Total hip arthroplasty for primary osteoarthrosis in younger patients in the Finnish arthroplasty register

4 661 primary replacements followed for 0–22 years

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Background Many studies have found a higher risk of revision after hip arthroplasty in younger patients. We evaluated the population-based survival of total hip arthroplasty (THA) in patients under 55 years of age and the factors affecting survival.

Methods The Finnish Arthroplasty Register was established in 1980, and 74 492 primary THAs were entered into the register between 1980 and 2001. 4 661 of these were evaluated, all of which had been performed for primary osteoarthrosis on patients under 55 years of age.

Results Proximally circumferentially porous-coated uncemented stems implanted between 1991 and 2001 had a 10-year survival rate of 99 (95% CI 98.5–99.6)% with aseptic loosening as endpoint. The risk of stem revision due to aseptic loosening was higher in cemented stems than in proximally porous-coated (RR 5.5, $p < 0.001$) or HA-coated (RR 6.6, $p = 0.01$) uncemented stems implanted during the same period.

According to Cox regression analysis of cups implanted 1991–2001, the risk of revision for all-polyethylene cemented cups was 3.0 times as high as that for press-fit porous-coated uncemented cups with aseptic loosening as endpoint ($p = 0.01$). However, when the endpoint was defined as any revision (including exchange of liner), there was no longer any difference between these two concepts, the 10-year survival rates being 94 (92.1–95.5)% for press-fit porous-coated uncemented cups and 93 (88.5–97.6)% for all-polyethylene cemented cups ($p = 0.9$).

Interpretation Modern uncemented stems seem to have better resistance to aseptic loosening than cemented stems in younger patients. Thus, for younger patients, uncemented proximally circumferentially porous- and HA-coated stems are the implants of choice. Press-fit porous- and HA-coated uncemented cups may have better endurance against aseptic loosening than cemented cups in younger patients. However, when all revisions (including exchange of liner) are taken into account, the survival of modern uncemented cups is no better than that of all-poly cemented cups.

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Due to higher demands of the population and the better long-term results of THA, the proportion of younger and more active patients being treated with this procedure has steadily increased. A good long-term outcome (≥ 90% 10-year survival rate, NICE 2003) has been recorded for patients under 55 years of age, but most of these reports have been from highly specialized clinics and refer to only one brand of implant (McLaughlin and Lee 2000, Kim et al. 2002, Aldinger et al. 2003, Capello et al. 2003, Jacobsen et al. 2003, Kim et al. 2003). Only a few register-based studies have reported the results of THA in young patients at a population-based level (Havelin et al. 2000, Malchau et al. 2002). Most previous studies have found that the risk of revision is higher in younger patients than

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in older ones (Herberts and Malchau 2000, Furnes et al. 2001).

We evaluated the population-based survival of primary THA for primary osteoarthrosis in patients under 55 years of age, and the factors affecting survival of the implants.

Patients and methods

The Finnish Arthroplasty Register

Finland has a population of approximately 5.2 million. Since 1980, the Finnish Arthroplasty Register has been collecting information on total hip, knee, ankle, shoulder, elbow, wrist and hand joint replacements. Health care authorities, institutions and orthopedic units are obliged to provide the National Agency for Medicines with information that is essential for maintenance of the Register.

The coverage of the Finnish Arthroplasty Register was analyzed in 1994–1995 by comparing its data with those of the discharge registers of the participating hospitals; it was found to cover 90% of implantations. Since 1995, the data of the register have been compared with those of hospital discharge registers every few years. Currently, over 95% of implantations are recorded. An English translation of the notification form used by the Finnish Arthroplasty Register has been discussed previously (Puolakka et al. 2001a).

History of the Arthoplasty Register and time-dependent trends

Since the Finnish Arthroplasty Register was founded, details have been collected about every single THA performed. Detailed information about femoral and acetabular components and about head diameter and type has, however, only been recorded separately since 1996. Information about the cementing technique, the cement mixing technique and brand of cement used, the application of systemic antibiotic prophylaxis, and the occurrence of primary complications, if any, has also been collected since 1996. Owing to the different types of data entered into the register at different times, the above factors could not be included in analyses covering the whole follow-up period. Data on prostheses implanted in 1980–1995 have been checked in the past few years, and thus data on cups and stems could be used separately in all analyses.

Table 1. Numbers of THAs performed in Finland from 1980 to 2001 and subgroups analyzed in the study

	No. of operations
All THAs 1980–2001	74 492
< 55 years of age	10 460
Primary arthrosis	4 661
46–54 years of age	3 811
< 46 years of age	850

Epidemiological trends were analyzed for three time periods: 1980–1981, 1990–1991, and 2000–2001. The effects of implant fixation (cemented vs. uncemented) and implant concept on the survival of THA were analyzed separately for the whole study period and for the decades 1980–1990 and 1991–2001.

Inclusion criteria

During the whole study period (1980–2001), 74 492 THAs were performed in Finland. Of these operations, 10 460 (14%) were performed on patients under 55 years of age and primary osteoarthrosis was the indication in 45% (n = 4 661) of these cases. These 4 661 THAs were therefore included in the final analysis (Table 1). The study group consisted of 3 657 patients, 27% (n = 1 004) of whom were operated bilaterally. The median duration of follow-up was 6.2 (0–22) years.

Primary operation

The gender, age and personal identification number of the patients and the affected side had been recorded for all primary operations. The effect of hospital type on THA survival was studied by dividing the hospitals into subgroups by number of operations performed annually for primary osteoarthrosis on patients under 55 years of age, i.e., more than 10 operations, or 10 or less. The number and percentage of different implants used in the operations and the fixation method of each component (cemented or uncemented) were evaluated.

The success rates of different implant concepts were analyzed. For statistical comparisons, stems were divided into 5 groups, and cups into 4 groups. The stems were classified as uncemented proximally circumferentially porous-coated, uncemented extendedly porous-coated (porous-coating on more than half of the stem length), uncemented proximally circumferentially HA-coated, uncemented uncoated (including isoelastic, grit-blasted and sand-blasted uncemented stems), and cemented (including polished, grit-blasted and sand-blasted cemented stems). The cups were classified as uncemented porous-coated press-fit, uncemented HA-coated press-fit, uncemented smooth-threaded and cemented all-polyethylene. Only implant brands used in 10 or more operations over the whole study period were included in the concept analysis (Appendix 1).

Revision operation

For a revision arthroplasty, the date of the index operation, the design of the revised prosthesis and the indication for revision were recorded. Indications for revision and the revision burden (derived as a percentage by dividing the number of revisions done over a certain period by the total number of primary and revision THAs performed over the same period) were analyzed.

Statistics

Associations between categorical variables were analyzed by the Chi-square test or Fisher's exact test, whichever was appropriate. The normality of distributions was established by the Kolmogoroff-Smirnoff goodness-of-fit test with the Lilliefors (1967) method of significance correction. The independent samples t-test was applied for comparisons between two normally distributed groups. When the distributions were skewed, the Mann-Whitney U-test was applied.

The endpoint for survival was defined as revision when either one component (including exchange of liner) or the whole implant was removed or exchanged. Kaplan-Meier survival data were used to construct the survival probabilities of implants at 7 and 10 years. Survival data obtained in the Kaplan-Meier analysis were compared by the log-rank test. The Cox multiple-regression model was applied to study differences between groups and to adjust for potential confounding factors. The factors studied with the Cox model were as follows: implant concepts, fixation of stems and cups (cemented vs. uncemented), hospital THA volume (≤ 10 THAs or > 10 THAs annually), age group (≤ 45 and 46–54 years), and gender. All models included adjustment for differences in age (≤ 45 and 46–54 years) and gender. When effect of age, sex and hospital volume on survival of implants were analyzed with the Cox model, adjustment was also made for implant concepts (Furnes et al. 2001). Cox regression analyses provided estimates of survival probabilities and revision risk ratios (RR) for different factors. Estimates from Cox analyses were used to construct adjusted survival curves at mean values of the risk factors. The Wald test was applied to calculate p-values for data obtained from the Cox multiple regression analysis. Differences between groups were considered statistically significant if the p-values were less than 0.05 in a two-tailed test.

We used SPSS 11.0 software (SPSS Inc., Chicago, IL, USA).

Results

Primary operation

Patient characteristics. Of the 4 661 THAs, 3 811 (82%) were performed on patients aged 46–54 years and the rest on patients aged 45 years or younger (Table 1). Of all THAs, 2 508 (54%) were performed on the right hip. Males made up 2 420 (52%) of the patients.

The number of hospitals performing THAs for primary osteoarthrosis on younger patients increased over the study period, from 30 at the beginning of the period (1980–1981) to 49 in the early years of the following decade (1990-1991), and to 64 at the end of the study period (2000–2001). Over the whole study period, only 5 hospitals (3 university hospitals, 1 hospital run by a private foundation and one central hospital) performed more than 10 THAs annually on patients under 55 years of age. During the last time period analyzed (2000–2001), 52 of the 64 hospitals studied performed fewer than 10 THAs annually on these younger patients.

Femoral components. Over the whole study period, 73 different femoral components were used, 52 of them in fewer than 20 operations. 78% of the stems implanted were uncemented and 22%

Table 2a. Distribution of femoral and acetabular components implanted during three time periods

	1980–1981	1990–1991	2000–2001
Stem % (n)			
Uncemented	2% (3)	95.8% (410)	81.9% (601)
Cemented	98% (151)	4.2% (18)	18.1% (133)
Cup % (n)			
Uncemented	2% (3)	94.8% (405)	87.7% (643)
Cemented	98% (151)	5.2% (22)	12.3% (90)

Table 2b. The most common femoral and acetabular components implanted during three time periods

	1980–1981		1990–1991		2000–2001	
	Brand	n (%)	Brand	n (%)	Brand	n (%)
Stem	Lubinus IP	60 (36.1)	Bi-Metric	144 (33.3)	Bi-Metric	305 (41.6)
	Brunswick	20 (12.0)	Mathys Isoelast.	54 (12.5)	ABG HA	165 (22.5)
	Charnley	17 (10.2)	Anatomic Mesh	44 (10.2)	Exeter Universal	38 (5.2)
Cups	Lubinus Std	62 (37.3)	Biomet PFU	98 (22.6)	ABG HA	180 (24.5)
	Brunswick	20 (12.0)	HG II	60 (13.9)	Biomet Vision	167 (22.8)
	Charnley	17 (10.2)	PC Pegged	44 (10.2)	Biomet PFU	73 (9.9)

were cemented. At the end of the study period (2000-2001), the 3 most common stem brands (Bi-Metric, ABG HA and Exeter Universal) accounted for 72% of all stems implanted. The proportion of uncemented stems rose dramatically from the beginning of the study to the early 1990s (Table 2a and b).

Acetabular components. Between 1980 and 2001 inclusive, 79 different acetabular components were used in Finnish hospitals, 47 of them in fewer than 20 operations. 82% of the cups implanted were uncemented and 18% were cemented. At the end of the study period (2000–2001), the 3 most common cup brands (ABG HA, Biomet Vision and Biomet PFU) constituted 64% of all cups implanted. The proportion of uncemented cups also rose markedly from the beginning of the study period to the early 1990s (Table 2a and b).

Revision operation

During the study period, the total number of THA revision operations performed on patients who had undergone THA for primary osteoarthrosis at the age of 54 years or younger was 709. Thus, the revision burden was 15% for the whole follow-up period. The most common reason for revision was aseptic loosening, which accounted for 82% (n = 581) of operations. The next most common reason was fracture of the implant, which amounted to 3.0% (n = 21) of revisions. Infection and prosthesis dislocation each accounted for 2.7% (n = 19) of operations. Malposition of the prosthesis was the reason for revision in 2.3% (n = 16) and periprosthetic fracture in 1.1% (n = 8) of cases. Other, miscellaneous reasons accounted for 6.3% (n = 45) of revisions.

Follow-up results for all primary operations

Stem fixation. Kaplan-Meier analysis of all data showed that the survival of uncemented stems was significantly higher than that of cemented stems (all revisions: $p < 0.001$; aseptic loosening: $p < 0.001$). The Cox regression analysis, with or without adjustment for age and gender, gave similar results.

Kaplan-Meier analysis of stems implanted during the first decade (1980–1990) of the study period showed that survival of uncemented stems was notably better than that of cemented stems (all revisions: $p < 0.002$; aseptic loosening: $p < 0.001$). In Kaplan-Meier analysis of the last decade, there was a difference in overall survival in favor

Table 3. Survival of implant concepts. Endpoint defined as revision due to any reason. 7- and 10-year survival rates obtained from the Kaplan-Meier analysis

Implant concept	No. of revisions /total operations	Mean FU (yr)	At risk 7 yr	% 7-year survival (95% CI)	At risk 10 yr	% 10-year survival (95% CI)	Adjusted RR for revision (95% CI)	P-value
Stems								
Prox. porous-coated uncemented	106/2197	5.9	739	95 (93–96)	225	91 (89–93)	0.6 (0.4–0.8)	<0.001
Ext. porous-coated uncemented	37/318	11	240	93 (90–96)	186	89 (85–93)	0.5 (0.3–0.7)	<0.001
HA-coated uncemented	8/526	3.4	41	95 (91–99)	0	–	0.5 (0.2–1.0)	0.05
Uncoated uncemented	89/441	9.3	310	88 (85–91)	206	80 (75–84)	1.2 (0.9–1.6)	0.2
Cemented	154/833	9.6	462	92 (90–94)	359	87 (84–90)	1.0	
Cups								
Porous-coated uncemented	114/2194	5.6	673	94 (93–96)	197	88 (85–90)	0.8 (0.6–1.1)	0.2
HA-coated uncemented	10/571	3.3	54	95 (91–99)	6	93 (88–98)	0.7 (0.4–1.4)	0.4
Smooth threaded uncemented	228/650	10	447	83 (80–86)	322	69 (65–73)	2.0 (1.6–2.4)	<0.001
All-poly cemented	155/802	11	536	93 (92–95)	409	87 (85–90)	1.0	

FU = follow-up. RR = risk ratio from the Cox regression analysis (uncemented concepts compared to cemented concept; adjustment made for age and gender).

of uncemented stems with aseptic loosening as endpoint ($p < 0.001$). However, the difference in survival rates between uncemented and cemented stems was not statistically significant when endpoint was defined as any revision ($p = 0.2$). Similar results were obtained from the Cox regression analysis, both with and without adjustment for age and gender.

Cup fixation. When the whole study period was analyzed, we found no differences in survival rates between cemented and uncemented cups, either in the Kaplan-Meier analysis or in the Cox regression model.

In the Kaplan-Meier analysis of cups implanted during the first decade (1980–1990), overall survival of cemented cups was better than that of uncemented cups (all revisions: $p = 0.01$; aseptic loosening: $p = 0.02$). The Cox regression analysis gave similar results (with or without adjustment for age and gender).

Neither Kaplan-Meier analysis nor the Cox regression model revealed any differences in survival rates between cemented and uncemented cups implanted during 1991–2001, either with all revisions or aseptic loosening as endpoint.

Stem concepts. Analysis of the whole study period showed that proximally and extendedly porous-coated uncemented stems had better overall survival than uncoated uncemented or cemented stems with all revisions as endpoint ($p < 0.001$ for all comparisons; Table 3). The overall survival rate of HA-coated uncemented stems was higher than that of uncoated uncemented stems ($p = 0.001$). There was also a trend for better survival of HA-coated uncemented stems than of cemented stems, but the difference was not statistically significant ($p = 0.05$). When aseptic loosening was defined as endpoint, both porous-coated and HA-coated uncemented stems showed better overall survival than other stem concepts (HA-coated vs. extendedly porous-coated: $p = 0.004$; HA-coated uncemented vs. cemented: $p = 0.02$; $p < 0.001$ for all other comparisons; Table 4). The overall survival rate of extendedly porous-coated uncemented stems was higher than that of uncoated uncemented ($p = 0.001$) and cemented stems ($p < 0.001$).

The 7- and 10-year survival rates of stem concepts implanted during 1980-1990 are presented in Table 5. Both proximally and extendedly porous-coated uncemented stems were found to have better overall survival than uncoated uncemented or cemented stems with aseptic loosening as endpoint (extendedly porous-coated vs. uncoated uncemented: $p = 0.001$; proximally porous-coated uncemented vs. cemented: $p = 0.002$; $p < 0.001$ for other comparisons; Figure 1, Table 5). With all revisions as endpoint, extendedly porous-coated uncemented stems had a better overall survival rate than uncoated uncemented and cemented stems ($p < 0.001$ for both comparisons). There was also

Table 4. Survival of implant concepts. Endpoint defined as revision due to aseptic loosening. 7- and 10-year survival rates obtained from the Kaplan-Meier analysis

Implant concept	No. of revisions /total operations	Mean FU (yr)	At risk 7 yr	% 7-year survival (95% CI)	At risk 10 yr	% 10-year survival (95% CI)	Adjusted RR for revision (95% CI)	P-value
Stems								
Prox. porous-coated uncemented	35/2197	5.9	737	98 (98–99)	225	97 (96–98)	0.2 (0.2–0.3)	<0.001
Ext. porous-coated uncemented	31/318	11	240	94 (91–97)	186	90 (87–94)	0.5 (0.3–0.7)	<0.001
HA-coated uncemented	2/526	3.4	41	99 (98–100)	0	–	0.1 (0.0–0.6)	0.006
Uncoated uncemented	76/441	9.3	309	90 (87–93)	206	82 (78–86)	1.2 (0.9–1.6)	0.3
Cemented	132/833	9.6	462	93 (91–95)	358	88 (86–91)	1.0	
Cups								
Porous-coated uncemented	54/2194	5.6	672	98 (97–99)	197	93 (91–95)	0.5 (0.3–0.7)	<0.001
HA-coated uncemented	2/571	3.3	53	98 (96–100)	6	98 (96–100)	0.2 (0.0–0.7)	0.02
Smooth threaded uncemented	208/650	10.0	447	85 (82–88)	321	71 (68–75)	2.0 (1.6–2.5)	<0.001
All-poly cemented	137/802	11	535	94 (93–96)	408	89 (86–91)	1.0	

FU = follow-up. RR = risk ratio from the Cox regression analysis (uncemented concepts compared to cemented concept; adjustment made for age and gender).

Table 5. Seven– and 10–year survival rates of stem concepts obtained from the Kaplan–Meier analysis

Stem concept	No. of operations	All revisions % 7-year survival (95% CI)	All revisions % 10-year survival (95% CI)	Aseptic loosening % 7-year survival (95% CI)	Aseptic loosening % 10-year survival (95% CI)
1980–1990					
Prox. porous-coated uncemented	304	92 (89–95)	83 (79–88)	96 (93–98)	92 (88–95)
Ext. porous-coated uncemented	287	94 (91–97)	89 (86–93)	95 (92–98)	91 (87–94)
HA-coated uncemented	0	–	–	–	–
Uncoated uncemented	266	90 (86–93)	80 (75–85)	92 (88–95)	82 (78–87)
Cemented	472	93 (90–95)	87 (84–90)	93 (91–96)	88 (85–91)
1991–2001					
Prox. porous-coated uncemented	1893	95 (94–97)	94 (93–96)	99 (99–100)	99 (99–100)
Ext. porous-coated uncemented	31	–	–	–	–
HA-coated uncemented	526	95 (91–99)	–	99 (98–100)	–
Uncoated uncemented	175	85 (80–91)	83 (76–89)	87 (81–92)	85 (79–91)
Cemented	361	92 (87–96)	90 (84–96)	94 (89–98)	92 (86–97)

a trend for better survival of porous-coated uncemented stems than of uncoated uncemented stems, but the difference was not statistically significant ($p = 0.05$). HA-coated uncemented stems were not implanted during the 1980s. The Cox regression analysis gave similar results (with or without adjustment for age and gender).

The 7- and 10-year survival rates of stem concepts implanted during 1991–2001 are presented in Table 5. With aseptic loosening as endpoint, both proximally porous-coated and HA-coated uncemented stems were found to have a better overall survival rate than uncoated uncemented or cemented stems (HA-coated uncemented vs. cemented: $p = 0.003$; $p < 0.001$ for all other comparisons; Figure 2, Table 5). Uncoated uncemented stems showed lower overall survival rate than cemented stems ($p = 0.01$). With all revisions as endpoint, proximally porous-coated and HA-coated uncemented stems had better overall survival rates than uncoated uncemented stems ($p < 0.001$ for both comparisons). HA-coated uncemented stems had a higher overall survival rate than cemented stems ($p = 0.04$). There was also a trend for better overall survival for proximally porous-coated uncemented stems as compared to cemented stems, but

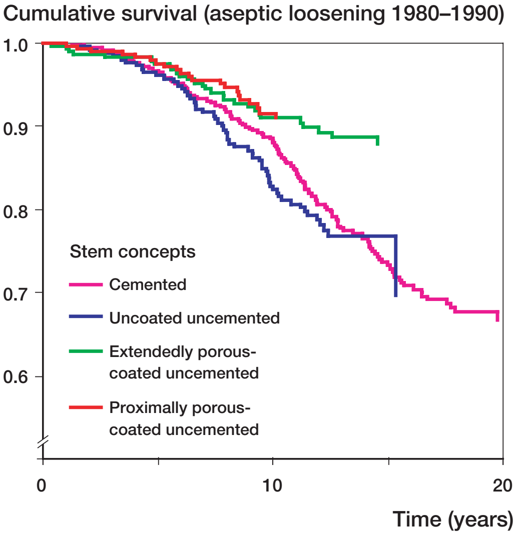

Figure 1. Cox-adjusted survival curves calculated for 1 421 stems implanted during 1980–1990, with stem concept as the strata factor. The endpoint was defined as stem revision due to aseptic loosening. Adjustment was done for age and sex.

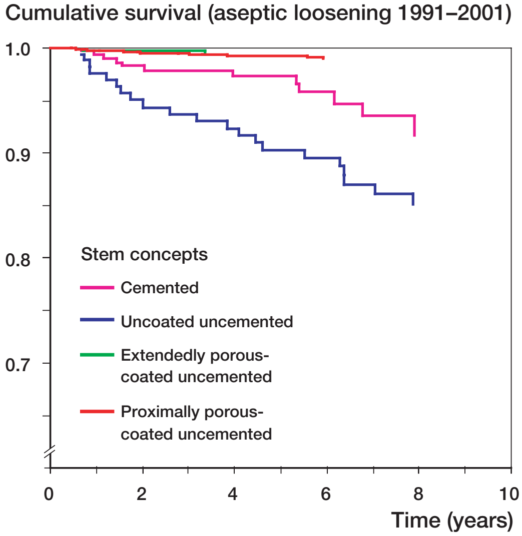

Figure 2. Cox-adjusted survival curves of 3 240 stems implanted during 1991–2001, with stem concept as the strata factor. The endpoint was defined as stem revision due to aseptic loosening. Adjustment was done for age and sex. Only 31 extendedly porous-coated stems were implanted during 1991-2001; these were not included in the analysis.

the difference was not statistically significant (p = 0.08). After adjustment for age and sex, there was no more a statistically significant difference in the risk of revision between HA-coated uncemented and cemented stems in the Cox model (RR 2.2, 95% CI 0.9–5.2; p = 0.07). Otherwise, the Cox model (with or without adjustment for age and gender) gave similar results.

Cohort effect among stem concepts. Kaplan-Meier analysis showed that proximally porous-coated uncemented stems implanted during 1991–2001 had better overall survival than stems of the same concept implanted during the first decade of the study period (1980–1990), either with all revisions ($p < 0.001$) or with aseptic loosening ($p < 0.001$) as endpoint (Table 5). The Cox regression analysis gave similar results (with or without adjustment for age and gender).

Cemented and uncoated uncemented stems did not show any differences in survival between the cohorts of 1980–1990 and 1991–2001.

Cup concepts. When the whole study period was analyzed and the endpoint was defined as any revision, the overall survival rate of smooth-threaded uncemented cups was lower than that of any other cup concept ($p < 0.001$ for all comparisons; Table 3). With aseptic loosening as endpoint, both porous-coated and HA-coated press-fit uncemented cups had better overall survival than smooth-threaded uncemented or all-polyethylene cemented cups (HA-coated vs. all-polyethylene: p = 0.008; $p < 0.001$ for all other comparisons); Table 4). In addition, all-polyethylene cemented cups had significantly better overall survival than smooth-threaded uncemented cups ($p < 0.001$). The Cox regression analysis gave similar results (with or without adjustment for age and gender).

The 7- and 10-year survival rates of cup concepts implanted during 1980-1990 are presented in Table 6. Analysis of the cups implanted during the first decade of the study period (1980-1990) revealed that the overall survival rates of porous-coated uncemented and all-polyethylene cemented cups were higher than those of smooth-threaded uncemented cups, either with all revisions or aseptic loosening as endpoint (porous-coated vs. smooth-threaded, all revisions, p = 0.001; $p < 0.001$ for all other comparisons; Figures 3 and 4; Table 6). With all revisions as endpoint, there was also a trend for all-polyethylene cemented cups to have a higher overall survival rate than press-fit porous-coated uncemented cups, but the difference was not statis-

Table 6. Seven- and 10-year survival rates of cup concepts obtained from the Kaplan-Meier analysis

Cup concept	No. of operations	All revisions % 7-year survival (95% CI)	All revisions % 10-year survival (95% CI)	Aseptic loosening % 7-year survival (95% CI)	Aseptic loosening % 10-year survival (95% CI)
Cohort of 1980–1990					
Porous-coated uncemented	195	89 (84–93)	74 (68–81)	96 (93–98)	92 (88–95)
HA-coated uncemented	9	–	–	–	–
Smooth threaded uncemented	533	82 (79–85)	68 (64–72)	84 (80–87)	70 (66–74)
All-poly cemented	534	93 (91–95)	87 (84–90)	94 (92–96)	88 (85–91
Cohort of 1991–2001					
Porous-coated press-fit uncemented	1999	95 (94–97)	94 (92–96)	99 (98–99)	98 (97– 99)
HA-coated press-fit uncemented	562	96 (92–100)	–	99 (98–100)	–
Smooth threaded uncemented	117	89 (83–96)	89 (83–96)	92 (86–98)	92 (86–98)
All-poly cemented	268	95 (91–98)	93 (89–98)	95 (92–99)	94 (89–98)

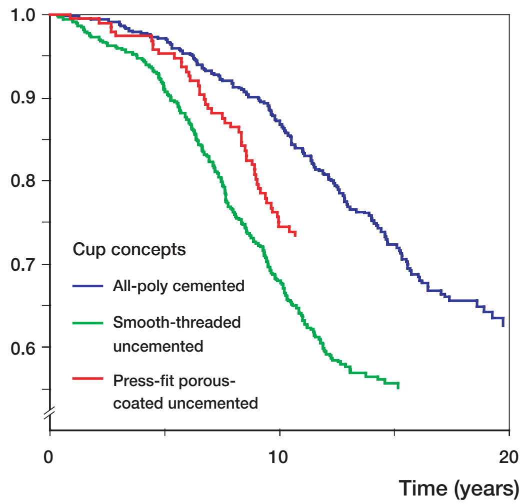

Figure 3. Cox-adjusted survival curves calculated for 1 271 cups implanted during 1980–1990, with cup concept as the strata factor. The endpoint was defined as stem revision for any reason. Adjustment was done for age and sex. Only 9 HA-coated cups were implanted during 1980–1990; these were not included in the analysis.

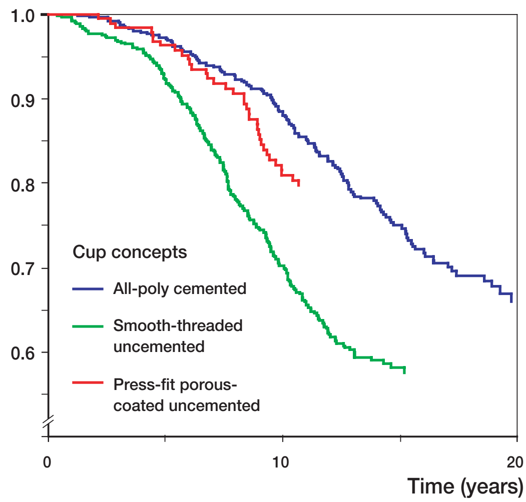

Figure 4. Cox-adjusted survival curves calculated for 1 271 cups implanted during 1980–1990, with cup concept as the strata factor. The endpoint was defined as stem revision due to aseptic loosening. Adjustment was done for age and sex. Only 9 HA-coated cups were implanted during 1980–1990; these were not included in the analysis.

tically significant ($p = 0.05$; Figure 4, Table 6). The Cox regression analysis gave similar results (with or without adjustment for age and gender).

Table 6 lists the 7- and 10- year survival rates for cup concepts implanted during 1991–2001. Analysis of the cups implanted during the last decade of the study period (1991–2001) showed that the overall survival rates of press-fit porous-coated and HA-coated uncemented cups were higher than those of other concepts when the endpoint was defined as aseptic loosening (porous-coated vs. smooth threaded: $p < 0.001$; porous-coated vs. all-polyethylene cemented: $p = 0.008$; HA-coated vs. smooth-threaded: $p = 0.001$; HA-coated vs. all-polyethylene cemented: $p = 0.03$; Figure 5, Table 6). Cox regression analysis revealed that, with aseptic loosening as endpoint and adjustment for age and gender, there was a trend for all-polyethylene cemented cups to have a higher risk of revision than press-fit HA-coated uncemented cups, but the

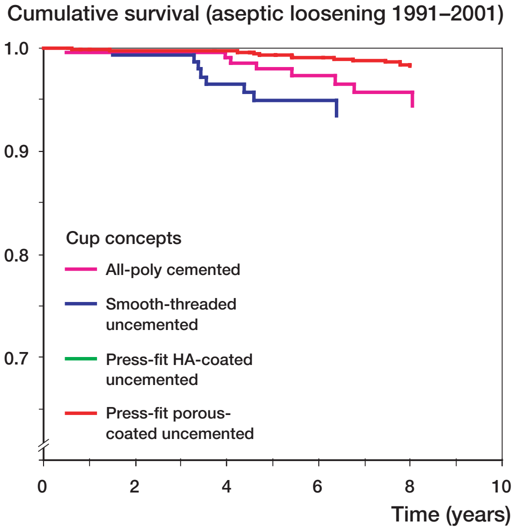

Figure 5. Cox-adjusted survival curves calculated for 2 946 cups implanted during 1991–2001, with cup concept as the strata factor. The endpoint was defined as cup revision due to aseptic loosening. Adjustment was done for age and sex. The curve of HA-coated press-fit uncemented cups is not shown as they had a 100% Cox-adjusted survival rate at 4 years.

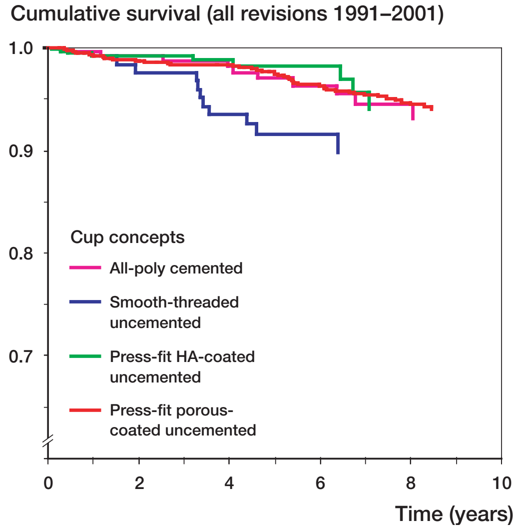

Figure 6. Cox-adjusted survival curves calculated for 2 946 cups implanted during 1991–2001, with cup concept as the strata factor. The endpoint was defined as stem revision for any reason. Adjustment was done for age and sex.

difference was not statistically significant (RR 6.9, 95% CI 0.8–56; $p = 0.07$). Otherwise, results from the Cox regression analysis were similar to those obtained from Kaplan-Meier analysis. When the endpoint was defined as revision for any reason, porous-coated and HA-coated uncemented cups had better overall survival rates than smooth-threaded uncemented cups (porous-coated vs. smooth threaded: $p = 0.006$; HA-coated vs. smooth threaded: $p = 0.02$; Figure 6, Table 6). In the Cox model (with adjustment for age and gender), there was a trend for smooth-threaded uncemented cups to have a higher risk of revision than press-fit HA-coated uncemented cups, but the difference was not statistically significant (RR 2.3, 95% CI 0.9–5.8; $p = 0.08$). Otherwise, results from the Cox regression analysis were similar to those obtained from Kaplan-Meier analysis.

Cohort effect among cup concepts. Kaplan-Meier analysis of press-fit porous-coated uncemented cups indicated that the cohort of 1991–2001 had better overall survival than the cohort of 1980–1990, either with all revisions or aseptic loosening as endpoint ($p < 0.001$ for both comparisons; Table 6). The results were similar in the Cox model (with adjustment for age and gender).

The cohort effect was also apparent for smooth-threaded uncemented cups. Such cups implanted during 1991–2001 had higher overall survival rates than cups of the same concept implanted during 1980–1990 (all revisions: $p = 0.03$; aseptic loosening: $p = 0.01$; Table 6). The Cox regression analysis gave similar results (with or without adjustment for age and gender).

Neither HA-coated uncemented cups nor all-polyethylene cemented cups showed any significant differences in survival rates between the cohorts of 1980–1990 and 1991–2001.

Sex and age as risk factors. Cox regression analysis of all data showed that females had a higher risk of revision than males, either with all revisions (RR 1.2, 95% CI 1.0–1.4; $p = 0.02$) or aseptic loosening (RR 1.2, 95% CI 1.0–1.4; $p = 0.02$) as endpoint. The Cox regression analysis gave similar results (with or without adjustment for age and implant concepts). When the risk of stem revision was analyzed with the Cox model, there was no difference in revision risk between genders with either all revisions or aseptic loosening being used as endpoint. However, females had a higher risk of cup revision than males when either all revisions (RR 1.2, 95% CI 1.1–1.5; $p = 0.01$) or aseptic loosening (RR 1.3, 95% CI 1.1–1.5; p = 0.009) was used as endpoint. The results were similar after adjustment for age and cup concepts.

With any revision as endpoint, patients < 46 years of age were found to have a 1.2-fold (95% CI 1.0–1.5; p = 0.03) increased risk of revision as compared to older patients (46–54 years). However, after adjustment for sex and implant concepts, the difference disappeared. With aseptic loosening as endpoint, the risk of revision in the young age group (< 46 years) was 1.3 (95% CI 1.1–1.6; p = 0.005) times as high as that in the older age group (46–54 years). Adjustment for sex and implant concepts in the Cox model gave similar results. When the risk of stem revision was analyzed with the Cox model, there was no difference in revision risk between the age groups, either with all revisions or aseptic loosening as endpoint (with or without adjustment for sex and stem concepts). However, the young age group had a higher risk of cup revision than the older age group when either all revisions (RR 1.2, 95% CI 1.1–1.5; p = 0.01) or aseptic loosening (RR 1.3, 95% CI 1.1–1.5; p = 0.009) was used as endpoint. Adjustment for sex and cup concepts in the Cox model gave similar results.

The effect of hospital volume on survival of implants. Neither the Kaplan-Meier analysis nor the Cox multiple-regression model found a difference in revision risk between hospitals performing more than 10 and those performing 10 or fewer THAs annually, irrespective of whether the endpoint was defined as revision for any reason or as aseptic loosening.

Discussion

Register-based studies provide valuable insight into the use of the THA procedure in a certain patient-group, as the number of arthroplasties studied is substantially larger in register-based studies than in clinical studies from single centers (Kim et al. 2002). In addition, such nationwide studies enable trends in THAs to be shown better and on a larger scale. Furthermore, the results can be compared with those of other Nordic arthroplasty registers, which gives a broad overview of the results for both single implants and the methods applied in THA. As the results have been reported from many sources, their scientific reliability is high. The statistical methods used in our study were valid, as we applied not only Kaplan-Meier survival analysis but also Cox multiple regression analysis to take account of confounding factors. The importance of considering confounding factors in the survival analysis of hip implants has been shown previously (Furnes et al. 2001). Nevertheless, we acknowledge that the current register-based study has certain limitations. We were not, for example, able to report any subjective outcome measurements, e.g., Harris Hip Score or disease-specific quality of life measurements. Moreover, as far as younger patients are concerned, a register-based study such as ours may have diagnostic pitfalls in that a small proportion of the patients (females in particular) diagnosed with primary osteoarthrosis may in fact have mild developmental dysplasia (Harris 1986). It has been reported that patients with developmental dysplasia of the hip have poorer outcome of THA than other patient groups (Furnes et al. 2001). There was some heterogeneity in the concept groups studied. Firstly, the concept of uncemented uncoated stems included both failed brands and brands with reported good results. Secondly, the concepts of proximally HA-coated and extendedly porous-coated uncemented stems each included only two brands. However, the major concept groups (i.e. cemented stems and proximally porous-coated stems, all-polyethylene cemented cups and press-fit porous-coated uncemented cups) include many brands, none of which have been reported before as failures. When studying the results of studies on THAs, we should evaluate those based on registers and those reported by single centers from different points of view. The results from these different sources are not, however, mutually exclusive; on the contrary, they complement each other. Both types of study will certainly be needed in future evaluations of the results of hip implants and the methods used in THA.

In our study, the sex distribution of young patients differed from that of older ones, the majority of the young patients being males. This sex distribution differs from that of patients aged 65 years or older when undergoing THA for primary osteoarthrosis over the same study period: in one study 65% (n =

19 701) of those patients were females and 35% (n = 10 622) were males (p < 0.001) (Nevalainen et al. 2003). Earlier studies have, however, shown that THAs are performed more frequently in females than in males (Paavolainen et al. 1991, Havelin et al. 2000, Puolakka et al. 2001a, Malchau et al. 2002). The reason for the different sex distribution among young patients is unclear. One possible explanation is that males are more active physically and thus prone to subtle microtraumas that accelerate the degenerative process. Thus, hip osteoarthrosis may develop earlier in males. Alternatively, males may not accept as much physical impairment as females and may therefore undergo THA earlier. Epidemiological studies have provided evidence that physical activity, whether sports or strenuous work, increases the risk of hip osteoarthrosis (Vingard et al. 1993, Lievense et al. 2001). Such studies have not, however, shown that gender is an independent risk factor for hip osteoarthritis. In our series, females had a higher risk of revision than males. To our knowledge, this finding has not been reported previously. The etiology remains obscure.

It is unclear whether the results would be better if THAs were performed on young patients in fewer hospitals, and if these patients were concentrated in tertiary centers. The results were no better for hospitals performing more than 10 THAs on young patients than were those for other hospitals. It is possible that the hospitals performing a high number of THAs treated the youngest and most difficult patients. In retrospect, the hospitals working as tertiary referral centers in Finland made some poor choices, using new, undocumented uncemented implants that were not introduced into smaller hospitals until later (Puolakka et al. 1999, 2001a). Technical problems during the operation should not be expected in young patients with “normal” bony anatomy in the hip if we compare them with young patients with secondary osteoarthrosis due to conditions such as hip dysplasia, Perthes’ disease, epiphyseolysis or rheumatoid arthritis, or due to post-traumatic arthrosis. This is why we concentrated on patients with primary osteoarthrosis as an indication for the operation. However, some of the patients whose diagnosis was recorded in the register as primary osteoarthrosis may in fact have had mild developmental dysplasia or other childhood hip disease, which can be technically more challenging to treat surgically (Harris 1986). Furthermore, soft tissue balance is generally better in younger rather than older patients.

The number of different femoral and acetabular components used by Finnish orthopedic surgeons during 1980–2001 was high. Over 50% of the implant brands were used in fewer than 20 operations. Similar results have been reported from Norway (Havelin et al. 2000). We attribute this trend primarily to commercial influences on orthopedic surgeons. However, at the end of the study period (2000–2001), the 3 most common and well-documented stems constituted 72% of all stems implanted; similarly, the three most common cups constituted 64% of all cups implanted.

The proportion of uncemented stems and cups used rose dramatically from the beginning of the study period to the early 1990s. This upward trend reflects improvements in uncemented implant designs. The countertendency noted in 2000–2001 probably partly reflects poor experience of the earlier uncemented concepts. The proportions of cemented and uncemented implants used nationwide have only been reported from the Nordic countries. The use of uncemented implants is most common in Finland. In Norway, both in 1988 and in 1998, 18% of acetabular and 13% of femoral components were uncemented (Havelin et al. 2000); in Denmark, 64% of all hip prostheses implanted during 1995-1998 were cemented (Lucht 2000); and in Sweden, cemented designs were used in 93% of all hip arthroplasties (Herberts and Malchau 2000). These figures from other Nordic countries, however, include all age groups, not only younger patients. Moreover, not all Nordic countries use the same implant brands, and the results for cemented and uncemented implants as subgroups cannot be directly compared between registers. Although uncemented implants have been used more commonly than cemented ones in Finland, there is also a wide experience of cemented THA in Finland; for example 50% of all cups (n = 25 150) and 39% of all stems (n = 19 991) implanted in Finland during 1991–2001 (all age and diagnosis groups) were cemented (Nevalainen et al. 2003).

Results were good with uncemented circumferentially porous-coated and HA-coated stems.

Despite the improved cementing technique used and the systematic instruction of Finnish orthopedic trainees in modern third-generation cementing techniques during the 1990s, the results for cemented stems did not improve significantly from the 1980s to the 1990s in young patients. What is more, modern uncemented stems implanted during the 1990s had clearly better results than cemented stems. However, one possible confounding factor is the documentation of the cementing technique, which the register only has precise information on since 1996. The improved performance of uncemented proximally porous-coated stems implanted during the 1990s is an important finding. The results for some uncemented stems implanted at special centers have been good (McLaughlin and Lee 2000, Kim et al. 2002, 2003, Aldinger et al. 2003, Capello et al. 2003, Jacobsen et al. 2003), and the results of the Swedish Arthoplasty Register also showed a trend towards better survival of uncemented implants in young patients (Malchau et al. 2002). However, our report is the first to confirm good results for uncemented stems on a nationwide level. Even though the follow-up of proximally HA-coated uncemented stems was relatively short in this study, it is notable that to date there has only been one study reporting long-term results of HA-coated stems (Capello et al. 2003).

The concepts of uncemented press-fit porous-coated and HA-coated cups performed well among our younger patients. The follow-up of press-fit HA-coated uncemented cups was relatively short in this study. However, long-term results of press-fit HA-coated uncemented cups have not been reported so far. Good mid-term results have been reported previously for single brands of these concepts (Giannikas et al. 2002, Malchau et al. 2002). Giannikas et al. (2002) reported good medium-term results with the ABG hip, but polyethylene wear of the acetabular insert was noted with concern. Harris-Galante I and Romanus cups showed good 10-year survival rates in the Swedish Arthroplasty Register (Malchau et al. 2002). The poor survival of uncemented cups implanted in the 1980s is tentatively attributed to the widespread use of uncemented smooth-threaded cups (Engh et al. 1990, Tallroth et al. 1993, Simank et al. 1997) and uncemented cups, the polyethylene liner of which had an inferior locking mechanism (Chen et al. 1995, Scott et al. 2000, Puolakka et al. 2001b, Young et al. 2002). Even though there was a statistically significant difference between survival rates and revision risks for press-fit porous-coated uncemented and all-polyethylene cemented cups, this difference was rather small from a clinical point of view. In addition, the difference was significant only with aseptic loosening as endpoint. When the endpoint was defined as any revision (including exchange of liner), the difference declined to a non-significant level.

Poorer survival of prostheses in young patients has been reported both for single implants (Joshi et al. 1993, Ballard et al. 1994, Dorr et al. 1994, Devitt et al. 1997) and on a nationwide level (Malchau et al. 1993, 2002, Furnes et al. 2001). In our series, however, the poorer survival of THAs in younger patients seems to have been related mainly to the inferior implants more commonly used in their operations, and not only to the age of the patient. It is interesting that there was a difference in the risk of cup revision but not in the risk of stem revision between the age groups. Young and active patients apparently stress their hip joints more than older patients, a tendency that leads eventually to aseptic loosening of the cup. Our results suggest that in young patients, press-fit porous and HA-coated uncemented cups have better endurance against aseptic loosening than cemented cups, but that the excessive polyethylene wear of uncemented cups leads to osteolysis and to exchange of the liner. Thus, when all revisions are taken into account, the survival of modern uncemented cups is no better than that of all-polyethylene cemented cups. This is in accordance with previous reports (Callaghan et al. 1995, Barrack et al. 1997, Thompkins et al. 1997, Havelin et al. 2002). In young patients, however, modern uncemented stems seem to have better resistance to aseptic loosening than cemented stems.

For younger, more active patients, the primary concern in THA should be function and durability. The key issue for successful THA for primary osteoarthrosis in young patients is therefore selection of the right implant. Uncemented proximally circumferentially porous and HA-coated stems appear to be the implants of choice for young patients. We could find no difference in survival between proximally porous and HA-coated stem concepts; hence, both stem concepts can be recommended for these patients. In the long run, the resistance of press-fit porous-coated uncemented cups to aseptic loosening may be better than that of cemented cups in young patients. However, the difference found here, although statistically significant, was clinically so small that it must be confirmed by more long-term results. More studies are also needed to establish whether new surface solutions (metal-on-metal, highly cross-linked polyethylene) will reduce cup wear and so change the results to the advantage of either cemented or uncemented cups in young patients. Orthopedic surgeons in Finland have paid dearly for experimenting with new, undocumented implants; moreover, these same implants have been found to perform poorly in other countries also. New uncemented concepts should be first tested with RSA measurements in a small group of patients, and then in multicenter prospective clinical studies, before they are widely introduced in hospitals (Kärrholm 2003).

No competing interests declared.

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Contributions

Antti Eskelinen – study design, data analysis and writing, Ville Remes – study design and writing, Ilkka Helenius – study design and writing, Pekka Pulkkinen, statistical supervisor of the Finnish Arthroplasty Register – data analysis, Juha Nevalainen, supervisor of the Finnish Arthroplasty Register – writing, Pekka Paavolainen, head of the Research Group – study design and writing