta Orthop 2010 October;81(5):535–41.
22. Lie SA, Engesaeter LB, Havelin LI, Gjessing HK, Vollset SE. Dependency issues in survival analyses of 55,782 primary hip replacements from 47,355 patients. Stat Med 2004 October 30;23(20):3227–40.
23. Ranstam J, Karrholm J, Pulkkinen P, Makela K, Espehaug B, Pedersen AB, *et al*. Statistical analysis of arthroplasty data. II. Guidelines. Acta Orthop 2011 June;82(3):258–67.
24. Troelsen A, Malchau E, Sillesen N, Malchau H. A review of current fixation use and registry outcomes in total hip arthroplasty: the uncemented paradox. Clin Orthop Relat Res 2013 July;471(7):2052–9.
25. Annual ReportAustralian Orthopaedic Association National Joint Replacement Registry. Adelaide: AOA; 2011.
26. 8th Annual Report 2011National Joint Registry for England and Wales 2011.
27. New Zealand Joint Registry. New Zealand Orthopaedic Association; 2012. Twelve year Report.
28. Annual Report 2012Danish Hip Arthroplasty Register 2013.
29. Annual Report 2010Swedish Hip Arthroplasty Register 2013.
30. 2013 Annual ReportHip and Knee Replacement in Canada; Canadian Joint Replacement Registry (CJRR), ISBN 978-1-77109-182-4; 2013. Report No.
31. Makela KT, Matilainen M, Pulkkinen P, Fenstad AM, Havelin L, Engesaeter L, *et al*. Failure rate of cemented and uncemented total hip replacements: register study of combined Nordic database of four nations. BMJ 2014;348:f7592.
32. McMinn DJ, Snell KI, Daniel J, Treacy RB, Pynsent PB, Riley RD. Mortality and implant revision rates of hip arthroplasty in patients with osteoarthritis: registry based cohort study. BMJ 2012;344:e3319.
33. Havelin LI, Engesaeter LB, Espehaug B, Furnes O, Lie SA, Vollset SE. The Norwegian Arthroplasty Register: 11 years and 73,000 arthroplasties. Acta Orthop Scand 2000 August;71(4):337–53.
34. Makela KT, Eskelinen A, Pulkkinen P, Paavolainen P, Remes V. Results of 3,668 primary total hip replacements for primary osteoarthritis in patients under the age of 55 years. Acta Orthop 2011 October;82(5):521–9.
35. Abdulkarim A, Ellanti P, Motterlini N, Fahey T, O'Byrne JM. Cemented versus uncemented fixation in total hip replacement: a systematic review and meta-analysis of randomized controlled trials. Orthop Rev (Pavia) 2013 February 22;5(1):e8.
36. Annual Report 2013Australian Orthopaedic Association National Joint Replacement Registry 2013.
37. Makela K, Eskelinen A, Pulkkinen P, Paavolainen P, Remes V. Cemented total hip replacement for primary osteoarthritis in patients aged 55 years or older: results of the 12 most common cemented implants followed for 25 years in the Finnish Arthroplasty Register. J Bone Joint Surg Br 2008 December;90(12):1562–9.

38. Laupacis A, Bourne R, Rorabeck C, Feeny D, Tugwell P, Wong C. Comparison of total hip arthroplasty performed with and without cement – a randomized trial. J Bone Joint Surg Am 2002 October;84A(10):1823–8.
39. McCalden RW, MacDonald SJ, Rorabeck CH, Bourne RB, Chess DG, Charron KD. Wear rate of highly cross-linked polyethylene in total hip arthroplasty. A randomized controlled trial. J Bone Joint Surg Am 2009 April;91(4):773–82.
40. Berry DJ, von KM, Schleck CD, Harmsen WS. Effect of femoral head diameter and operative approach on risk of dislocation after primary total hip arthroplasty. J Bone Joint Surg Am 2005 November;87(11):2456–63.
41. Bystrom S, Espehaug B, Furnes O, Havelin LI. Femoral head size is a risk factor for total hip luxation: a study of 42,987 primary hip arthroplasties from the Norwegian Arthroplasty Register. Acta Orthop Scand 2003 October;74(5):514–24.
42. Arthursson AJ, Furnes O, Espehaug B, Havelin LI, Soreide JA. Prosthesis survival after total hip arthroplasty–does surgical approach matter? Analysis of 19,304 Charnley and 6,002 Exeter primary total hip arthroplasties reported to the Norwegian Arthroplasty Register. Acta Orthop 2007 December;78(6):719–29.
43. Pennington M, Grieve R, Sekhon JS, Gregg P, Black N, van der Meulen JH. Cemented, cementless, and hybrid prostheses for total hip replacement: cost effectiveness analysis. BMJ 2013;346:f1026.
44. Dale H, Fenstad AM, Hallan G, Havelin LI, Furnes O, Overgaard S, *et al*. Increasing risk of prosthetic joint infection after total hip arthroplasty. Acta Orthop 2012 October;83(5):449–58.
45. Lindalen E, Havelin LI, Nordsletten L, Dybvik E, Fenstad AM, Hallan G, *et al*. Is reverse hybrid hip replacement the solution? Acta Orthop 2011 December;82(6):639–45.
46. Kumar A, Gopinath V. New Drug Development: A Review 2013 June 30. http://www.irjpas.com/zipphp?file=File_Folder/IRJPAS%203%283%2929-37.pdf&id=235&quat=3.
47. Malchau H. On the Importance of Stepwise Introduction of New Hip Implant Technology: Assessment of Total Hip Replacement Using Clinical Evaluation, Radiostereometry, Digitezed Radiography and a National Hip Registry [Thesis]. Sweden: Göteborg University; 1995.
48. Espehaug B, Havelin LI, Engesaeter LB, Vollset SE. The effect of hospital-type and operating volume on the survival of hip replacements. A review of 39,505 primary total hip replacements reported to the Norwegian Arthroplasty Register, 1988–1996. Acta Orthop Scand 1999 February;70(1):12–8.
49. Franks P, Clancy CM. Referrals of adult patients from primary care: demographic disparities and their relationship to HMO insurance. J Fam Pract 1997 July;45(1):47–53.