Department of Orthopaedics and Traumatology
Helsinki University Central Hospital
University of Helsinki

PRIMARY TOTAL HIP ARTHROPLASTY FOR PRIMARY OSTEOARTHRITIS IN FINLAND

– A NATIONAL REGISTER BASED ANALYSIS

Keijo Mäkelä

ACADEMIC DISSERTATION

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Supervised by:

Docent Ville Remes MD, PhD
Department of Orthopaedics and Traumatology, Peijas, Helsinki University Central Hospital and
University of Helsinki, Finland

Antti Eskelinen MD, PhD
Coxa Hospital for Joint Replacement and University of Tampere, Finland

Reviewed by:

Docent Teemu Moilanen MD, PhD
Coxa Hospital for Joint Replacement and University of Tampere, Finland

Docent Hannu Miettinen MD, PhD
Department of Orthopaedics and Traumatology, Kuopio University Hospital and the University of Eastern Finland

Discussed with:

Professor Leif Havelin MD, PhD
The Norwegian Arthroplasty Register, Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen, Norway and Department of Surgical Sciences, University of Bergen, Norway

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2. LIST OF ORIGINAL PUBLICATIONS

The present thesis is based on the following original papers, which will be referred to in the text by their Roman numerals:

I Mäkelä KT, Eskelinen A, Pulkkinen P, Paavolainen P, Remes V. Total hip arthroplasty for primary osteoarthritis in patients fifty-five years of age or older. An analysis of the Finnish Arthroplasty Registry. J Bone Joint Surg Am 2008; 90: 2160-70.

II Mäkelä K, Eskelinen A, Pulkkinen P, Paavolainen P, Remes V. Cemented total hip arthroplasty for primary osteoarthritis in patients 55 years or over – Results of the 12 most common cemented implants followed for 25 years in the Finnish Arthroplasty Register. J Bone Joint Surg Br 2008; 90: 1562-9.

III Mäkelä KT, Eskelinen A, Pulkkinen P, Paavolainen P, Remes V. Cementless total hip arthroplasty for primary osteoarthritis in patients aged 55 years old or over – results of the 8 most common cementless designs compared to cemented reference implants in the Finnish Arthroplasty Register. Acta Orthop 2010; 81: 42-52.

IV Mäkelä KT, Peltola M, Häkkinen U, Remes V. Geographical variation in incidence of primary total hip arthroplasty: a population-based analysis of 34,642 replacements. Arch Orthop Trauma Surg 2009; Jun 24. [Epub ahead of print].

V Mäkelä KT, Häkkinen U, Peltola M, Linna M, Kröger H, Remes V. The effect of hospital volume on length of stay, re-admissions and complications of total hip artrhoplasty in Finland – a population-based register analysis of 81 hospitals and 28,218 replacements. Submitted.

3. ABBREVIATIONS

AOA	Australian Orthopaedic Association
ASA	American Society of Anesthesiologists
CI	confidence interval
DDH	developmental dysplasia of the hip
DHR	the Danish Hip Arthroplasty Register
HA	hydroxyapatite
HHS	Harris Hip Score
ICD	International Classification of Diseases
LOS	length of stay
LUIC	length of uninterrupted institutional care
NAR	the Norwegian Arthroplasty Register
NICE	National Institute for Clinical Excellance
NOMESCO	the Nordic Medico-Statistical Committee
OA	osteoarthritis
OECD	Organisation for Economic Co-operation and Development
OR	odds ratio
RA	rheumatoid arthritis
RR	risk ratio
SHAR	the Swedish Hip Arthroplasty Register
THA	total hip artrhroplasty
THR	total hip replacement

4. ABSTRACT

Introduction

Promising results on the performance of cementless implants for patients under 55 years of age have been obtained. As to whether the survival of cementless total hip replacements is as good as that of cemented total hip replacements for those patients aged 55 years and older has been investigated in this study.

Considerable variation in THA incidence between regions has been described. Suggested reasons for this variation include *inter alia* socio-economic factors and the number of surgeons in any particular region. Hospital volume is a known indicator of orthopaedic adverse events in patients undergoing THA. In systematic literature reviews, an association was found between higher hospital volumes and lower rates of mortality and hip dislocation.

Aims of the present study

The first aim was to evaluate the survival of THA in patients aged 55 years and older at the time of the primary operation on a nation-wide level. The second aim was to evaluate, on a nation wide-basis, the geographical variation of the incidence of primary THA for primary OA and also to identify those variables that are possibly associated with this variation. The third aim was to evaluate the effects of hospital volume: on the length of stay, on the numbers of re-admissions and on the numbers of complications of THR on population-based level in Finland.

Methods

1) From 1980 to 2004 inclusive, a total of 50,968 primary THRs that met our criteria were entered in the Finnish Arthroplasty Register. The survival rate of different implant groups was analysed.

2) Between 1980 and 2005 inclusive, a total of 41,034 primary cemented THAs performed for primary osteoarthritis in patients aged 55 years and over were entered in the Finnish Arthroplasty Register. The 12 most commonly used cemented total hip replacements (cup + stem combinations), which accounted for 84% (34,549) of all cemented replacements performed for primary OA, were subjected to survival analyses.

3) Inclusion criteria permitted 10,310 cementless replacements (8 designs) performed on patients aged 55 years or older to be selected for evaluation. The risk of revision for each of the 8 implants were compared with that of a group comprising three cemented designs as the reference (9,549 replacements).

4) Using Hospital Discharge Register, 34,642 THAs performed for primary OA over the 1998 to 2005 period were identified. The adjusted incidence indices for 21 hospital administrative regions were determined. Logistic regression analyses and generalized linear models were used for studying the association between potential explanatory factors with the variation in the incidence of THA.

5) Using the information from the Hospital Discharge Register, 28,218 THRs performed for primary osteoarthritis over the 1998 and 2005 period were identified. Hospitals were classified into four groups according to the number of THRs performed on an annual basis over the whole study period: 1-50 (Group 1), 51-150 (Group 2), 151-300 (Group 3) and 301 or over (Group 4). Logistic regression analyses and generalized linear models were used to study the effect of hospital volume: on length of stay, on unscheduled re-admissions and on re-operation, dislocation and infection rates.

Results

1) Cementless THRs had a significantly reduced risk of revision for aseptic loosening compared with cemented hip replacements ($p < 0.001$). When revision for any reason was the end point in the survival analyses, there were no significant differences found between the groups.

2) Only two designs of femoral component, the Exeter Universal (Stryker Howmedica, Mahwah, New Jersey, USA) and the Müller Straight (Zimmer, Warsaw, Indiana, USA) had a survivorship of over 95% at 10 years with revision for aseptic loosening as the endpoint.

3) In all patients aged 55 years or more, the Bi-Metric stem had a higher survival rate for aseptic loosening at 15 years follow-up than the cemented reference group [96% (95% CI 94-98) vs. 91% (CI 90-92)].

4) Adjusted incidence ratios of THA varied from 1.9- to 3.0-fold during the study period. When the ratio of THAs performed for primary OA to THAs performed for any reason was high, the absolute incidence of THAs was high ($p<0.001$). Neither the average income within a region nor the morbidity index was associated with the incidence of THA.

5) For the four categories of volume of THR performed per hospital, the length of the surgical treatment period was shorter for the highest volume group (Group 4) than for the lowest volume group (Group 1) ($p<0.0001$). The odds ratio for dislocations (0.70, 95% CI 0.55-0.90) was significantly lower in the Group 3, than in the Group 1.

Conclusions

1) In patients who were 55 years of age or older, the long-term survival of cementless total hip replacements was as good as that of the cemented replacements. However, multiple wear-related revisions of the cementless cups indicate that excessive polyethylene wear was a major clinical problem with modular cementless cups for all age groups.

2) The variation in the long-term rates of survival for different cemented stems was considerable for patients aged 55 years or older.

3) Cementless proximal porous-coated stems were found to be a good option for elderly patients. Even though biological fixation is a reliable fixation method of THA, polyethylene wear and osteolysis remain a serious problem for cementless cups.

4) When hip surgery was performed on with a large repertoire, the indications to perform THAs due to primary OA were tight. Socio-economic status of the patient had no apparent effect on THA rate.

5) Specialization of hip replacements in high volume hospitals should reduce costs by significantly shortening the length of stay, and may reduce the dislocation rate.

5. INTRODUCTION

This study was performed to analyse if cementless fixation of THA is as durable as cement fixation in patiets aged 55 years and older. It was also performed to analyse surgeon and hospital volume related parameters in THA. It was not the aim of the study to analyse hip resurfacing arthroplasty, which has become popular in recent years, or bearing couples of the prostheses. Long term bearing couples data are not available from the Finnish Arthroplasty Register.

Total hip arthroplasty (THA) is the golden standard of treatment for severe osteoarthritis (OA) of the hip refractory for conservative treatment. Cemented low-friction arthroplasty, which was pioneered by Sir John Charnley (Charnley 1960, Charnley 1961) is largely the basis of the modern THA. Cemented Charnley prosthesis (Johnson & Johnson, New Brunswick, New Jersey, USA) is still considered as the gold standard for total hip arthroplasty, against which all new implants should be compared. A 10-year survival rate of 90 per cent or more (National Institute for Clinical Excellance, NICE) is considered a good long-term outcome. The 25-year survival rate of 80 per cent of the Charnley prosthesis has remained unsurpassed (Callaghan et al. 2000, Berry et al. 2002, Wroblewski et al. 2002, Della Valle et al. 2004a, Buckwalter et al. 2006, Morshed et al. 2007). A good long-term outcome has also been recorded with other cemented implants (Havinga et al. 2001, Räber et al. 2001, Williams et al. 2002, Kale et al. 2003, Carrington et al. 2009, Clauss et al. 2009). However, most of these studies refer to only one total hip replacement design performed in a single center. In the Nordic countries national registers were established: for Sweden in 1979, for Finland in 1980, for Norway in 1987 and for Denmark in 1995, to evaluate the population-based results of THA. Data based on Nordic arthroplasty registers have shown that the survival of cemented implants for elderly and sedentary patients with primary osteoarthritis is high (Havelin et al. 2000, Havelin et al. 2002, Malchau et al. 2002, SHAR 2007, Havelin et al. 2009). The use of cemented implants in Finland is not as common as that found in Sweden and in Norway, and the results have not been as flattering (Puolakka et al. 2001a). Further, in patients under the age of 55 years in Finland, the population-based survival of cementless proximal porous coated stems was even better than the survival of cemented stems (Eskelinen et al. 2005, Eskelinen et al. 2006). High survival rates have also been found for cementless stems as based on data from the Norwegian Arthroplasty Register (Havelin et al. 2000, Hallan et al. 2007). However, due to excessive wear of the polyethylene liner, survival of modular cementless cups has not been as good as that of cemented cups (Havelin et al. 2000, Malchau et al. 2002, SHAR 2007, Havelin et al. 2009).

Variation in surgery rates within a single country have already been reported in several studies published during the 1970s and 1980s (McPherson et al. 1982, Wennberg et al. 1982, Chassin et al. 1986). The incidence ratio of THA has been shown to vary from 1.25 to 4.7 between regions of the same country (Keskimäki et al. 1994, Birkmeyer et al. 1998, Pedersen et al. 2005, Dixon et al. 2006). Several studies have examined explanatory variables related to regional variation of THA including: population density, surgeon density, socio-economic factors, and surgeon enthusiasm (Keller et al. 1990, Peterson et al. 1992, Baron et al. 1996, Keskimäki et al. 1996, Wright et al. 1999, Söderman et al. 2000, Hawker et al. 2002, Hudak et al. 2002, Mahomed et al. 2003, Skinner et al. 2003, Milner et al. 2004, Pedersen et al. 2005, Dixon et al. 2006).

The association of hospital volume with the results of total hip replacements (THR) has been investigated in several studies (Lavernia et al. 1995, Espehaug et al. 1999, Katz et al. 2001, Solomon et al. 2002, Doro et al. 2006, Battaglia et al. 2006, Shervin et al. 2007). It has been suggested, that surgeon volume and hospital volume are the best indicators of orthopaedic adverse events in patients undergoing THR surgery (Solomon et al. 2002). Lower provider volume has been associated with longer hospital stay after THR surgery (Doro et al. 2006, Judge et al. 2006) and also with higher costs (Kreder et al. 1997, Martineau et al. 2005, Mitsuyasu et al. 2006).

6. REVIEW OF LITERATURE

6.1 ETIOLOGY OF PRIMARY OA

Osteoarthritis of the hip can result from several different patterns of joint failure. Underlying pathological changes due to conditions including: osteonecrosis, trauma, sepsis, Paget's disease and rheumatoid arthritis can result in degeneration of the joint. Anatomical abnormalities such as DDH or slipped capital femoral epiphysis can result in osteoarthritic changes. In 70-90 per cent of patients undergoing THA in Nordic countries, neither an anatomical abnormality nor any specific disease can be identified (Rantanen et al. 2006, SHAR 2007, DHR 2008, NAR 2008, AOA 2009). This condition is called primary OA of a hip and the diagnosis of it is performed by the exclusion of other causes.

6.1.1 GENETICS

It has been proved that primary OA of the hip is strongly genetically determined, with an estimated heritability in excess of 50 per cent (Spector et al. 1996, Chitnavis et al. 1997). Twin-pair, sibling-risk and segregation studies have revealed a major genetic component that is transmitted in a nonmendelian manner. OA therefore fits best into the complex, multifactorial class of common diseases (Loughlin 2005). Ingvarsson et al. (2000) combined two Icelandic population-based databases: a national register of THRs and a genealogy database of all available Icelandic genealogy records for the last 11 centuries. A large number of familial clusters of patients with THR for OA were identified. Icelandic OA patients with THR were significantly more closely related to each other than matched controls drawn from the general Icelandic population. Bukulmez et al. (2006) compared the prevalence of arthroplasty for idiopathic hip OA among siblings of the patients with that of the prevalence among the siblings of the patients' spouses. Familial aggregation for THA was observed after controlling for age and sex, which suggests a genetic contribution to end-stage hip OA. Chitnavis et al. (1997) have found that the relative risk for having THR in the patients' siblings was 1.86 that found for their spouses. Lanyon et al. (2000) found that the age-adjusted odds ratios in THR patients' siblings was 6.4 that obtained for the control group for hip OA. Lanyon et al. (2004) conducted a sibling study, in which at least one sibling of a family had undergone THR. These authors found that the age adjusted odds ratios for hip OA were twofold higher in siblings of index THR patients who had no osteophyte response than that of their corresponding siblings whose index case had osteophytes. They concluded that careful phenotypic characterisation is essential for genetic studies of hip OA.

Osteoarthritis of the hip can occur as part of a generalized process (Croft et al. 1992a, Hochberg et al. 1995, Dahaghin et al. 2005). Susceptibility genes for OA can be identified with association studies (Ikegawa 2007). For example, replication studies have confirmed the association of functional sequence variations in the secreted frizzled-related protein-3 and asporin genes with the occurrence of OA. Recent studies have also prompted discussion of population-spesific differences in reported associations (Ikegava 2007). A meta-analysis of the association between aspartatic acid (D)-repeat polymorphism in the gene encoding asporin and OA found a positive association between knee OA and the D14 allele with non-significant heterogeneity. In hip OA significant heterogeneity was identified and there was no positive association for any allele in any comparison. It was concluded that though the association of the asporin D 14 allele and knee OA has global relevance, its effect has ethnically associated differences (Nakamura et al. 2007).

Significant differences in the underlying prevalence of hip OA between populations have been reported (Lohmander et al. 2006). OA accounted for a greater percentage among whites as an indication for THR (59% for women and 66% for men) than among Japanese (36% of women and 30% of men) (Oishi et al. 1998). In a population-based study in San Francisco conducted by Hoaglund et al. (1995), a primary OA diagnosis in patients having THA was the greatest among white subjects (66%), followed by black subjects (54%), Hispanics (53%) and Asians (28%). The mean age of patients undergoing THR for primary OA was 70 years for white subjects and almost 10 years less for all other groups. Nevitt et al. (2002) found that hip OA was 80-90 per cent less frequent in Beijing, China than in white persons in the US.

6.1.2 AGE AND GENDER

Epidemiological studies have documented that aging is a major risk factor for OA of the hip (Havelin et al. 1993, Corti and Rigon 2003, D'Ambrosia 2005, Andrianakos et al. 2006). Although the incidence of OA before the age of 50 is lower among women than among men, it increases progressively in women after the menopause, and remains relatively unaltered among men after the fifth decade of life (Oliveria et al. 1995). This suggests that a decrease in gonadal steroids in post-menopausal women play a role in the development of OA (Oliveria et al. 1996). In asymptomatic subjects Lanyon et al. (2003) found that minimum hip joint space width progressively decreased in post-menopausal women, whereas it remained relatively unaltered in men throughout life. Jacobsen and Sonne-Holm (2005) also found a progressive decrease in mean minimum hip joint space width after the fifth decade of life in females but no such decrease in male.

6.1.3 MODERATE DYSPLASIA

Hip dysplasia is a well-known pre-osteoarthritic condition leading to premature radiological OA of the hip. The extent and rate at which degeneration develops in moderately dysplastic hips, however, is not defined. Jacobsen et al. (2005) investigated relationship between hip dysplasia and OA by analysing standardized pelvic radiographs and found a prevalence of hip dysplasia of 3.4 per cent. Mild to moderate hip dysplasia was not an unusual condition in the population; prevalences range from 3.5 per cent to 10.7 per cent depending on the index used. There were significant relationships between radiographic OA discriminators and the radiographic parameters of hip dysplasia. Moreover, in a study carried out by Jacobsen and Sonne-Holm (2005), hip dysplasia was reported to be associated with the development of hip OA. In a systematic review of the literature by Lievense et al. (2004), six out of nine studies reported a positive association between hip dysplasia and hip OA (Murray 1965, Wedge et al. 1991, Hasegawa 1994, Murphy et al. 1995, Laforgia et al. 1996, Lane et al. 2000). The only prospective follow up study reported that patients with dysplasia had a 2.8 higher risk of developing hip OA (Lane et al. 2000). Three studies reported either a negative or no association (Terjesen et al. 1982, Lau et al. 1995, Yoshimura et al. 1998). In a study conducted by Chitnavis et al. (2000), up to 40 per cent of hips of patients undergoing THR manifested acetabular dysplasia and a further 10 per cent possibly had previously slipped upper femoral epiphyses.

6.1.4 FEMOROACETABULAR IMPINGEMENT

Evidence is emerging that subtle morphologic abnormalities around the hip result in femoroacetabular impingement and may be a contributing factor to OA (Ganz et al. 2003, Beck et al. 2005, Parvizi et al. 2007a, Tannast et al. 2008). The morphologic abnormalities result in abnormal contact between the femoral neck/head and the acetabular margin, which causes tearing of the labrum and avulsion of the underlying cartilage region, continued deterioration and eventual onset of arthritis (Parvizi et al. 2007a). The most frequent location for femoroacetabular impingement is the anterosuperior rim area. The most critical motion is the internal rotation of the hip at 90 degrees flexion. Two types of femoroacetabular impingement have been identified. Cam-type femoroacetabular impingement, which is more prevalent in young male patients, is caused by an offset pathomorphology between the head and neck and produces an outside-in delamination of the acetabulum. Pincer-type femoroacetabular impingement is more prevalent in middle-aged women and is produced by a more linear impact between a local (retroversion of the acetabulum) or general overcoverage (coxa profunda/protrusio) of the acetabulum. The damage pattern of pincer-type impingement is more restricted to the rim than that of the cam-type, and the process of joint degeneration is slower. Most hips, however, show a mixed femoroacetabular impingement pattern with cam predominance (Ganz et al. 2008). In the study conducted by Gosvig et al. (2008), the overall prevalence of cam deformity was found to be approximately 17 per cent in men and 4 per cent in women. It was hypothesized that the preosteoarthritic cam deformity may represent a silent slipped capital epiphysis especially in men.

6.1.5 OVERWEIGHT

An association between being overweight and hip OA has not been thought to be as important as it is in knee OA. However, in a systematic review of literature of 12 studies (Saville and Dickson 1968, Kraus et al. 1978, Hartz et al. 1986, van Saase et al. 1988, Heliovaara et al. 1993b, Tepper and Hochberg 1993, Olsen et al. 1994, Roach et al. 1994, Vingård et al. 1997a, Cooper et al. 1998, Gelber et al. 1999, Oliveria et al. 1999) on the influence of obesity on the developement of OA of the hip, Lievense et al. (2002) found moderate evidence for a positive association between obesity and the occurrence of the hip OA, with an odds ratio of approximately two. In later studies conducted by Flugsrud et al. (2002), Karlson et al. (2003), Flugsrud et al. (2006), Harms et al. (2007) and Liu et al. (2007) associations between higher BMI and an increased risk of THR and also between higher BMI and hip OA were found (Järvholm et al. 2005). However, in a study by Reijman et al. (2007) a high BMI at baseline was reported not to be associated with the incidence and progression of hip OA.

6.1.6 HEAVY PHYSICAL WORKLOADS

6.1.6.1 Occupational activities

The possible causal relationship between heavy physical workloads over prolonged periods of time and the development of hip OA has been the focus of several studies. Lievense et al. (2001) reviewed 16 studies (Partridge and Duthie 1968, Lindberg and Danielsson 1984, Jacobsson et al. 1987, Thelin 1990, Vingård et al. 1991, Croft et al. 1992b, Croft et al. 1992c, Vingård et al. 1992, Heliövaara et al. 1993b, White et al. 1993, Olsen et al. 1994, Roach et al. 1994, Thelin et al. 1997, Vingård et al. 1997b, Coggon et al. 1998, Yoshimura et al. 2000) and found moderate evidence for a positive association, with an odds ratio of approximately three, between previous heavy physical workload and the occurrence of hip OA. All the 16 studies reviewed revealed a positive association between physical workload and hip OA. In a study of Rossignol et al. (2005), occupations with the greatest prevalence rate ratio for hip, knee and hand OA were: female cleaners (6.2), women in the clothing industry (5.0), male masons and other construction workers (2.9), in addition to male and female workers in agriculture (2.8). Early onset of OA was seen in the more heavy labour jobs with almost 40 per cent of patients reporting their first symptoms before the age of 50. Thelin and Holmberg (2007) concluded that farmers had a significantly increased risk of OA of the hip as compared with their urban reference counterparts.

6.1.6.2 Sports

Lievense et al. (2003) reviewed 22 studies (Puranen et al. 1975, Kraus et al. 1978, Eastmond et al. 1979, Klünder et al. 1980, Sohn and Micheli 1985, Panush et al. 1986, Andersson et al. 1989, Jucker 1990, Konradsen et al. 1990, Marti and Knobloch 1991, Lindberg et al. 1993, Vingård et al. 1993, Kujala et al. 1994, van Dijk et al. 1995, Vingård et al. 1995, Spector et al. 1996, Cooper et al. 1998, Lane et al. 1998, Vingård et al. 1998, Kujala et al. 1999, Lane et al. 1999, Kettunen et al. 2000) to provide updated data on the relation between sporting activities and the occurrence of the hip OA. It was concluded that there is moderate evidence for a positive association between hip OA and sporting activities in general, with an odds ratio of approximately two. However, no high-quality cohort studies were available for the best evidence synthesis, so the analysis was based on retrospective studies only. In a later study made by Schmitt et al. (2004), competitive sports were found to entail a high risk of hip arthrosis.

6.2 EPIDEMIOLOGY OF THA

6.2.1 WOMEN TO MEN RATIO

Women are more likely than men to suffer from osteoarthritis (O'Connor 2007). Therefore, more than 50 per cent of patients undergoing THA in Nordic countries are women (Lohmander et al. 2006). The mean ratios of women to men for the incidence of primary THR for primary OA in the 1996-2000 period were: 1.12

in Denmark, 1.15 in Finland, 1.29 in Iceland, 2.03 in Norway and 1.17 in Sweden (Lohmander et al. 2006). Females accounted for 58 per cent of the primary THA patients in Denmark, 60 per cent in Sweden, and 70 per cent in Norway during the 1995-2006 period, when all diagnoses were included (Havelin et al. 2009). In Australia, 55 per cent of patients with primary THR were women from year 1999 to 2009 (AOA 2009).

6.2.2 AVERAGE AGE

The average age of patients undergoing THA is slightly higher for women than for men. The mean age of patients was 68 years in Finland in 2005. In Sweden, the mean age was 67 years for men and 70 years for women during last 10 years (SHAR 2007). In Denmark, the mean age was 70 years for women and 66 years for men in 2007 (DHR 2008). In Australia, the mean age for primary THRs from 1999 to 2009 was 67 years (69 years for women, 65 years for men) (AOA 2009). The mean age of the patients in Norway at the time of THA was 70 years for the 1987-2006 period (NAR 2007).

6.2.3 INDICATIONS

Primary OA is the most common indication for THA in Nordic countries. In 2004, 76 per cent of THAs were performed for primary OA in Finland (Rantanen et al. 2006). In 2007, 75 per cent of THAs were performed for primary OA in Norway, 7 per cent for late sequelae from fracture of proximal femur and 7 per cent for sequelae from dysplasia (NAR 2008). In 2007, 83 per cent of THAs were performed for primary OA in Sweden, 10 per cent for fracture and 2 per cent for avascular necrosis. However, for patients under 50 years, only 57 per cent of THAs were performed for primary OA during 1992-2007 (SHAR 2007). In 2007, 78 per cent of THRs were performed for primary OA in Denmark, 7 per cent for late sequelae from fracture of proximal femur and 6 per cent for fresh fractures of the proximal femur (DHR 2008). In Australia, 89 per cent of THRs were performed for primary OA, 4 per cent were for avascular necrosis and 3 per cent for a fractured neck of the femur during 1999-2009 (AOA 2009). However, significant differences in the underlying prevalence of hip OA between different populations have been reported (Lohmander et al. 2006).

6.2.4 INCIDENCE

The incidence rate per year per 100 000 of primary THR for primary OA increased from 68 to 80 in Denmark, from 71 to 77 in Finland, from 76 to 93 in Norway and from 86 to 99 in Sweden between the years 1996 to 2000 (Lohmander et al. 2006). The number of hip arthroplasties will further increase because 75 per cent of THAs are performed on patients of 60 years of age and older. However, the age-adjusted incidence of osteoarthrosis is not increasing (Danielsson and Lindberg 1997). In Norway, the overall incidence per 100,000 of the population was 152 primary total hip replacements in 2003 (NAR 2007). In Australia, the incidence of THR for any reason was 102 per 100 000 for the 2005-2006 period (AOA 2007).

6.3 RESULTS OF DIFFERENT THA FIXATION CONCEPTS

6.3.1. BACKGROUND OF THA

Cemented low-friction arthroplasty was pioneered by Sir John Charnley (Charnley 1960, Charnley 1961) who largely laid the basis of modern total hip arthroplasty. However, the problem of aseptic loosening of cemented implants soon emerged. Harris et al. (1976) reported extensive non-linear osteolysis in the proximal femur after cemented THA. This phenomenon was believed to be due to "cement disease", and poor results of cemented THAs were considered to be associated with the use of bone cement. Thus, cementless THAs were developed as a solution to this problem. Some of first reports on cementless THAs were encouraging (Lord and Bancel 1983). However, the high failure rate of smooth threaded cups due to aseptic loosening soon became obvious (Engh et al. 1990, Tallroth et al. 1993, Simank et al. 1997). Porous surfaced cementless cups had better resistance to early aseptic loosening than smooth threaded cups (Engh et al. 1990), but polyethylene wear and osteolysis remained a problem (Barrack et al. 1997, Malchau et al.1997, Puolakka et al. 1999, Puolakka et al. 2001b, Havelin et al. 2002, Young et al. 2002, Duffy et al. 2004, von Schewelov et al. 2004). Promising short- to mid-term results of cementless THAs with highly cross-linked polyethylene bearings have recently been published (McCalden et al. 2009, Fukui et al. 2010). However, longer follow-up of cementless replacements with alternative bearings (highly cross-linked polyethylene, ceramic-on-ceramic, metal-on-metal) is needed. Long term bearing couples data are not available from the Finnish Arthroplasty Register. Resurfacing hip arthroplasties have been performed for relatively young patients during last ten years in Finland. It was not the aim of the current study to analyse hip resurfacing arthroplasty.

6.3.2 CEMENTED THA

Minimum 25-year survival rates for aseptic loosening of cemented all-polyethylene cups in patients with no special attention to age ranged between 85-92 per cent for single centre studies (Callaghan et al. 2000, Della Valle et al. 2004a). However, the number of reports on the long term results of cemented cups is low compared to those studies on cemented stems. The long term survival of metal-backed cemented cups was found to be poor (Williams et al. 2002, Hook et al. 2006).

Minimum 25-year survival rates for aseptic loosening of cemented stems in patients of undefined age was 93 per cent (Callaghan et al. 2000) compared with 85 per cent for any reason (Berry et al. 2002). Minimum 10- to 15 -year survival rates have been found to vary between 83-100 per cent for aseptic loosening (Havinga et al. 2001, Räber et al. 2001, Sanchez-Sotelo et al. 2002, Williams et al. 2002, Issack et al. 2003, Hook et al. 2006, Hauptfleisch et al. 2006, Riede et al. 2007, Callaghan et al. 2008, Clauss et al. 2009, Carrington et al. 2009) compared with 78-98 per cent for any reason (Alho et al. 2000, Annaratone et al. 2000, Sanchez-Sotelo et al. 2002, Issack et al. 2003, Hook et al. 2006, Clauss et al. 2009, Carrington et al. 2009).

The long-term results of cemented THA are presented in Table 1. The focus of this review is mainly restricted to those studies for which the main diagnosis was primary osteoarthritis and the average patient age was 50 years or older.

Study	Hips	Stem	Cup	Mean age (range)	FU yr average (range)	Osteolysis (%)	Survival rates for aseptic loosening		Survival rates for any reason	
							Cup	Stem	Cup	Stem
Callaghan et al. 2000	330	Charnley	Charnley	56 (35-71)	minimum 25	60	85	93	-	-
Alho et al. 2000	110	Lubinus IP/SP	Lubinus	≥60	12	-	-	-	88	78
Berry et al. 2002	2000	Charnley	Charnley	63 (24-92)	minimum 25	-	-	-	87	85
Räber et al. 2001	112	Müller Straight	-	62 (38-80)	14 (12-16)	-	-	88	-	-
Sanchez-Sotelo et al. 2002	249	Harris Design-2	various	66 (16-89)	15 (10-19)	-	-	92	-	90
Williams et al. 2002	325	Exeter Universal	various	67 (24-87)	10-12	0.5	-	100	-	-
Issack et al. 2003	120	Spectron	various	68 (17-85)	16 (13-17)	7.5	-	93	-	90
Della Valle et al. 2004a	123	various	Charnley	60 (23-87)	21 (20-23)	-	92	-	-	-
Annaratone et al. 2000	98	Lubinus SP II	various	72 (60-86)	mean 10	-	-	-	-	98
Hook et al. 2006	142	Exeter Universal	various	61 (18-84)	12 (10-17)	20	-	99	-	98
Hauptfleisch et al. 2006	118	Charnley Elite Plus	various	69 (43-88)	9 (7-10)	-	-	83	-	-
Riede et al. 2007	161	Müller straight	Sulfix-6	68 (25-86)	15	-	-	94	-	-
Havinga et al. 2001	227	Müller straight	not mentioned	71 +/- 7	10	-	-	94	-	-
Kovac et al. 2006	170	Müller style Ti (Lima-Lto)	PE (Lima-Lto)	65 (48-80)	15 (12-16)	56	-	75	-	-
Hamadouche et al. 2002	85	Ceraver Osteal	Ceraver Osteal (alumina)	62 (32-89)	18-20	-	-	-	61	87
Madey et al. 1997	357	Charnley	Charnley	69 (24-88)	minimum 15					
Callaghan et al. 2008	304	Iowa	TiBac	68 (24-89)	19-24	36	92	97	-	-
Clauss et al. 2009.	165	Müller straight	various	69 (26-86)	20	-	-	87	-	81
Carrington et al. 2009	325	Exeter Universal	various	68 (24-87)	15-17	-	-	100	-	81

Table 1. The long-term results of cemented THA in studies from single centres.

6.3.3 CEMENTLESS THA

Minimum 15-year survival rates for cementless porous-coated cups in patients of various ages varied between 77-99 per cent for aseptic loosening (Bojescul et al. 2003, Della Valle et al. 2004b, Kim 2005, Anseth et al. 2009). Minimum 10-year survival rates for aseptic loosening of the same kind of implants has been reported to vary between 92-99 per cent (Archibeck et al. 2001, Meding et al. 2004, Parvizi et al. 2004b, Berli et al. 2007, Firestone et al. 2007, Garcia-Rey et al. 2009). There are also reports of threaded cups with roughblasted outer surfaces that give better results than smooth threaded cups (Pieringer et al. 2003, Pospichill and Knahr 2005, Vervest et al. 2005, Pieringer et al. 2006, Zwartele et al. 2007). On the other hand, some HA-coated grit-blasted press-fit cups have poor survivorship (Kim et al. 2006, Reikerås and Gunderson 2006).

Minimum 10-year survival rate for cementless cups for any reason varies between 81-100 per cent with osteolysis rates between 4-56 per cent (Xenos et al. 1999, Reitman et al. 2003, Gaffey et al. 2004, Oosterbos et al. 2004, Meding et al. 2004, Moskal et al. 2004, Parvizi et al. 2004b, Pieringer et al. 2006, Röhrl et al. 2006, Berli et al. 2007). There are also numerous reports of catastrophic failure rates due to poor polyethylene liner wear resistance and osteolysis (Malchau et al. 1997, Puolakka et al. 2001b, von Schewelov et al. 2004, Hallan et al. 2006).

Minimum 15-year survival rate for cementless stems in patients with no special attention to age has varied between 83 and 98 per cent for aseptic loosening (Teloken et al. 2002, Bojescul et al. 2003, Grant and Nordsletten 2004, Kim 2005, de Aragon and Keisu 2007, Anseth et al. 2009), and also for any reason (Rajaratnam et al. 2008). The minimum 10-year survival rate has varied between 82 and 100 per cent (Xenos et al. 1999, Archibeck et al. 2001, Aldinger et al. 2003, Reitman et al. 2003, Berend et al. 2004, Meding et al. 2004, Parvizi et al. 2004a, Pospischill and Knahr 2005, Vervest et al. 2005, Pieringer et al. 2006, Surdam et al. 2007, Zwartele et al. 2007, Garcia-Rey et al. 2009).

There are several reports that focused on elderly patients who had undergone cementless THA. McAuley et al. (1998) reported on 196 cementless THRs in patients 65 years and older (mean age 71 years, range 65-87). At a minimum five-year follow-up (average 8 years) the re-operation rate was 4 per cent (7 hips). In a study of Purtill et al. (2001), the mean five-year survival (range 2-11 years) of 123 cementless stems in octogenarians (mean age 83 years) was 100 per cent. In a study of Keisu et al. (2001), the 2-11 year survival rate for aseptic loosening of 92 cementless THAs in patients of 80-89 years of age was 100 per cent. Reitman et al. (2003) reported on 72 hips of patients whose mean age was 70 years (minimum 65 years). In a minimum 10 year follow-up the survival for any reason was 92 per cent for the cup and 99 per cent for the stem. In a study of Pieringer et al. (2003), the three to seven year survival for aseptic loosening of 48 cementless THAs in patients of 80-91 years of age was 100 per cent. Berend et al. (2004) reported on 49 hips with a cementless stem in patients with mean age of 79 years. These authors reported 100 per cent survival of the stem for aseptic loosening in 0.5-5.5 years follow-up.

The mid- and long-term results of cementless THA are presented in Table 2. The focus of this review is on studies for which the main diagnosis was primary OA and the average patient age 50 years or older.

Study	Hips	Stem	Cup	Mean age (range)	FU yr average (range)	Wear (mm/yr)	Osteolysis femur/ acetab(%)	Survival rates for aseptic loosening Cup	Survival rates for aseptic loosening Stem	Survival rates for any reason Cup	Survival rates for any reason Stem
Malchau et al. 1997	539	PCA	PCA	50 (20-72)	7-10	-	10/5	-	-	94	95
Thanner et al. 1999	84	PCA	PCA	50 (24-64)	9 (7-11)	0.15	1/5	-	-	85	96
	87	H-G I	H-G I	50 (24-64)	9 (7-11)	0.16	16/3	-	-	99	86
Xenos et al. 1999	100	PCA	PCA	58 (22-81)	minimum 10	-	17/39	95	97	93	95
Clohisy and Harris 1999	237	various	H-G I	59 (23-87)	10 (7-13)	0.10	-/5	100	-	96	-
Archibeck et al. 2001	92	Anatomic Hip	H-G II	52 (31-69)	10 (8-11)	0.16	5/16	96	100	-	-
Keisu et al. 2001	123	Taperloc	Universal	80-89	5 (2-11)	0.08	1/4	100	100	-	-
Engh et al. 2001	211	AML	AML TriSpike	55 (16-87)	13 (2-18)	-	27/16	95	99	-	-
D'Antonio et al. 2001	314	Omnifit	various	51 (18-81)	11 (10-13)	-	44/13	-	-	-	98
Bourne et al. 2001	307	Mallory Head	Hex Loc	64	10-13	0.25	-/49	95	100	90	99
Puolakka et al. 2001b	107	Bi-Metric	PFU	57(28-77)	6 (4-7)	0.20	-/8	-	-	87	100
Giannikas et al. 2002	71	ABG I	ABG I	55 (26-65)	4 (2-7)	0.25	6/0	-	-	97	97
Aldinger et al. 2003	354	CLS	various	57 (13-81)	12 (10-15)	-	0/-	-	95	-	92
Teloken et al. 2002	67	Trilock	cemented	50 (25-72)	15 (14-17)	-	4/-	-	95	-	-
Bojescul et al. 2003	100	PCA	PCA	58 (22-81)	15 (15-17)	-	39/24	77	94	-	-
Reitman et al. 2003	92	Mallory Head	Hex Loc	70 (min 65)	minimum 10	-	8/7	100	100	93	98
Pieringer et al. 2003	87	Alloclassic SL	various	83 (80-91)	5 (3-7)	-	1/1	-	100	-	94

Study	Hips	Stem	Cup	Mean age (range)	FU yr average (range)	Wear (mm/yr)	Osteolysis femur/ acetab(%)	Survival rates for aseptic loosening		Survival rates for any reason	
								Cup	Stem	Cup	Stem
Oosterbos et al. 2004	100	ABG I	ABG I	72 (55-84)	10	-	-/6	-	-	100	97
Marshall et al. 2004	200	Integral	various	56 (31-81)	11 (10-15)	-	-	-	-	-	98
von Schewelov et al. 2004	154	Omnifit	Omnifit	50 (19-83)	6 (0.5-12)	0.20	25	-	-	57	100
Moskal et al. 2004	137	PCA	PCA	69 (27-95)	11-13	-	24/7	-	-	87	95
Meding et al. 2004	105	Bi-Metric	Nelson Cup	56 (27-78)	10 (10-12)	-	1/14	92	100	91	100
Parvizi et al. 2004a	129	Taperloc	various	61 (32-79)	11 (6-15)	-	-	-	-	80	99
Berend et al. 2004	49	Mallory-Head	various	79	0.5-5.5	-	5/2	-	100	-	98
Grant and Nordsletten 2004	116	Lord	Lord	62 (32-77)	17 (15-20)	-	-	65	98	64	92
Gaffey et al. 2004	72	cemented	H-G I	63 (27-86)	13-15	0.15	-/7	-	-	81	-
Della Valle et al. 2004b	204	various	H-G I	52 (20-84)	15-18	-	-/25	99	-	92	-
Herrera et al. 2004	312	ABG I	ABG I	65 (25-86)	7-10	-	17/6	-	-	97	99
Parvizi et al. 2004b	90	H-G I	H-G I	58 (23-80)	15 (10-18)	-	-	-	-	96	87
Pospichill et Knahr 2005	103	Zweymüller	Zweymüller	59 (28-84)	14 (10-17)	0.07	3/0	96	100	85	-
Kim 2005	131	PCA	PCA	48 (19-69)	19 (18-20)	0.18	40/54	79	93	-	-
Shetty et al. 2005	134	Furlong	various	75 (26-95)	14 (13-15)	-	0	-	-	-	99
Vervest et al. 2005	221	Zweymüller	Zweymüller	65	10-12	0.04	-/6	96	100	-	-
Pieringer et al. 2006	124	Alloclassic SL	Alloclassic CSF	59 (29-72)	12 (11-14)	-	11/5	98	100	95	100
Capello et al. 2006	166	Omnifit	various	51 (18-73)	15-18	-	49/-	-	100	-	95
Lombardi et al. 2006	191	Mallory Head	various	-	14 (10-18)	-	-	-	100	-	98
Chen et al. 2006	157	Prodigy	Duraloc	56 (20-80)	6 (0.1-8.2)	0.10	5/2	-	-	100	99

Study	Hips	Stem	Cup	Mean age (range)	FU yr average (range)	Wear (mm/yr)	Osteolysis femur/ acetab(%)	Survival rates for aseptic loosening Cup	Survival rates for aseptic loosening Stem	Survival rates for any reason Cup	Survival rates for any reason Stem
Röhrl et al. 2006	58	various	H-G I/H-G II	55 (38-69)	12	0.09	-/56	100	-	91	-
Hallan et al. 2006	21	PCA	PCA	43 (24-60)	16 (9-18)	0.20	62	-	-	43	76
	25	HG	HG I	47 (19-62)	17 (7-17)	0.20	64	-	-	64	84
	25	Profile	Tri-Lock Plus	56 (25-74)	12 (7-14)	0.21	48	-	-	68	88
Berli et al. 2007	280	not mentioned	Morscher	71 (24-94)	14 (13-17)	0.1	-/1	97	-	95	-
de Aragon and Keisu 2007	114	Lord	not mentioned	60 (38-86)	21 (15-25)	-	-	-	-	-	83
Surdam et al. 2007	258	Multilock	H-G II/ Trilogy	53 (14-74)	9 (5-13)	-	7/7	99	98	-	-
Zwartele et al. 2007	135	Zweymüller	Zweymüller	66 (41-82)	12 (10-17)	-	4/1	97	96	-	-
Firestone et al. 2007	149	cemented	H-G II	69 (32-87)	minimum 10	0.15	16/0	99	-	-	-
Castoldi et al. 2007	157	ABG I	ABG I	59 (31-87)	10 (8-13)	0.25	-/5	-	-	92	96
Rajaratnam et al. 2008	331	Furlong	various	71 (31-90)	17 (15-21)	-	-	-	-	-	97
Garcia-Rey and Garcia-Cimbrelo 2008	83	H-G I	H-G I	57+/-9	15 (3-19)	0.13	-/7	-	-	79	-
“	93	Multilock	H-G II	64+/-5	10 (7-12)	0.11	-/2	-	-	97	-
Garcia-Rey et al. 2009	111	Profile	Duraloc	57 (21-72)	13 (12-15)	0.10	4/1	100	100	95	100
Anseth et al. 2009	113	H-G	H-G I/II	54 (28-74)	15-20	0.15	-	97	90	97	90

Table 2. The mid- and long-term results of cementless THA in studies from single centers.

In conclusion, polyethylene wear and periprosthetic osteolysis are the main problem of the cementless THA. Survival of cementless stems is excellent and does not depend on the patient's age. More wear-resistant articulations for cementless cups are needed. Whether hard-on-hard articulations and highly cross-linked polyethylene will improve the results of cementless cups is still unknown. Laboratory data indicate greatly reduced wear rates for these new bearing couples (Clarke et al. 2000, Goldsmith et al. 2000, Shishido et al. 2003, Oonishi et al. 2004, Affatato et al. 2005, Dumbleton et al. 2006), but only short-term clinical data is available as yet (Dorr et al. 2000, Long et al. 2004, Seyler et al. 2006, Vassan et al. 2007).

6.4 REGIONAL VARIATION IN THE INCIDENCE OF THA

Regional variations in surgery rates were described in several studies as early as the 1970s and 1980s (McPherson et al. 1982, Wennberg et al. 1982, Chassin et al 1986, Keskimäki et al. 1994). Procedures with unproven effectiveness and those performed for clinical conditions with multiple reasonable treatment options, including: coronary artery disease, prostate cancer or osteoarthritis, are most commonly subjected to over- or underuse (Birkmeyer et al. 1998). The ratio of the regional highest and lowest rate of THAs was 4.7-fold in the Medicare population in the USA (Birkmeyer 1998). THAs, coronary artery bypass grafting and transurethral prostatectomy were considered to have intermediate variation profiles, compared to the high variation profiles: of back surgery, lower extremity revascularization, and radical prostatectomy; and the low variation profiles of surgery for hip fracture and resection for colorectal cancer (Birkmeyer et al. 1998). In a previous study from Finland, the ratio of the regional highest and the lowest rate of THAs was threefold. The four procedures with the highest variability were lumbar disc and uterus operations, hemorrhoidectomy and THAs due to OA (Keskimäki et al 1994). In Denmark, the incidence ratio between counties with the highest and the lowest incidence rates of THA was only 1.4 (Pedersen et al. 2005). Dixon et al. (2006) reported that age- and sex-standardized incidence rates of THA varied by 25-30 per cent in England in 2000.

Several reports have dealt with explaining the variables related to the regional variation of THA (Keller et al. 1990, Peterson et al. 1992, Baron et al. 1996, Keskimäki et al. 1996, Wright et al. 1999, Söderman et al. 2000, Hawker et al. 2002, Hudak et al. 2002, Mahomed et al. 2003, Skinner et al. 2003, Milner et al. 2004, Pedersen et al. 2005, Dixon et al. 2006). Keller et al. (1990) suggested that the variation in the incidences of major orthopaedic procedures may be explained by differences in the number of orthopaedic surgeons among the regions. In a study carried out by Peterson et al. (1992), however, the THA rates among Medicare beneficiaries in the USA were not associated with the orthopaedic surgeon density *per se*, although they were inversely proportional to the numbers of the Medicare population per square mile. Pedersen et al. (2005) reported no association between population density and the numbers of orthopaedic surgeons with the incidence variation in Denmark. In a study by Dixon et al. (2006), population size did not correlate with regional variation in England either.

The proportion of patients with primary OA of total number of the patients who received THA did not associate with the variation of the incidence rate in a study of Pedersen et al. (2005).

The incidence rates of THAs have been found to be low in several large cities including: London (Dixon et al. 2006), Copenhagen (Pedersen et al. 2005), Stockholm, Gothenburg and Malmö (Söderman et al. 2000). In a study emanating from England, people in rural areas were at least as likely to be managed for OA of the hip by their GPs and hospital consultants as their counterparts in urban areas (Milner et al. 2004).

In the study by Dixon et al. (2006), the numbers of limiting long-term illnesses and standardized mortality rates in a region offering THAs were not associated with the incidence rate of THAs *per se*. However, substantial variation in the incidence rates of THA against socio-economic status was found in England, with the most deprived fifth of the population experiencing significantly lower rates of surgery than those belonging to higher socio-economic groups (Dixon et al. 2004). Milner et al. (2004) reported that people in England who were socio-economically deprived were about twice as likely to be in need of THA, than those who were more prosperous but were less likely to receive those particular services. In a study based on data obtained from the Finnish Hospital Discharge Register for the 1987-1988 period, the THA rates due to OA favoured the better-off. It was concluded, that although the Finnish health care system operates universal coverage without formal barriers to equal access, systematic socioeconomic inequity in the use of individual surgical treatments prevail (Keskimäki et al. 1996). In a more recent study by Dixon et al. (2006), social class and unemployment rates were not correlated with age-standardized operation rates in England. Pedersen et al. (2005) found no association between age- and sex-adjusted regional incidence rates of THA with hospital costs, or with GDP per capita in Denmark.

6.5 THE EFFECT OF HOSPITAL VOLUME ON PERFORMANCE OF THA

6.5.1 THE LENGTH OF STAY AND COSTS

The length of post-operative stay after THR varies. Although too early a discharge after THR has been cautioned against (Parvizi et al. 2007b), some THRs have even been performed as day-case surgery (Berger et al. 2004). However, reducing the length of stay lowers the cost of care per patient and allows for an increase in bed occupancy (Williams et al. 2005). Doro et al. (2006) studied 275,813 primary THAs from the Nationwide Inpatient Sample database including data of both Medicare and non-Medicare patients. Hospitals were divided into quartiles to differentiate low- and high-volume centres. The average length of stay for THA admissions was 6.84 days for low volume hospitals, and decreased in each quartile to 5.78 days for the highest volume hospital quartile. Mitsuyasu et al. (2006) studied 1561 THA or total knee arthroplasty patients from 2001 to 2003 in 10 Japanese national hospitals and nine private hospitals. Participating hospitals were divided into either a high or a low volume group. These authors found that the mean length of stay was significantly shorter for the high volume group than for the low volume group. Further, total hospital charges were lower for the high volume group than for the low volume group. Kreder et al. (1997) stated that the duration of hospitalization was inversely related to surgeon volume and positively associated with hospital volume. Hospital charges were inversely related to hospital volume, even after adjusting for patient-related factors and also other factors including: the duration of hospitalization, the year of the operation, and the destination after discharge. Martineau et al. (2005) analysed direct costs of 940 primary THAs of three Canadian hospitals. Mean in-hospital costs for patients having THAs in a high volume institution (≥300 THAs/year) compared with two low-volume Canadian institutions (<300 THAs/year) were: 3023 US dollars +/- 93 US dollars versus 4952 US dollars +/- 91 US dollars, respectively. It was stated, that as THAs continue to be scrutinized for cost containment, having the procedure carried out in a high volume centre seems to be an effective method of controlling costs.

Short length of stay (LOS) did not associate with low hospital volume in any of the studies found and reviewed. According to existing known litterature, elective THAs should be performed at high volume centres to reduce LOS and costs.

6.5.2 UNSCHEDULED RE-ADMISSIONS

Unscheduled re-admission rate is a national key performance indicator used by the UK Department oh Health (Adeyemo and Radley 2007). A 28-day emergency re-admission rate has been used as a clinical indicator to compare surgical and orthopaedic performance between trusts in England and also in Scotland (Courtney et al. 2003). In a study conducted by Cullen et al. (2006), 8.5 per cent of patients were re-admitted within 28 days of discharge after THR. The main reasons of re-admission were thrombo-embolic complications, dislocations and wound complications. Reducing the LOS lowered the cost of care per patient and allowed for increased bed occupancy rates, but the effect on emergency readmission rates was equivocal (Williams et al. 2005). The odds ratio of emergency readmission for primary hip replacement was 0.54 when LOS was four to seven days and 0.55 when it was eight to 14 days, whereas an odds ratio 1.0 was obtained, when the LOS was four days or less (Williams et al. 2005). Factors associated with increased odds of readmission were: being male, increasing socioeconomic deprivation and high numbers of co-morbidity conditions (Williams et al. 2005).

6.5.3. MORTALITY

Katz et al. (2001) studied 58,521 primary THAs performed on patients covered by Medicare in the USA for the 1995-1996 period. Patients treated with primary THA in hospitals in which more than 100 procedures were performed per year had a lower risk of death than those treated in hospitals in which 10 or fewer procedures were performed per year (OR 0.58). Kreder et al. (1997) evaluated the hospital discharge register for Washington State for the 1988-1991 period. These authors determined the occurrence of death within three months and one year for 8,774 THAs. Patients of the lowest-volume surgeon group had three times the risk of dying within three months after elective THA than those in the highest-volume surgeon group. Moreover, patients who had been operated on in the highest-volume hospitals had significantly higher survival within one year after THA than those patients operated on in lower-volume hospitals. In a study based on Medicare data for the 1993-1994 period, Taylor et al. (1997) studied in-house and 30-day mortality against hospital volume. Low-volume hospitals (fewer than 25 THAs annually) had a nearly four times greater in-house mortality and three times greater 30-day mortality rate compared with high-volume hospitals in which more than 199 procedures were done per year. Lavernia and Guzman (1995) published a report based on the Florida hospital discharge database. A total of 19,925 primary elective hip and knee arthroplasties were included. Surgeons with a low volume of THAs were associated with a higher mortality rate than high volume surgeons. Doro et al. (2006) studied 275,813 primary THAs from the Nationwide Inpatient Sample database including data of both Medicare and non-Medicare patients. Hospitals were divided into quartiles to differentiate low- and high-volume centres. Mortality increased with decreasing hospital case volume, and the lowest volume hospitals had an adjusted odds ratio of 1.9.

Low mortality did not associate with low hospital volume in any of the studies found and reviewed. According to the existing known literature, elective THAs should be performed at high volume centres in order to reduce mortality.

6.5.4 DISLOCATIONS

Dislocation rates during the first year after THR has been reported to range from less than one per cent to 3.9 per cent (Phillips et al. 2003, Khatod et al. 2006, Meek et al. 2006). In a study by von Knoch et al. (2002), the incidence of dislocation increased with time, being 1.8 per cent at one year, seven per cent at five years and after that it increased to one per cent every subsequent five-year period. Several factors are constantly reported to be statistically associated with THR dislocation rates, these are: surgical diagnosis, femoral head size, patient age and gender, American Society of Anesthesiologists (ASA) score, cognitive dysfunction, surgical approach, surgeon volume and hospital volume (Meek et al. 2006).

In a study carried out by Solomon et al. (2002), 69 per cent fewer dislocations and infections occurred in hospitals in which more than 100 THRs were performed annually, compared with those hospitals in which fewer than 25 THRs were performed annually. Surgeon volume was the strongest predictor of adverse events. Katz et al. (2001) stated that patients treated with THR at hospitals and by surgeons with higher annual caseloads had lower rates of dislocation. In two systematic reviews of the literature by Battaglia et al. (2006) and Shervin et al. (2007), a positive association between higher hospital and surgeon volumes and lower rates of hip dislocation was found.

6.5.5 INFECTIONS

In recent studies, the rate of deep prosthetic infections was found to vary between 0.6 per cent and 0.9 per cent after THR (Gastmeier et al. 2005, Muilwijk et al. 2006, Phillips et al. 2006). Independent risk factors for surgical site infections after THR are: patient's age, surgical diagnosis, ASA score and duration of operation (Ridgeway et al. 2005). In a systematic literature review, no association between hospital volume and infection rate was found (Shervin et al. 2007).

6.5.6 RE-OPERATIONS

In a study made by Dobzyniak et al. (2006), 39 per cent of all THR revisions were performed within five years after the index THR. Of these, 33 per cent were performed because of instability, 30 per cent for aseptic loosening and 14 per cent for infection. Clohisy et al. (2004) reported that instability was the commonest reason for early revision whereas osteolysis was the commonest reason for late revision. In a report based on data obtained from the Norwegian Arthroplasty Register, a high annual number of cemented THRs per hospital was not associated with lower revision rates, whereas the revision rate decreased with an increasing number of uncemented THRs (Espehaug et al. 1999). In a study by Manley et al. (2008), patients operated on by low-volume surgeons had a greater risk of arthroplasty revision at six months but no greater risk of revision at the time of longer-term follow-up. No significant association between hospital volume and the rate of revisions of THA was found by Kreder et al. (1997), Judge et al. (2006) and Manley et al. (2008). However, Kreder et al. (1997) found an association between high surgeon volume and low rate of revisions within three months and within one year.

	Study 1	Study 2	Study 3	Study 4	Study 5
Study design	Prospective, observational	Prospective, observational	Prospective, observational	Prospective, observational	Prospective, observational
Types of data	Register-based	Register-based	Register-based	Register-based	Register-based
Number of hips	50,968	34,549	19,859	34,642	28,218
Females (%)	61	65	59	57	57
Mean age (years)	70	72	68	68	68
Mean follow up (years)	6.9	7.3	7.6	-	4.7
Time period	1980-2004	1980-2005	1980-2005	1998-2005	1998-2005
Number of hospitals	84	82	77	73	81

Table 3. Summary of study design, type of data, patients and follow-up time.

7. AIMS OF THE PRESENT STUDY

The main purpose of this study was to evaluate the survival of THA in patients aged 55 years and older at the time of primary THA on a nation-wide level and in addition to consider regional variation in incidence of THA and also the effects of hospital volume on the performance of THA.

The specific aims of the studies were to assess:

1. The population-based survival of different THR concepts of primary total hip replacement for primary osteoarthritis for patients aged 55 years and older.

2. The population-based survival of primary cemented total hip replacements for primary osteoarthritis for patients aged 55 years and older.

3. The population-based survival of primary cementless total hip replacements for primary osteoarthritis for patients aged 55 years and older.

4. Regional variation in the incidence of primary THA due to primary OA and the factors associated with it.

5. The effects of hospital volume on the length of post-operative stay, unscheduled re-admissions, costs and complication rates related to THA on a population level.

8. PATIENTS AND METHODS

8.1 PATIENTS

8.1.1 FINNISH ARTHROPLASTY REGISTER-BASED STUDIES (I, II AND III)

In studies I, II and III, only patients aged 55 years and older at the time of the primary operation were included. In order to eliminate the effect of diagnosis as a confounding factor, only those patients with primary osteoarthritis as a recorded indication for operation were included.

During the study period covered in study I (from 1980 to 2004), 90,954 primary total hip replacements were performed in Finland. Of these operations, 80,805 (89%) were performed on patients aged 55 years and older. Primary OA was an indication in 81 per cent (n=65,673) of these operations. After excluding implants according to our study exclusion criteria (see Methods), 50,968 total hip replacements were included in the final analysis in study I. The mean age and gender distribution of the patients were recorded (Table 4).

During the study period of study I, 135 different stem designs were used in Finland, of which 84 (62%) were used in fewer than 50 operations. Cementless stems were used in 29 per cent of the primary operations. During the same study period, 132 different cup designs were used, of which 73 (55%) were used in fewer than 50 operations. Cementless cups were used in 39 per cent of the primary operations during the study period. During the study period in study I, 4273 revision operations were performed on patients of the study group (Table 5).

During the study period covered in study II (from 1980 to 2005), 101,720 primary total hip replacements were performed in Finland. Of these operations, 87,578 (86%) were performed on patients aged 55 years and over, and primary osteoarthritis was the indication in 81 per cent (n=71,146) of these operations. Of these 71,146 THRs, 41,034 (58%) were cemented. The 12 most commonly used cemented replacements, i.e. cup + stem combinations, were identified and included in the final analyses in study II (Table 6, Table 7). These 12 replacements had been used in 34,549 operations (84% of all cemented replacements). During the study period of study II, 2,809 revision operations were performed on patients of the study group (Table 8).

During the study period of study III (1980-2005), 101,720 primary THRs were performed in Finland. Of these, 87,578 (86%) were performed on patients aged 55 years or older. Primary OA was the indication in 71,146 (81%) of these operations, and cementless total hip implants were implanted in 30,112 (42%).

Those designs used in more than 500 operations and also designs with more than 20 hips at risk at five years were included in study III. These criteria permitted the inclusion of eight designs (10,310 replacements). All other designs were excluded. The risk of revision for each design was compared with that of 9,549 cemented reference implants (Tables 9 and 10). A 10-year survival rate exceeding 90 per cent is commonly regarded as a good long-term outcome (National Institute for Clinical Excellence, NICE). The three best performing cemented designs in Finland (study II) fulfilled this criterion and where chosen as the reference implants. These three cemented reference designs were the Exeter Universal stem combined with the All-poly cup (Stryker, Mahwah, NJ), the Müller Straight stem combined with the Müller Standard cup (Zimmer, Warsaw, Ind.) and the Lubinus SP II stem combined with the Lubinus IP cup (Waldemer Link, Hamburg, Germany). Revisions were linked to the primary operation by using the patient's personal identification number, which is assigned to every resident in Finland. Numbers and indications for revisions were recorded (Table 11).

Total Hip Replacement*	No. of Hips	Duration of Follow-up† (yr)	Age† (yr)	Women (%)	No. of Hospitals	Time Period
Cementless group 1	7145	5.7 (0-18)	64 (55-87)	49	69	1986-2004
Cementless group 2	5743	6.3 (0-19)	65 (55-90)	53	65	1985-2004
Hybrid group	3784	4.9 (0-16)	70 (55-95)	59	55	1988-2004
Cemented group	34,296	7.1 (0-25)	72 (55-96)	65	81	1980-2004
Total	**50,968**	**6.9 (0-25)**	**70 (55-96)**	**61**	**84**	**1980-2004**

Table 4. Demographic data on the patients with a total hip replacement analyzed in study I. * Cementless group 1 consisted of implants with a cementless, straight, proximally porous-coated stem and a modular, cementless, press-fit porous-coated cup, and cementless group 2 consisted of implants with a cementless, anatomic, proximally porous-coated and/or hydroxyapatite-coated stem with a modular, press-fit and/or hydroxyapatite-coated cup. †The values are given as the mean, with the range in parentheses.

THR	No.	Aseptic loosening (both)*	Aseptic loosening (cup)	Aseptic loosening (stem)	Infection	Dislocation	Malposition	Fracture of the prosthesis	Periprothetic fracture	Other reason £	Total
Cementless Group #1	7145	54 (9.5%)	96 (16.9%)	32 (5.6%)	19 (3.3%)	126 (22.2%)	26 (4.6%)	21 (3.7%)	35 (6.2%)	159 (28.0%)	568 (100%)
Cementless Group #2	5743	50 (9.8%)	144 (28.2%)	64 (12.5%)	14 (2.7%)	39 (7.6%)	30 (5.9%)	15 (2.9%)	36 (7.1%)	118 (23.1%)	510 (100%)
Hybrid THR	3784	17 (8.0%)	16 (7.5%)	62 (29.2%)	25 (11.8%)	44 (20.8%)	18 (8.5%)	4 (1.9%)	18 (8.5%)	8 (3.8%)	212 (100%)
Cemented THR	34,296	1036 (34.7%)	476 (16.0%)	837 (28.1%)	155 (5.2%)	233 (7.8%)	59 (2.0%)	23 (0.8%)	105 (3.5%)	59 (2.0%)	2983 (100%)
Total	**50,968**	**1157**	**732**	**995**	**213**	**442**	**133**	**63**	**194**	**344**	**4273**

Table 5. Reasons for revisions in study I. No. = number of primary operations. *Number of revision operations, percentage of all revisions in parenthesis. £Other reason includes, for example, liner revisions due to excessive wear. THR = total hip replacement. Cementless group #1 = a cementless, straight, proximally porous-coated stem with a modular, cementless, press-fit porous-coated cup. Cementless group #2 = a cementless, anatomic, proximally porous- and/or hydroxyapatite-coated stem with a modular, press-fit and/or hydroxyapatite-coated cup.

THR Brands	Number	Mean follow-up	Mean age	Women (%)	Number of hospitals	Years of implantation
Elite Plus/ Elite Plus	885	6.3	72.2	66.3	14	1993-2004
Lubinus IP/ Lubinus IP	5790	12.0	69.4	65.4	36	1980-1995
Lubinus SP II/ Lubinus IP	7240	8.1	72.3	66.7	48	1986-2005
Lubinus SP II/ Lubinus FC	701	2.6	73.3	61.1	12	2000-2005
Lubinus SP II/ Lubinus Eccentric	2693	5.9	73.4	66.3	33	1988-2005
Exeter/ Exeter Metal-backed	876	11.6	69.0	59.6	21	1981-1991
Exeter Universal/ Exeter All-poly	5048	5.9	73.1	64.9	42	1989-2005
Exeter Universal/ Exeter Contemporary	5572	2.9	72.9	61.5	51	1996-2005
Müller straight/ Müller Std	2309	10.7	70.9	64.1	30	1980-1998
Spectron EF/ Reflection all-poly	1929	1.8	73.6	65.7	29	1999-2005
Biomet Interlok/ Biomet Müller	581	7.5	73.3	71.1	15	1990-2004
Charnley/ Charnley LPW	925	11.0	68.8	63.0	17	1980-2003
Together	**34549**	**7.3**	**71.9**	**64.8**	**82**	

Table 6. Demographic data in study II.

THR Brands	Material	Surface	Special design features	Recent manufacturer
Stems				
Elite Plus	stainless steel	matt (Vaquasheen)	straight, small collar, proximal flange	Johnson & Johnson
Lubinus IP	CoCr alloy	matt	straight, collar, monoblock, IP=Interplanta	Link
Lubinus SP II	CoCr alloy	matt	anatomic, collar, modular, SP=Status Physiologus	Link
Exeter	stainless steel	matt	straight, collarless	Stryker Howmedica
Exeter Universal	stainless steel	polished	straight, collarless	Stryker Howmwdica
Müller Straight	CoCr alloy	matt	straight, small collar, fluted macrostructure	Zimmer
Spectron EF	CoCr alloy	proximally roughened	straight, collar	Smith & Nephew
Biomet Interlok	CoCr alloy	matt	straight, collar/collarless	Biomet
Charnley flat-back	stainless steel	polished	straight, collarless, flat-backed	Johnson & Johnson
Cups				
Elite Plus	UHMW poly	-	-	Johnson & Johnson
Lubinus IP	UHMW poly	-	IP=Interplanta, groove design	Link
Lubinus FC	UHMW poly	-	flanged	Link
Lubinus Eccentric	UHMW poly	-	deep design, snap fit	Link
Exeter Metal-backed	UHMW poly	-	metal backing	Stryker Howmedica
Exeter All-poly	UHMW poly	-	low/high version	Stryker Howmedica
Exeter Contemporary	UHMW poly	-	-	Stryker Howmedica
Müller Std	UHMW poly	-	-	Stryker Howmedica
Reflection	UHMW poly/ XLPE poly	-	flanged, ridges/grooves	Smith & Nephew
Biomet Müller	UHMW poly	-	-	Biomet
Charnley LPW	UHMW poly	-	LPW=long posterior wall	Johnson & Johnson

Table 7. Material, surface and design of the femoral and acetabular components in study II.

THR brands	N	Aseptic loosening (cup + stem)	Aseptic loosening (cup)	Aseptic loosening (stem)	Infection	Dislocation	Malposition	Fracture of the prosthesis	Periprothetic fracture	Another reason	Together
All other THRs	36597	919 (21.5%)	1074 (25.1%)	891 (20.8%)	141 (3.3%)	385 (9.0%)	117 (2.7%)	80 (1.9%)	199 (4.6%)	474 (11.1%)	4280 (100.0%)
Elite Plus/ Elite Plus	885	28 (26.9%)	7 (6.7%)	53 (51.0%)	2 (1.9%)	4 (3.8%)	3 (2.9%)	1 (1.0%)	6 (5.8%)	0 (0%)	104 (100.0%)
Lubinus IP/ Lubinus IP	5790	464 (51.1%)	150 (16.5%)	225 (24.8%)	25 (2.8%)	6 (0.7%)	5 (0.6%)	10 (1.1%)	15 (1.7%)	8 (0.9%)	908 (100.0%)
Lubinus SP II/ Lubinus IP	7240	161 (26.7%)	96 (15.9%)	198 (32.9%)	24 (4.0%)	71 (11.8%)	18 (3.0%)	1 (0.2%)	19 (3.2%)	14 (2.3%)	602 (100.0%)
Lubinus SP II/ Lubinus FC	701	4 (22.2%)	0 (0%)	0 (0%)	6 (33.3%)	8 (44.4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	18 (100.0%)
Lubinus SP II/ Lubinus Eccentric	2693	30 (19.7%)	23 (15.1%)	58 (38.2%)	11 (7.2%)	16 (10.5%)	6 (3.9%)	0 (0%)	3 (2.0%)	5 (3.3%)	152 (100.0%)
Exeter/ Exeter Metal-backed	876	73 (42.7%)	28 (16.4%)	46 (26.9%)	2 (1.2%)	4 (2.3%)	1 (0.6%)	7 (4.1%)	8 (4.7%)	2 (1.2%)	171 (100.0%)
Exeter Universal/ Exeter All-poly	5048	34 (14.4%)	57 (24.2%)	29 (12.3%)	28 (11.9%)	46 (19.5%)	11 (4.7%)	0 (0%)	23 (9.7%)	8 (3.4%)	236 (100.0%)
Exeter Universal/ Exeter Contemporary	5572	10 (7.1%)	21 (15.0%)	10 (7.1%)	19 (13.6%)	52 (37.1%)	9 (6.4%)	0 (0%)	14 (10.0%)	5 (3.6%)	140 (100.0%)
Müller Straight/ Müller Std	2309	66 (33.7%)	46 (23.5%)	55 (28.1%)	14 (7.1%)	2 (1.0%)	2 (1.0%)	4 (2.0%)	5 (2.6%)	2 (1.0%)	196 (100.0%)
Spectron EF/ Reflection all-poly	1929	4 (12.1%)	6 (18.2%)	2 (6.1%)	9 (27.3%)	10 (30.3%)	1 (3.0%)	0 (0%)	1 (3.0%)	0 (0%)	33 (100.0%)
Biomet Interlok/ Biomet Müller	581	14 (24.6%)	11 (19.3%)	21 (36.8%)	3 (5.3%)	2 (3.5%)	0 (0%)	0 (0%)	4 (7.0%)	2 (3.5%)	57 (100.0%)
Charnley/ Charnley LPW	925	79 (41.1%)	18 (9.4%)	66 (34.4%)	8 (4.2%)	5 (2.6%)	0 (0%)	3 (1.6%)	5 (2.6%)	8 (4.2%)	192 (100.0%)
Together	**71146**	**1886 (26.6%)**	**1537 (21.7%)**	**1654 (23.3%)**	**292 (4.1%)**	**611 (8.6%)**	**173 (2.4%)**	**106 (1.5%)**	**302 (4.3%)**	**528 (7.4%)**	**7089 (100.0%)**

Table 8. Reasons for revisions of 12 most common cemented and all other total hip replacements in study II. N = number of primary operations.

THR Brands	Number	Mean follow-up	Mean age	Women (%)	Number of hospitals	Years of implantation
Anatomic Mesh/HG-II	604	11.1	63	56	24	1989-1997
PCA Std/PCA Pegged	508	11.6	63	55	23	1985-1995
Bi-Metric/PFU	2,687	8.8	63	49	53	1986-2001
Bi-Metric/Mallory	637	8.7	67	60	11	1989-2000
Bi-Metric/Vision	2,055	3.4	65	48	47	1998-2005
ABG I/ABG I	565	9.1	65	55	25	1992-1997
ABG I/ABG II	1,765	5.9	66	51	36	1996-2003
ABG II/ABG II	1,489	2.5	67	55	31	2000-2005
Cemented reference	9,549	8.8	72	66	62	1980-2005
Together	**19,859**	**7.6**	**68**	**59**	**77**	**1980-2005**

Table 9. Demographic data of the implants analyzed in study III. Abbreviations: HG-II = Harris-Galante II, PCA Std = Porous Coated Anatomic Standard, PFU = Press-Fit Universal and ABG = Anatomique Benoist Girard.

THR Brands	Material	Surface	Special design features	Manufacturer
Stems				
Bi-Metric	titanium alloy	proximally porous coated	straight, collarless	Biomet
Anatomic Mesh	titanium alloy	proximally porous coated	anatomic	Zimmer
ABG I	titanium alloy	proximally grit-blasted and HA-coated	anatomic	Stryker Howmedica
ABG II	titanium alloy	proximally grit-blasted and HA-coated	anatomic	Stryker Howmedica
PCA Standard	CoCr alloy	proximally porous coated	anatomic	Stryker Howmedica
Exeter Universal	stainless steel	polished	straight, collarless, cemented	Stryker Howmedica
Müller Straight	CoCr alloy	matt	straight, small collar, fluted macrostructure	Zimmer
Lubinus SP II	CoCr alloy	matt	anatomic, collar, modular	Link
Cups				
ABG I	titanium alloy	grit-blasted and HA-coated	hemispherical, open screw-holes	Stryker Howmedica
ABG II	titanium alloy	grit-blasted and HA-coated	hemispherical, screw-holes plugged	Stryker Howmedica
Biomet Mallory	titanium alloy	porous coated	hemispherical, open screw-holes, fins	Biomet
Biomet Universal	titanium alloy	porous coated	hemispherical, open screw-holes	Biomet
Biomet Vision	titanium alloy	porous coated	hemispherical, screw-holes plugged	Biomet
Harris-Galante II	titanium alloy	porous coated	hemispherical, open screw-holes	Zimmer
PCA Pegged	cobalt-chromium	porous coated	hemispherical, open screw-holes	Stryker Howmedica
Exeter All-poly	polyeyhylene	-	cemented	Stryker Howmedica
Müller Std	polyeyhylene	-	cemented	Zimmer
Lubinus IP	polyeyhylene	-	groove design	Link

Table 10. Material, surface, design features and manufacturer of the implants in study III. Abbreviations: THR = total hip replacement, HG-II = Harris-Galante II, PCA = Porous Coated Anatomic, PFU = Press-Fit Universal and ABG = Anatomique Benoist Girard.

THR brands	N	Aseptic loosening (cup + stem)	Aseptic loosening (cup)	Aseptic loosening (stem)	Infection	Dislocation	Malposition	Fracture of the prosthesis	Periprothetic fracture	Another reason	Together
Anatomic Mesh/HG-II	604	17 (15.0%)	23 (20.4%)	17 (15.0%)	0 (0.0%)	4 (3.5%)	7 (6.2%)	4 (3.5%)	2 (1.8%)	39 (34.5%)	**113 (100.0%)**
PCA Std/PCA Pegged	508	19 (14.1%)	81 (60.0%)	19 (14.1%)	2 (1.5%)	1 (0.7%)	2 (1.5%)	0 (0.0%)	1 (0.7%)	10 (7.4%)	**135 (100.0%)**
Bi-Metric/PFU	2,687	26 (7.5%)	67 (19.4%)	10 (2.9%)	9 (2.6%)	57 (16.5%)	14 (4.1%)	16 (4.6%)	15 (4.3%)	131 (38.0%)	**345 (100.0%)**
Bi-Metric/Mallory	637	5 (7.8%)	11 (17.2%)	3 (4.7%)	1 (1.6%)	12 (18.8%)	3 (4.7%)	5 (7.8%)	3 (4.7%)	21 (32.8%)	**64 (100.0%)**
Bi-Metric/Vision	2,055	11 (15.9%)	1 (1.4%)	6 (8.7%)	8 (11.6%)	28 (40.6%)	5 (7.2%)	0 (0.0%)	4 (5.8%)	6 (8.7%)	**69 (100.0%)**
ABG I/ABG I	565	10 (9.4%)	27 (25.5%)	3 (2.8%)	1 (0.9%)	6 (5.7%)	3 (2.8%)	3 (2.8%)	6 (5.7%)	47 (44.3%)	**106 (100.0%)**
ABG I/ABG II	1,765	1 (1.6%)	6 (9.5%)	2 (3.2%)	5 (7.9%)	13 (20.6%)	10 (15.9%)	1 (1.6%)	10 (15.9%)	15 (23.8%)	**63 (100.0%)**
ABG II/ABG II	1,489	2 (3.9%)	1 (2.0%)	3 (5.9%)	3 (5.9%)	10 (19.6%)	7 (13.7%)	4 (7.8%)	19 (37.3%)	2 (3.9%)	**51 (100.0%)**
Cemented reference	9,549	227 (28.4%)	142 (17.8%)	253 (31.7%)	38 (4.8%)	73 (9.1%)	20 (2.5%)	5 (0.6%)	24 (3.0%)	16 (2.0%)	**798 (100.0%)**
Together	**19,859**	**318 (18.2%)**	**359 (20.6%)**	**316 (18.1%)**	**67 (3.8%)**	**204 (11.7%)**	**71 (4.1%)**	**38 (2.2%)**	**84 (4.8%)**	**287 (16.5%)**	**1,744 (100.0%)**

Table 11. Reasons for revision of the eight most common cementless brands and the cemented reference designs in study III. Abbreviations: THR = total hip replacement, N = number of primary operations, HG-II = Harris-Galante II, PCA Std = Porous Coated Anatomic Standard, PFU = Press-Fit Universal and ABG = Anatomique Benoist Girard.

8.1.2 HOSPITAL DISCHARGE REGISTER-BASED STUDIES (IV AND V)

The study population used in both studies IV and V was formed by selecting patients fulfilling the following criteria from the Hospital Discharge Register: International Classification of Diseases code (ICD-10, WHO) for primary OA or secondary OA for developmental dysplasia of the hip (M16.0, M16.1, M16.2 and M16.3) and operation codes defined by the Nordic Centre for Classifications in Health Care (NFB30 for cementless THA, NFB40 for hybrid THA, NFB50 for cemented THA, NFB60 for demanding THA and NFB99 for other THA procedures such as hip resurfacing) performed between years 1998-2005. Patients with a diagnosis of secondary OA for developmental dysplasia of the hip (M16.2 and M16.3) were included because there is variation in the use of codes for primary OA and for secondary OA due to the occurrence of developmental dysplasia. Patients who had congenital hip dislocation are allocated a different diagnosis code (Q65.0-Q65.9) to those of secondary OA for developmental dysplasia of the hip and were thus excluded from this study. Patients living in the autonomous province of Ahvenanmaa throughout the time of study period were excluded from the study, because an unknown number of those patients were operated on in Sweden. Only 0.5 per cent of Finnish citizens live in the province of Ahvenanmaa (Statistics Finland). In total 50 patients were excluded because they were living abroad.

In study IV, the numbers and incidences of THA for OA were reported separately for each hospital region. The municipality of residence of each patient determined the hospital region to which he or she belonged. According to Finnish law all inhabitants of Finland must belong to one of the hospital regions. The data from the largest hospital region of Helsinki and Uusimaa (HUHD) was divided into two districts as the HUHD population accounts for 30 per cent of the inhabitants in Finland. The subgroups were Helsinki for Helsinki city and Uusimaa for the rest of the Helsinki metropolitan area, which are comparable in size. The hospital region data were then calculated on a yearly basis for the years 1998 to 2005 inclusive. These data also include THAs performed in private hospitals region by region. Over the 1998 to 2005 period, 44,093 primary THAs were performed in Finland. Of these, 34,642 were included in study IV.

In study V, the diagnosis of secondary hip OA other than that for secondary OA due to DDH was noted retrospectively from the beginning of 1988. A patient was excluded, when there was a diagnosis of secondary hip OA in the Hospital Discharge Register between the beginning of 1988 and the day of operation (Table 12). Patients who had an entitlement to reimbursement from the Social Insurance Institution database for the following conditions were excluded: sequelae of transplantation, uraemia requiring dialysis, rheumatoid arthritis or connective tissue disease. Total hip replacements *per se* were evaluated according to the following: the length of stay, the length of uninterrupted institutional care and unscheduled re-admissions.

Thus, it was possible, that two THRs in the same patient could be evaluated. The total number of these THRs was 28,218. However, when considering re-operations, dislocations and infections, only cases for which the index THA was the only THA of the patient during years 1988-2006 were evaluated. The reason for this was that the side of the operation (left/right) was not reliably coded in the Hospital Discharge Register. If the data of the side of the operation is missing, then it would not be possible to identify the hip in question with certainty from the register data in order to evaluate the outcomes. Thus the total number of patients and hips in the analyses of re-operations, dislocations and infections was 22,084 (Table 13).

S72.0	Fracture of neck of femur
S72.1	Pertrochanteric fracture of femur
S72.2	Subtrochanteric fracture of femur
M91.1	Juvenile osteochondrosis of head of femur (Legg-Calvé-Perthes)
M93.0	Slipped upper femoral epiphysis (nontraumatic)
S324	Fracture of acetabulum
M45.*	Ankylosing spondylitis
Q65.*	Luxatio coxae congenita
M16.4	Post-traumatic coxarthrosis, bilateral
M16.5	Other post-traumatic coxarthrosis
M16.6	Other secondary coxarthrosis, bilateral
M16.7	Other secondary coxarthrosis
M16.9	Coxarthrosis, unspecified
M87.*	Osteonecrosis
M00.*	Pyogenic arthritis
M05.*	Seropositive rheumatoid arthritis
M06.*	Other rheumatoid arthritis
M07.*	Psoriatic and enteropathic arthropathies
M08.*	Juvenile arthritis
D66.	Hereditary factor VIII deficiency
D67.	Hereditary factor IX deficiency
D68.	Other coagulation defects
M36.2	Haemophilic arthropathy
Q77.	Osteochondrodysplasia with defects of growth of tubular bones and spine
Q78.	Other osteochondrodysplasias
Q79.	Congenital malformations of the musculoskeletal system, not elsewhere classified

Table 12. Exclusion criteria (ICD-10 diagnosis) in study V.

Cohort	Number a (per cent) of hips	Number b (per cent) of hips
1998	3077 (9.4)	2060 (7.8)
1999	3033 (9.2)	2149 (8.2)
2000	3184 (9.7)	2322 (8.8)
2001	3337 (10.2)	2542 (9.6)
2002	3590 (10.9)	2819 (10.7)
2003	3896 (11.9)	3209 (12.2)
2004	3673 (11.2)	3123 (11.8)
2005	4428 (13.5)	3860 (14.6)
Total	**28218 (100)**	**22084 (100)**

Table 13. Number a refers to annual number of hips in study V. Number b refers to evaluation of re-operations, dislocations and infections, when patients with unilateral THR implants only were evaluated over the 1988-2005 period.

8.2 METHODS

8.2.1 FINNISH ARTHROPLASTY REGISTER-BASED STUDIES (I, II AND III)

To understand further the effects of age, we decided to perform analyses separately for three different age groups: 55 to 64 years, 65 to 74 years, and 75 years or over (I, II and III).

In study I, total hip replacements (cup and stem combinations) that had been used in more than 50 operations during the study period were included. Consequently, prosthetic components with well-documented poor results such as cementless, smooth threaded cups, and implants that did not fit in any of the groups of interest were excluded.

In study II, only cemented designs used in more than 500 operations during the study period were included. These criteria permitted the inclusion of 12 THRs (cup + stem combinations).

The mean age of the patients and gender distribution were analysed (I, II and III). In study I, success rates of different implant groups were analysed. In total all 50,968 THAs were classified in one of the four following THA groups: 1) a cementless, straight, proximally circumferentially porous-coated stem with a modular, porous-coated press-fit cup (cementless group 1); 2) a cementless, anatomic, proximally circumferentially porous- and/or hydroxyapatite-coated stem, with a modular, porous- and/or hydroxyapatite-coated press-fit cup (cementless group 2); 3) a hybrid total hip replacement (a cemented stem combined with a modular, press-fit cup); and 4) a cemented total hip replacement (a cemented loaded-taper or composite-beam stem combined with an all-polyethylene cup).

In study I, a total of 50,968 femoral components were separately classified into four stem groups: 1) cementless, straight, proximally circumferentially porous-coated; 2) cementless, anatomic, proximally circumferentially porous- or hydroxyapatite-coated (fit and fill); 3) composite-beam cemented and 4) loaded-taper cemented stems.

In study I, a total of 50,968 acetabular components were also separately classified into three cup groups: 1) cementless, press-fit porous-coated; 2) cementless, press-fit hydroxyapatite-coated and 3) cemented, all-polyethylene cups.

In study II, the 12 most common cemented cup + stem combinations used during the study period were identified and included in the final analyses.

In study III, the eight most common cementless cup + stem combinations used during the study period were determined and included in the final analysis. These eight cementless replacements were then compared with the three best performing cemented replacements in study II.

8.2.2 HOSPITAL DISCHARGE REGISTER-BASED STUDIES (IV AND V)

In study IV, annual regional indices of the incidence of THA for primary OA were explained by the following independent variables: the region-specific ratio of primary THA for primary OA to that of primary THA for any reason, the need-adjusted expenses of specialized care (Hujanen et al. 2006), the proportion of patients aged from 18 to 64 years having permanent disability pension for orthopaedic disorders or connective tissue diseases, the morbidity-index, the average income in a region as estimated by state taxation, the relative number of orthopaedic surgeons and anesthesiologists, the population density and the average distance the inhabitants of a region had to travel to the nearest hospital performing THAs.

In study IV, the region-specific ratios of primary THA for primary OA (NFB30-NFB99 for diagnosis codes M16.0, M16.1, M16.2, M16.3) to primary THA for any reason (NFB30-NFB99 for any reason) were calculated from the individuals' data, which were obtained from the Hospital Discharge Registers.

Need-adjusted expenses of specialized care were defined as net expenses of a municipality and of a region in relation to the need for those services by the population (Hujanen et al. 2006). The data of need-adjusted expenses of specialized care were gathered from the SOTKAnet Indicator Bank. The SOTKAnet Indicator Bank is an information service of the National Institute for Health and Welfare that provides key population welfare and health data from 1990 onwards for all Finnish municipalities. Thus SOTKAnet data are organized in terms of the current administrative division into municipalities. SOTKAnet is based on data gathered by the National Institute for Health and Welfare and also those data obtained from other agencies that gather welfare and health information.

The morbidity index describes the health of the population of a specific municipality in relation to the average (set at a base index value of 100) for the country's total population. The figure is calculated for each municipality in Finland, and is standardized for gender and age. The index is based on three register variables: mortality, the proportion of the working-aged population receiving disability pension for any reason, and also the proportion of the total population entitled to special refunds on medicines. Each variable is separately calculated in proportion to the average of the total population of the country with the value of 100 set as the index base. The final index value is given as the mean of the three sub-indices (The Sotka Indicator Bank).

Data of the average incomes of a region as estimated by state taxation, data on population density and data on distances to the nearest hospital were obtained from Statistics Finland. Data of the number of orthopaedic surgeons and also the number of anesthesiologists were obtained from the Finnish Medical Association. Data on patients with disability pension due to orthopaedic disorders were obtained from SOTKA Indicator Bank.

In study V, the effect of hospital volume on the length of surgical treatment period (later referred to as the length of stay and abbreviated to LOS), the length of uninterrupted institutional care (LUIC) the rate of unscheduled re-admissions, in addition to the numbers of re-operations, dislocations and infections were determined. The surgical treatment period was defined as the period when THR was performed in the hospital as recorded in the Hospital Discharge Register. A surgical treatment period ended either in discharge, in transmission to another facility or death of the patient. Uninterrupted institutional care was defined as the combination of the surgical treatment period and the period immediately following period of rehabilitation. Uninterrupted institutional care ended either with death of the patient or with discharge which included those patients transferred to another facility such as old people's homes and institutions run by social welfare organisations. The maximum length of institutional care was limited to 60 days for calculation purposes. It was estimated with certainty that after 60 days patients stayed in institutional care for some other reason than the performed THR. There were only two patients during the whole study period who had received a period of uninterrupted institutional care lasting more than 60 days after THR. Re-operations, closed and open reductions of dislocated hip prostheses and infections of the THR were followed to the end of the year 2006.

In study V, hospitals were classified into four groups according to the number of THRs (NOMESCO-codes: NFB30-NFB99) performed annually during the study period: 1-50 (low volume hospitals, Group 1), 51-150 (average volume hospitals, Group 2), 151-300 (high volume hospitals, Group 3) and 301 or over (very high volume hospitals, Group 4) (Table 14). Low volume hospitals (Group 1) were used as a reference group.

A reduction of a dislocated THR was defined in two different ways in the current study. First, a reduction of a dislocated THR was considered performed if there was a notification in the Hospital Discharge Register that either an open or closed reduction of a dislocated total hip prosthesis had been performed (NFH30 or NFH32), associated with a diagnosis of an internal mechanical complication of endoprosthesis (ICD10: T84.0). However, closed reduction may also have been performed in the emergency room under light sedation anaesthesia. These patients are often discharged from the accidents and emergency units after closed reduction without an overnight stay in the hospital. According to regulations, it is mandatory to compile statistics on diagnosis codes in the accidents and emergency units but operational codes are not recorded routinely. Thus, a closed reduction of a dislocated THR was also considered to have been performed, when the patient had an unscheduled readmission with a diagnosis code of mechanical complication of the endoprosthesis (ICD: T84.0) but without admission as an inpatient. The hypothesis was that the majority of these cases are true dislocations, not periprosthetic fractures or aseptic loosenings of the implant. We performed a pilot study where this hypothesis was confirmed.

In study V, a diagnosis code for deep prosthetic infection (ICD-10: T84.5) was used in data search from the beginning of the surgical treatment period to the end of the follow-up. The data from the Finnish Arthroplasty Register was used to determine the numbers of re-operations performed due to deep prosthetic infections. Infected hips requiring a re-operation were included in the total number of deep prosthetic infections.

In study V, an unscheduled re-admission was recorded, when a patient was re-admitted to hospital or had a contact with the out-patient department or accident and emergency unit of any hospital in Finland during the first 14 and 42 days following the end of the surgical treatment period. Unscheduled re-admissions due to dislocations were included in all unscheduled readmissions.

In study V, the prices of a bed-day in hospital care and in primary health care were used in determining the amount of money saved when LOS diminishes. The price of a bed-day in hospitals performing THRs was on average 527 euros in Helsinki and Uusimaa district (HUS) during 2003-2005 (Peltola 2008). The price of a day of treatment in the whole country on average was not available. The price of a day of treatment in health care centres was 141 euros on average in Finland (Hujanen et al. 2008).

8.2.3 STATISTICAL METHODS (I, II, III, IV, V)

In studies I, II and III, the end point for survival was defined as revision when either one component (including liner and femoral head) or the whole implant was removed or exchanged. Both revision for any reason and revision for aseptic loosening served separately as end points. Revisions were linked to the primary operation by using the unique personal identification number assigned to each resident of Finland. Kaplan-Meier survival calculations were used to predict survival of implants at 10, 15 and 20 years (study I), at five, 10, 15 and 20 years (study II) and at seven, 10 and 15 years (study III) follow-up. At each follow-up time point, survival rates were only analysed for implants with more than 20 patients at risk. Survival data obtained by Kaplan-Meier analysis were compared using the log-rank test. Patients who died or emigrated from Finland during the follow-up period were censored at that point. The Cox multiple regression model was used to study differences between implants (study II and III) and implant groups (study I) in order to adjust for potential confounding factors. The factors studied with the Cox model were implants (studies II and III), implant groups (study I), age and gender. When stem groups were analysed using the Cox model in study I, loaded-taper cemented stems with well documented good long-term results served as the reference group. Similarly, all-polyethylene, cemented cups served as the reference group for analysing the acetabular side, whereas the cemented total hip replacements were used as the reference group for analysing total hip replacements. The Charnley prosthesis was chosen as the reference design in study II, because it is considered to be the gold standard when analysing long term results of THA. In study III, the three best performing cemented designs in Finland as identified in study II were chosen as the reference implants. These three cemented designs were the Exeter Universal stem combined with the All-poly cup, the Müller Straight stem combined with the Müller Standard cup and the Lubinus SP II stem combined with the Lubinus IP cup (Waldemer Link, Hamburg, Germany). When the effects of age and sex on implant survival were analysed using the Cox model, adjustment was also made for the THR groups (study I). Cox regression analyses provided estimates of survival probabilities and adjusted risk ratios for revision. Estimates obtained by the Cox analyses were used to construct adjusted survival curves at mean values of the risk factors. The Wald test was used to calculate p-values for data obtained from the Cox multiple regression analysis. A difference between groups was considered to be statistically significant if the p-values were less than 0.05 in a two-tailed test (studies I, II and III).

Both Kaplan-Meier and Cox regression are methods based on assumptions of independent observations. However, bilateral observations cannot be regarded as independent (Robertsson and Ranstam 2003, Bryant et al. 2006). Violation of this independence assumption may have an effect on the validity of the results. To avoid this violation, the data analysis could be performed by including only the correlated observations. This could be done by allowing only one prosthesis per patient or by including a shared frailty variable in the Cox regression. In studies I, II and III, bilateral observations were included in the analysed dataset. It has been found that the effect of neglecting bilateral prostheses is minute (Havelin et al. 1995, Robertsson and Ranstam 2003, Lie et al. 2004).

In study III, the proportional hazards assumption of the Cox model (meaning that the relative difference between revision rates should be constant over the time elapsed since the primary operation) was not reached in some analyses performed. Therefore, adjusted risk ratios were also established within time intervals (0-7 years, >7 years after the primary operation).

In study IV, regional incidences were reported both as unadjusted and adjusted for age and gender to improve comparisons. Patients were divided into the following cohorts: those under 40 years, those from 40 to 85 years, and those over 85 years. The 40 to 85 year old cohort was further divided into nine sub-cohorts with each sub-cohort comprising a five year increment sequentially up to 85 years. Adjustments were performed in relation to the average level of the year concerned (index 100).

We estimated the variation of regional rates by the method of extreme quotients (EQ = minimum/maximum) (Keskimäki et al. 1994).

In study IV, a least squares with fixed effects panel model for the statistical modeling of our data set was used, in order to determine which variables were associated with the relative frequency i.e. the regional incidence of primary THA operations. In the panel model, the number of years investigated was eight, and the number of regions was 21 each year making 168 observations in total.

In study V, variables were adjusted for confounding factors to improve the comparability of the data. Adjustments were performed by modelling the effect of the confounding factors, first by using the logistic regression model (two-class variables) or by using the generalized linear model (gamma-distribution, log-link, continuous variables). Then the prediction produced by the model for every patient was used to count the anticipated events. In addition, 95 per cent confidence intervals (95% CI) were determined. Several different factors were used in the adjustments. The age of the patient (under 40 years, over 40 years divided into nine groups of five year increments up to 85 years, and older than 85 years), the patient's sex, previous THA and co-morbidities (Table 15) were used in all adjustments. We also performed calculations using head size of the prosthesis in the adjustments to eliminate the effect of head size on the dislocation rates. Co-morbidities were determined using diagnoses of Hospital Discharge Register from the beginning of the year 1987 to the date of the operation, using the Social Insurance Institution database for entitlement to reimbursement and use and cost of drugs. The illnesses chosen were such that might have an effect on the performance of THR, on LOS or the rate of complications. The period elapsed between operation and follow-up time was used in adjusting the rate of complications.

8.2.4 ETHICAL CONSIDERATIONS

The National Agency for Medicines gave its permission to use data of the Finnish Arthroplasty Register. The National Institute of Health and Wellfare (THL) gave its permission to use data of the Hospital Discharge Register and other registers it held. Patients were not contacted personally and, therefore, permission of the ethical commitee was not needed for register-based studies.

9. RESULTS

The survival data of subgroups by age are not shown to make Tables easier to read.

9.1 THE FINNISH ARTHROPLASTY REGISTER-BASED STUDIES (I, II AND III)

9.1.1 FEMORAL COMPONENTS

9.1.1.1 Stem groups, survival rate for aseptic loosening

In study I, the 10- and 15-year survivorship of cementless stems for aseptic loosening for all patients studied was higher than that of cemented stems (Table 16). The Cox regression analyses revealed that cementless stem groups had a significantly lower risk of revision due to aseptic loosening than the cemented stem groups (Table 16, Figure 1). For the subgroups of patients aged 55 to 64 years and 65 to 74 years, cementless stem groups had a significantly lower risk of revision for aseptic loosening than the cemented stem groups. For patients aged 75 years and older, the difference in risk of revision between cementless and cemented groups was not statistically significant.

9.1.1.2 Cemented stems, survival rate for aseptic loosening

At 15-years in study II, the overall survival rate of the Exeter Universal stem was 96 per cent and that of the Charnley stem 79 per cent. The Cox regression analyses revealed that five stem designs had a significantly lower risk of revision when compared to the reference design, the Charnley stem (Table 17, Figure 2).

For patients aged from 55 to 64 years in study II, the Exeter Universal stem had a 10-year survival rate exceeding 95 per cent, and a 15-year survival rate of more than 90 per cent.

For patients aged from 65 to 74 years in study II, survival of the Exeter Universal and the Müller Straight stems exceeded 90 per cent at 15-years.

For patients aged 75 years and older, all femoral components excluding the Spectron showed survivorship of over 90 per cent at 10 years.

Stem groups	No. of Primary Operations	Mean Follow-up (yr)	No. at Risk at 10 Yr	10-Yr Survival†	No. at Risk at 15 Yr	15-Yr Survival†	No. at Risk at 20 Yr	20-Yr Survival†	Adjusted Risk Ratio for Revision‡	P Value
All (≥55 yr)										
Cementless straight	7145	5.7	1276	98 (98-99)	75	93 (90-96)	–	–	0.28 (0.22-0.36)	<0.001
Cementless fit and fill	5743	6.3	1474	97 (96-97)	145	91 (87-94)	1	-	0.41 (0.33-0.52)	<0.001
Composite-beam cemented	24,871	8.2	9412	92 (92-92)	3297	86 (85-87)	771	82 (80-83)	1.55 (1.36-1.77)	<0.001
Loaded-taper cemented	13,209	4.6	1250	95 (94-96)	277	86 (84-89)	63	77 (71-82)	1.0	–
Total	**50,968**									

Table 16. Survival of stem groups in study I. The end point was defined as revision because of aseptic loosening of the stem. †Ten, fifteen, and twenty-year survival rates were obtained from the Kaplan-Meier analysis. The values are given as the mean percentage, with the 95% confidence interval in parentheses. ‡The risk ratio is from the Cox regression analysis (other stem groups were compared with the loaded-taper cemented stems; adjustment was made for age and sex). The 95% confidence interval is given in parentheses. §The difference was not significant.

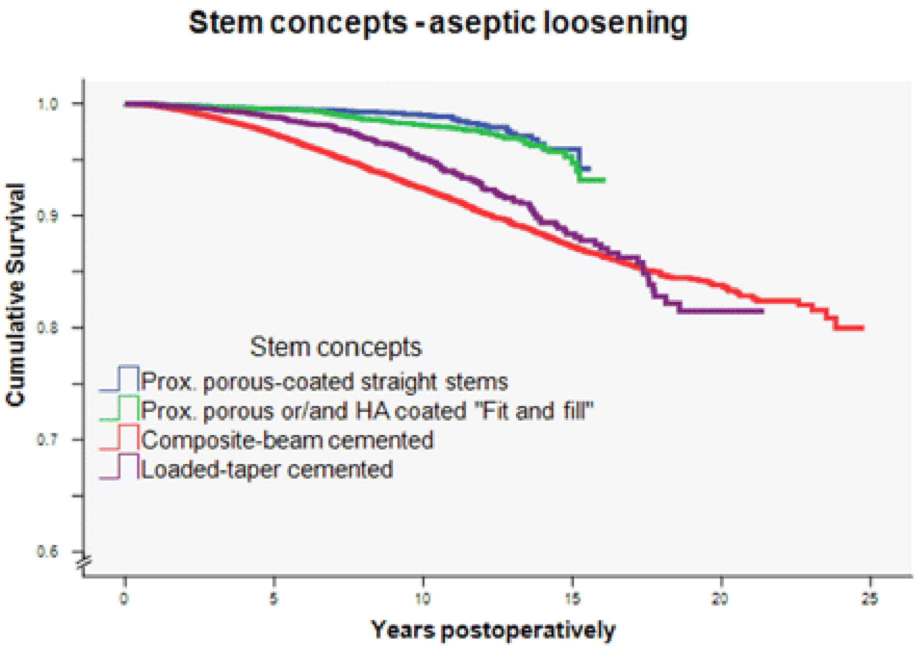

Figure 1. Cox-adjusted survivorship curves of 50,968 stems in patients who were fifty-five years of age or older, stratified according to the stem groups. The end point was defined as revision of the stem because of aseptic loosening. Adjustment was made for age and sex. HA = hydroxyapatite.

Age group	Stem brand	N*	MF yr	AR 5 yr	% 5-year survival (95 % CI)	AR 10 yr	% 10-year survival (95 % CI)	AR 15 yr	% 15-year survival (95 % CI)	AR 20 yr	% 20-year survival (95 % CI)	Adjusted RR for revision (95 % CI)	p-value
All (≥ 55 years)	Elite Plus	885	6.3	622	94 (92-96)	134	85 (81-88)	0	-	0	-	1.64 (1.25-2.16)	<0.001
	Lubinus IP	5790	12.0	5094	97 (97-97)	3682	91 (90-91)	2147	85 (84-86)	750	82 (81-83)	0.74 (0.62-0.88)	=0.001
	Lubinus SP II	10634	7.2	7352	98 (97-98)	3242	94 (94-95)	618	90 (88-91)	0	-	0.62 (0.52-0.76)	<0.001
	Exeter	876	11.6	760	96 (95-98)	540	89 (87-92)	307	83 (80-86)	83	77 (73-82)	0.83 (0.65-1.06)	NS (0.13)
	Exeter Universal	10620	4.3	4280	99 (99-99)	832	98 (97-98)	95	96 (94-97)	0	-	0.23 (0.17-0.30)	<0.001
	Müller Straight	2309	10.7	2010	98 (97-99)	1451	96 (95-97)	505	92 (91-94)	114	88 (85-92)	0.40 (0.32-0.51)	<0.001
	Spectron EF	1929	1.8	103	100 (99-100)	0	-	0	-	0	-	0.36 (0.16-0.81)	=0.014
	Biomet Interlok	581	7.5	453	97 (95-98)	179	92 (90-95)	0	-	0	-	0.90 (0.62-1.30)	NS (0.57)
	Charnley	925	11.1	797	97 (96-98)	565	88 (86-91)	243	79 (75-82)	71	70 (65-75)	1.0	-

Table 17. Survival of cemented stems in study II. End-point is defined as revision due to aseptic loosening of the stem. 5-, 10-, 15-, and 20-year survival rates obtained from the Kaplan-Meier analysis. *N = number of operations. MF = mean follow-up (years). AR = at risk. RR = risk ratio from the Cox regression analysis (other stem brands compared to the Charnley stem; adjustment made for age and gender). NS = non-significant.

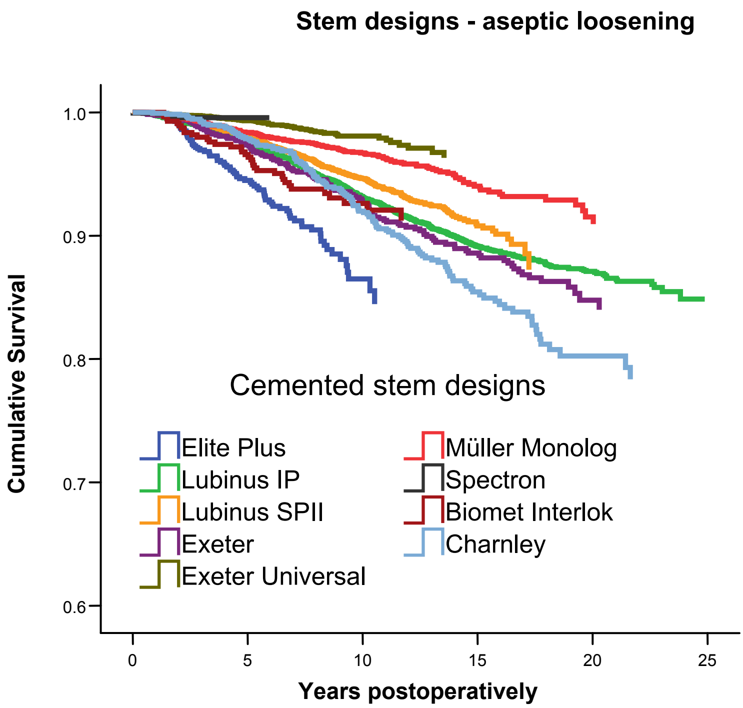

Figure 2. Cox-adjusted survival curves of 34,549 stems in patients aged 55 years or older in study II, with stem brands as the strata factor. The end point was defined as stem revision due to aseptic loosening. Adjustment has been made for age and gender.

9.1.1.3 Cementless stems, survival rate for aseptic loosening

When all patients aged 55 years or more were analysed as a single group, the Bi-Metric stem had a higher survival rate at 15 years than that of the reference group. The Cox regression analyses revealed that all cementless stems studied had a statistically significantly reduced risk of revision during the first seven years after the primary operation when compared to the reference group (Table 18). Beyond seven years of follow-up, the Bi-Metric and the ABG I stems still had significantly lower revision risks than the cemented reference group (Table 18, Figure 3).

For age groups 55 to 64 years and 65 to 74 years, the Bi-Metric stem had a higher 15-year survival rate than the reference group [95% (CI 92-97) vs. 84% (CI 80-87) and 98% (CI 97-99) vs. 90% (CI 89-91)], respectively.

9.1.2 ACETABULAR COMPONENTS

9.1.2.1 Cup groups, survival rate for aseptic loosening

In study I, the 10-year survivorship of cementless and cemented cups for aseptic loosening for all patients studied was nearly the same (Table 19). Cox regression analyses for all patients studied revealed that cementless cup groups had a significantly lower risk of revision for aseptic loosening than cemented all-polyethylene cups (Table 19, Figure 4). For the subgroups of patients aged 55 to 64 years and 65 to 74 years, the cementless cup groups had a significantly lower risk of revision for aseptic loosening than the cemented all polyethylene cups. For the subgroup of patients aged 75 years and older, cementless, hydroxyapatite-coated press-fit cups had significantly reduced risk of revision than the cemented all-polyethylene cups.

Age group	Stem brand	N*	MF yr	AR 7 yr	% 7-year survival (95% CI)	AR 10 yr	% 10-year survival (95% CI)	AR 15 yr	% 15-year survival (95% CI)	Adjusted RR for revision (95% CI)	p
All (≥ 55 years)	Anatomic Mesh	604	11.1	532	98 (97-99)	444	96 (94-98)	91	92 (89-95)	0.53 (0.37-0.76)	0.001
	FU ≤7 years									0.38 (0.21-0.71)	0.002
	FU > 7 years									0.64 (0.40-1.00)	0.05
	PCA Std	508	11.6	430	98 (96-99)	351	95 (92-97)	146	89 (86-93)	0.62 (0.44-0.88)	0.007
	FU ≤7 years									0.49 (0.27-0.89)	0.02
	FU > 7 years									0.68 (0.44-1.05)	0.08
	Bi-Metric	5,379	6.8	2,698	99 (99-99)	1,463	99 (98-99)	154	96 (94-98)	0.20 (0.15-0.27)	<0.001
	FU ≤7 years									0.18 (0.12-0.26)	<0.001
	FU > 7 years									0.24 (0.16-0.37)	<0.001
	ABG I	2,330	6.7	1,152	100 (99-100)	342	98 (97-99)	0	-	0.15 (0.09-0.25)	<0.001
	FU ≤7 years									0.08 (0.04-0.18)	<0.001
	FU > 7 years									0.40 (0.20-0.80)	0.009
	ABG II	1,489	2.5	0	-	0	-	0	-	0.31 (0.13-0.76)	0.01
	FU ≤7 years									0.31 (0.13-0.76)	0.01
	FU > 7 years									-	-
	Cemented reference	9,549	8.8	6,231	97 (96-97)	4,442	95 (94-95)	1,115	91 (90-92)	1.0	-
	FU ≤7 years									1.0	-
	FU > 7 years									1.0	-
	Total	19,859									

Table 18. Survival of cementless stems and the cemented reference group in study III. End-point is defined as revision due to aseptic loosening of the stem. 7-, 10-, and 15-year survival rates were obtained from the Kaplan-Meier analysis. Abbreviations: N* = number of operations, MF = mean follow-up (years), AR = at risk, RR = risk ratio from the Cox regression analysis (other stem brands compared to the cemented reference stems; adjustment made for age and gender), PCA Std= Porous Coated Anatomic Standard and ABG = Anatomique Benoist Girard.

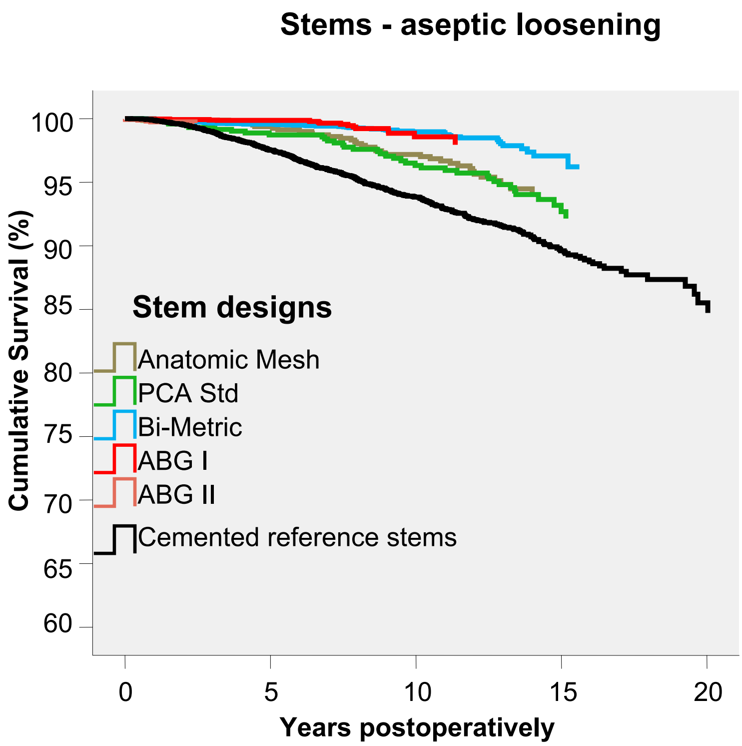

Figure 3. Cox-adjusted survival curves of 19,859 stems in patients aged 55 years or older with stem designs as the strata factors. The end point was defined as stem revision due to aseptic loosening. Adjustment was made for age and gender. Abbreviations; PCA = Porous Coated Anatomic and ABG = Anatomique Benoist Girard.

Age group	Cup group	N*	MF yr	AR 10 yr	% 10-year survival (95 % CI)	AR 15 yr	% 15-year survival (95 % CI)	AR 20 yr	% 20-year survival (95 % CI)	Adjusted RR for revision (95 % CI)	p
All (≥ 55 years)	Cementless, modular, press-fit porous-coated	10,973	6.4	2,644	96(95-96)	227	84(81-88)	1	-	0.54(0.47-0.62)	<0.001
	Cementless, modular, press-fit HA-coated	5,699	4.4	457	95(94-97)	1	-	-	-	0.42(0.32-0.54)	<0.001
	Cemented all-polyethylene	34,296	7.1	10,309	95(94-95)	3,567	88(87-89)	832	83(81-84)	1.0	-
	Total	50,968									

Table 19. Survival of cup groups in study I. The end point was defined as revision due to aseptic loosening of the cup. 10-, 15-, and 20-year survival rates obtained from the Kaplan-Meier analysis. N = number of primary operations. MF = mean follow-up (years). AR = at risk. RR = risk ratio from the Cox regression analysis (other cup groups were compared with the all-polyethylene, cemented cups; adjustment made for age and gender). HA = hydroxyapatite.

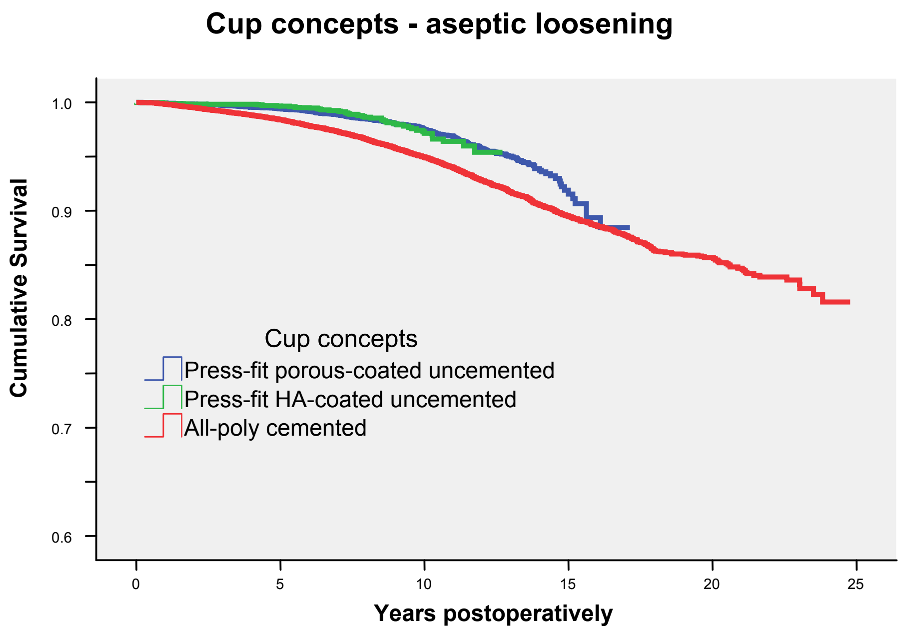

Figure 4. Cox-adjusted survival curves calculated for 50,968 cups with cup group as the strata factor in study I. The end point was defined as cup revision due to aseptic loosening. Adjustment was made for age and gender.

9.1.2.2 Cemented cups, survival rate for aseptic loosening

In study II, at 15 years, only the Exeter All-poly and the Müller Standard acetabular components exceeded survivorship of 90 per cent when all patients aged 55 years or older were analysed. Cox regression analysis showed that three acetabular components had a significantly reduced risk of revision when compared with the Charnley reference design (Table 20, Figure 5).

For the patients aged from 55 to 64 years of study II, the Exeter All-poly was the only cup with a significantly lower risk of revision than the Charnley LPW cup.

For the patients aged from 65 to 74 years of study II, the Exeter All-poly and the Müller Standard cups had a significantly lower risk of revision than the Charnley LPW cup.

For the patients older than 74 years of study II, all cup designs with available follow-up data, except the Exeter Metal-backed cup, had survival rates of 95 per cent or more.

9.1.2.3 Cementless cups, survival rate for aseptic loosening

When all patients aged 55 years or more were analysed as a single group, the survival of the PCA Pegged cup at 15 years was lower than that of the reference group. Apart from this exception, there were no differences in survival rates between cementless cups and that of the reference group at 15-years. The Cox regression analyses revealed that the PCA Pegged cup had a significantly increased risk of revision both during the first seven years postoperatively and beyond seven years of follow-up. Furthermore, during the first seven years the Press-Fit Universal, the Mallory, the Vision and the ABG II cups had significantly decreased risks of revision compared to the reference group (Table 21). Beyond seven years of follow-up, however, only the Press-Fit Universal cup still retained the lower revision risk (Table 21, Figure 6). The Vision and the ABG II cups were found to be scarce in the beyond the seven year analysis (Table 21).

For patients aged 55 to 64 years, the HG-II cup [87% (CI 82-91)] and the PFU cup [88% (CI 84-93)] had similar survival rates at 15 years as the reference cups [85% (CI 81-88)]. For patients aged 65 to 74 years, the PFU cup had a higher survival rate at 15 years than the reference group [96% (CI 94-98) vs. 92% (CI 91-93)].

Age group	Cup brand	N*	MF yr	AR 5 yr	% 5-year survival (95 % CI)	AR 10 yr	% 10-year survival (95 % CI)	AR 15 yr	% 15-year survival (95 % CI)	AR 20 yr	% 20-year survival (95 % CI)	Adjusted RR for revision (95 % CI)	p-value
All (≥ 55 years)	Elite Plus	885	6.3	619	98 (85-100)	133	93 (90-95)	0	-	0	-	1.29 (0.87-1.91)	NS (0.20)
	Lubinus IP	13030	9.9	10507	98 (98-98)	6667	94 (94-95)	2756	89 (88-90)	751	85 (83-86)	0.88 (0.72-1.09)	NS (0.24)
	Lubinus FC	701	2.6	94	99 (98-100)	0	-	0	-	0	-	0.72 (0.26-1.96)	NS (0.52)
	Lubinus Eccentric	2693	5.9	1826	99 (99-99)	251	95 (93-97)	9	-	0	-	0.76 (0.54-1.07)	NS (0.12)
	Exeter Metal-backed	876	11.6	758	97 (96-98)	538	92 (90-94)	308	86 (83-89)	83	80 (75-84)	1.05 (0.79-1.38)	NS (0.78)
	Exeter All-poly	5048	5.9	3045	99 (98-99)	830	97 (96-98)	95	93 (91-96)	0	-	0.61 (0.46-0.82)	=0.001
	Exeter Contemporary	5572	2.9	1236	99 (99-99)	3	-	0	-	0	-	0.54 (0.36-0.82)	=0.004
	Müller Std	2309	10.7	2008	99 (98-99)	1450	97 (96-97)	504	93 (91-94)	113	89 (87-92)	0.58 (0.44-0.76)	<0.001
	Reflection	1929	1.8	103	99 (98-100)	0	-	0	-	0	-	1.00 (0.52-1.95)	NS (0.99)
	Biomet Müller	581	7.5	451	98 (97-99)	179	95 (92-97)	0	-	0	-	1.12 (0.72-1.74)	NS (0.62)
	Charnley LPW	925	11.1	793	98 (98-99)	561	93 (91-95)	243	85 (82-89)	71	77 (72-82)	1.0	-

Table 20. Survival of cemented cups in study II. End-point is defined as the revision due to aseptic loosening of the cup. 5-, 10-, 15-, and 20-year survival rates obtained from the Kaplan-Meier analysis. *N = number of operations. MF = mean follow-up (years). AR = at risk. RR = risk ratio from the Cox regression analysis (other stem brands compared to the Charnley LPW cup; adjustment made for age and gender). NS = non-significant.

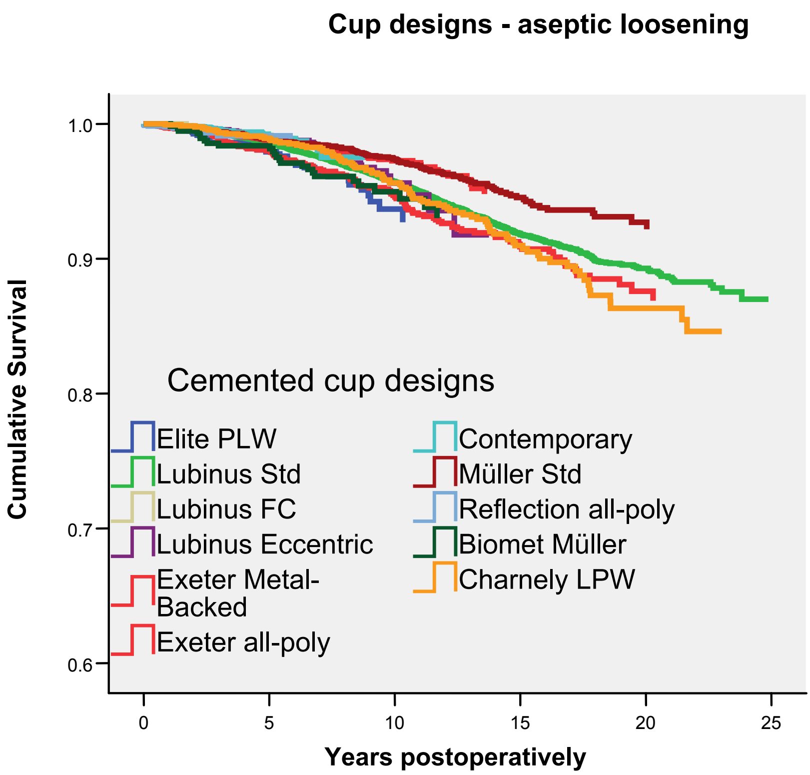

Figure 5. Cox-adjusted survival curves of 34 549 cups in patients aged 55 years or older, with cup brands as the strata factor in study II. The end point was defined as cup revision due to aseptic loosening. Adjustment has been made for age and gender.

Age group	Cup brand	N*	MF yr	AR 7 yr	% 7-year survival (95% CI)	AR 10 yr	% 10-year survival (95% CI)	AR 15 yr	% 15-year survival (95% CI)	Adjusted RR for revision (95% CI)	p-value
All (≥ 55 years)	HG-II	604	11.1	531	99 (98-100)	445	97 (95-98)	92	88 (84-92)	0.75 (0.53-1.05)	0.09
	FU ≤7 years									0.50 (0.24-1.03)	0.06
	FU > 7 years									0.82 (0.56-1.22)	0.3
	PCA Pegged	508	11.6	432	94 (92-96)	353	86 (83-89)	148	75 (70-80)	1.91 (1.49-2.44)	<0.001
	FU ≤7 years									2.21 (1.44-3.38)	<0.001
	FU > 7 years									1.70 (1.26-2.30)	<0.001
	PFU	2,687	8.8	2,035	98 (97-99)	1,192	97 (96-98)	145	91 (87-94)	0.54 (0.42-0.70)	<0.001
	FU ≤7 years									0.68 (0.47-0.99)	0.04
	FU > 7 years									0.45 (0.32-0.64)	<0.001
	Mallory	637	8.8	517	99 (98-100)	275	96 (94-98)	10	-	0.52 (0.31-0.86)	0.012
	FU ≤7 years									0.35 (0.14-0.85)	0.02
	FU > 7 years									0.68 (0.37-1.26)	0.2
	Vision	2,055	3.4	152	99 (98-100)	0	-	0	-	0.49 (0.27-0.89)	0.019
	FU ≤7 years									0.51 (0.27-0.97)	0.04
	FU > 7 years									3.39 (0.47-24.75)	0.2
	ABG I	565	9.1	454	98 (96-99)	330	93 (90-95)	0	-	1.17 (0.83-1.66)	0.4
	FU ≤7 years									0.81 (0.43-1.52)	0.5
	FU > 7 years									1.46 (0.96-2.24)	0.08
	ABG II	3,254	4.3	700	99 (99-100)	14	-	0	-	0.20 (0.11-0.38)	<0.001
	FU ≤7 years									0.22 (0.11-0.43)	<0.001
	FU > 7 years									0.19 (0.03-1.37)	0.1
	Cemented reference	9,549	8.8	6,221	98 (98-98)	4,441	96 (96-97)	1,113	92 (91-93)	1.0	--
	FU ≤7 years									1.0	-
	FU > 7 years									1.0	-
	Total	19,859									

Table 21. Survival of cementless cups and the cemented reference group in study III. End-point is defined as revision due to aseptic loosening of the cup. 7-, 10-, and 15-year survival rates were obtained from the Kaplan-Meier analysis. Abbreviations: N* = number of operations, MF = mean follow-up (years), AR = at risk, RR = risk ratio from the Cox regression analysis (other cup brands compared to the cemented reference cups; adjustment made for age and gender), HG-II = Harris-Galante II, PCA = Porous Coated Anatomic, PFU = Press-Fit Universal and ABG = Anatomique Benoist Girard.

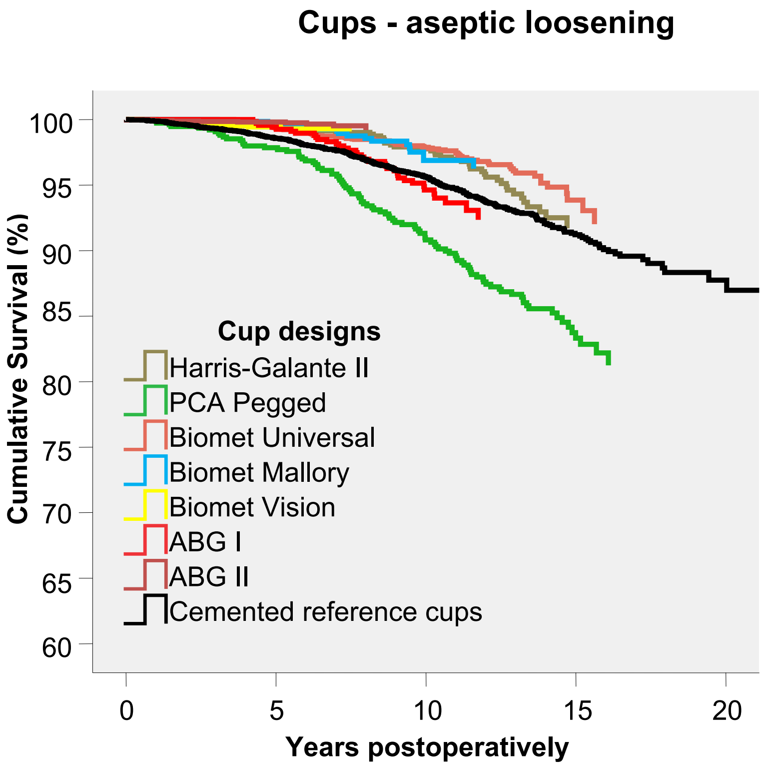

Figure 6. Cox-adjusted survival curves of 19,859 cups in patients aged 55 years or older with cup designs as the strata factors in study III. The end point was defined as cup revision due to aseptic loosening. Adjustment was made for age and gender. Abbreviations; PCA = Porous Coated Anatomic and ABG = Anatomique Benoist Girard.

9.1.3 TOTAL HIP REPLACEMENTS

9.1.3.1 Total hip replacement groups

9.1.3.1.1 Survival rate for aseptic loosening

In study I, the 10-year survivorship for all patients studied of cementless group 1 was higher than that of the other groups (Table 22). Both cementless groups and also the hybrid group had significantly lower risks of revision than the group of cemented replacements as determined by Cox regression analysis (Table 22, Figure 7). For the subgroups of patients aged 55 to 64 years and 65 to 74 years, cementless groups had a significantly lower risk of revision than the cemented group. For the subgroup of patients aged 75 years and older, the differences in risk of revision between groups were not statistically significant.

9.1.3.1.2 Survival rate for any reason

The 10-year survivorship for any reason of the cemented group for all patients studied was slightly higher than that of the other groups (Table 23). The Cox regression analysis for all patients studied and for the subgroups of age found no statistically significant differences in risk of revision between the groups (Table 23, Figure 8).

9.1.3.2 Cemented total hip replacements

9.1.3.2.1 Survival rate for aseptic loosening

At 15 years in study II, survival of only the Exeter Universal/Exeter All-poly exceeded 90 per cent for aseptic loosening. The Cox regression analyses revealed that the Elite Plus prosthesis had a higher risk of revision than the Charnley prosthesis (Table 24, Figure 9). For patients aged 55 to 64 years, the Exeter Universal/Exeter All-poly had a 15-year survival of 84 per cent. The Charnley prosthesis had a 20-year survival of 55 per cent for this same group. For patients aged 65 to 74 years, the 15-year survival of the Exeter Universal/Exeter All-poly and the Müller prosthesis for aseptic loosening exceeded 90 per cent. For patients aged 75 years or older, three designs had a substantially lower risk of revision than the Charnley prosthesis.

Age group	THR group	N*	MF yr	AR 10 yr	% 10-year survival (95 % CI)	AR 15 yr	% 15-year survival (95 % CI)	AR 20 yr	% 20-year survival (95 % CI)	Adjusted RR for revision (95 % CI)	p
All (≥ 55 years)	Cementless modular 1	7,145	5.7	1,280	96(95-96)	76	84(79-89)	-	-	0.34 (0.29 – 0.40)	<0.001
	Cementless modular 2	5,743	6.3	1,481	93(91-94)	147	80(76-84)	-	-	0.53 (0.46 – 0.61)	<0.001
	Hybrid THR	3,784	4.9	343	93(92-95)	6	-	-	-	0.68 (0.55 – 0.83)	<0.001
	Cemented THR	34,296	7.1	10,335	91(91-91)	3,575	83(82-84)	835	76(75-78)	1.0	-
	Total	50,968									

Table 22. Survival of total hip replacement groups in study I. The end point was defined as revision due to aseptic loosening of the cup and/or the stem. 10-, 15-, and 20-year survival rates obtained from the Kaplan-Meier analysis. *Number of revisions / number of total operations. MF = mean follow-up (years). AR = at risk. RR = risk ratio from the Cox regression analysis (other groups were compared with the cemented total hip replacements; adjustment made for age and gender). THR = total hip replacement. Cementless modular 1 = a cementless, straight, proximally porous-coated stem with a modular, cementless, press-fit porous-coated cup. Cementless modular 2 = a cementless, anatomic, proximally porous- and/or hydroxyapatite-coated stem with a modular, press-fit and/or hydroxyapatite-coated cup.

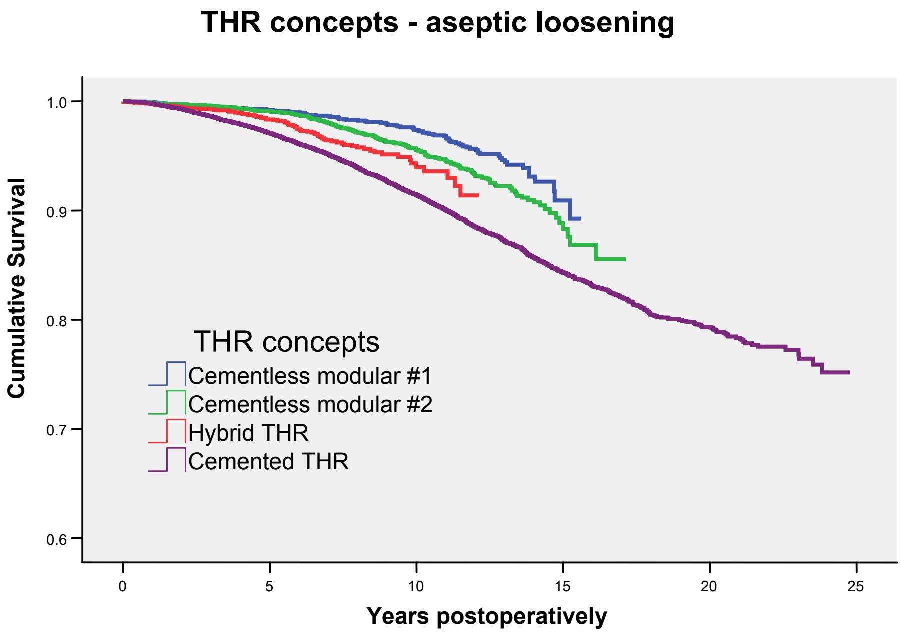

Figure 7. Cox-adjusted survival curves calculated for 50,968 total hip replacements with implant group as the strata factor in study I. The end point was defined as revision of the stem and/or the cup due to aseptic loosening. Adjustment was made for age and gender.

Age group	THR group	N*	MF yr	AR 10 yr	% 10-year survival (95 % CI)	AR 15 yr	% 15-year survival (95 % CI)	AR 20 yr	% 20-year survival (95 % CI)	Adjusted RR for revision (95 % CI)	p
All (≥ 55 years)	Cementless modular 1	7,145	5.7	1,296	86(85-88)	27	64(58-70)	-	-	0.91 (0.82 – 1.00)	NS (0.052)
	Cementless modular 2	5,743	6.3	1,487	87(86-88)	148	70(66-74)	-	-	0.91 (0.82 – 1.00)	NS (0.055)
	Hybrid THR	3,784	4.9	344	88(86-90)	6	-	-	-	1.09 (0.95 – 1.26)	NS (0.22)
	Cemented THR	34,296	7.1	10,343	89(89-89)	3,579	80(80-81)	836	73(72-74)	1.0	-
	Total	50,968									

Table 23. Survival of total hip replacement groups in study I. The end point was defined as revision for any reason. 10-, 15-, and 20-year survival rates obtained from the Kaplan-Meier analysis. N = number of primary operations. MF = mean follow-up (years). AR = at risk. RR = risk ratio from the Cox regression analysis (other total hip replacement groups were compared with cemented total hip replacements; adjustment made for age and gender). NS = non-significant. THR = total hip replacement. Cementless modular 1 = a cementless, straight, proximally porous-coated stem with a modular, cementless, press-fit porous-coated cup. Cementless modular 2 = a cementless, anatomic, proximally porous- and/or hydroxyapatite-coated stem with a modular, press-fit and/or hydroxyapatite-coated cup.

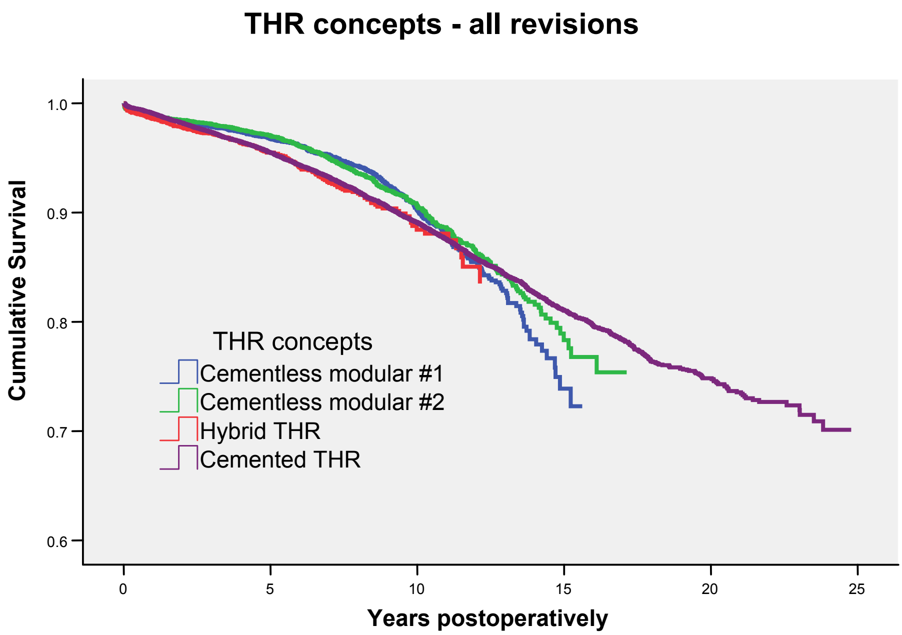

Figure 8. Cox-adjusted survival curves calculated for 50,968 total hip replacements with implant groups as the strata factor in study I. The end point was defined as revision for any reason. Adjustment was made for age and gender.

Age group	THR	N*	MF yr	AR 5 yr	% 5-year survival (95 % CI)	AR 10 yr	% 10-year survival (95 % CI)	AR 15 yr	% 15-year survival (95 % CI)	AR 20 yr	% 20-year survival (95 % CI)	Adjusted RR for revision (95 % CI)	p-value
All (≥ 55 years)	Elite Plus/ Elite Plus	885	6.3	622	93 (91-95)	134	84 (80-88)	0	-	0	-	1.69 (1.30-2.20)	<0.001
	Lubinus IP/ Lubinus IP	5790	12.0	5097	97 (96-97)	3689	89 (89-90)	2152	82 (81-83)	751	78 (76-79)	0.79 (0.67-0.93)	=0.005
	Lubinus SP II/ Lubinus IP	7240	8.1	5430	97 (97-98)	2994	93 (92-93)	610	87 (85-89)	0	-	0.71 (0.59-0.85)	<0.001
	Lubinus SP II/ Lubinus FC	701	2.6	94	99 (98-100)	0	-	0	-	0	-	0.38 (0.14-1.02)	NS (0.06)
	Lubinus SP II/ Lubinus Eccentric	2693	5.9	1830	97 (97-98)	251	92 (90-94)	9	-	0	-	0.82 (0.64-1.05)	NS (0.11)
	Exeter/ Exeter Metal-backed	876	11.6	760	96 (95-98)	542	87 (85-90)	309	79 (76-83)	83	72 (67-77)	0.90 (0.72-1.13)	NS (0.38)
	Exeter Universal/ Exeter All-poly	5048	5.9	3047	98 (98-99)	830	96 (95-97)	95	91 (89-94)	0	-	0.43 (0.34-0.54)	<0.001
	Exeter Universal/ Exeter Contemporary	5572	2.9	1236	99 (98-99)	3	-	0	-	0	-	0.38 (0.27-0.53)	<0.001
	Müller Straight/ Müller Std	2309	10.7	2010	98 (97-98)	1452	95 (94-95)	506	89 (88-91)	115	83 (79-88)	0.50 (0.40-0.62)	<0.001
	Spectron EF/ Reflection all-poly	1929	1.8	103	99 (98-100)	0	-	0	-	0	-	0.66 (0.36-1.19)	NS (0.17)
	Biomet Interlok/ Biomet Müller	581	7.5	453	95 (94-97)	179	90 (87-93)	0	-	0	-	1.09 (0.78-1.52)	NS (0.61)
	Charnley/ Charnley LPW	925	11.1	798	96 (95-98)	565	87 (85-90)	243	77 (73-80)	71	67 (61-72)	1.0	-

Table 24. Survival of cemented total hip replacements in study II. End-point is defined as the revision due to aseptic loosening of the cup and/or the stem. 5-, 10-, 15-, and 20-year survival rates obtained from the Kaplan-Meier analysis. *N = number of operations. MF = mean follow-up (years). AR = at risk. RR = risk ratio from the Cox regression analysis (other stem brands compared to the Charnley stem/Charnley LPW cup; adjustment made for age and gender). NS = non-significant**.**

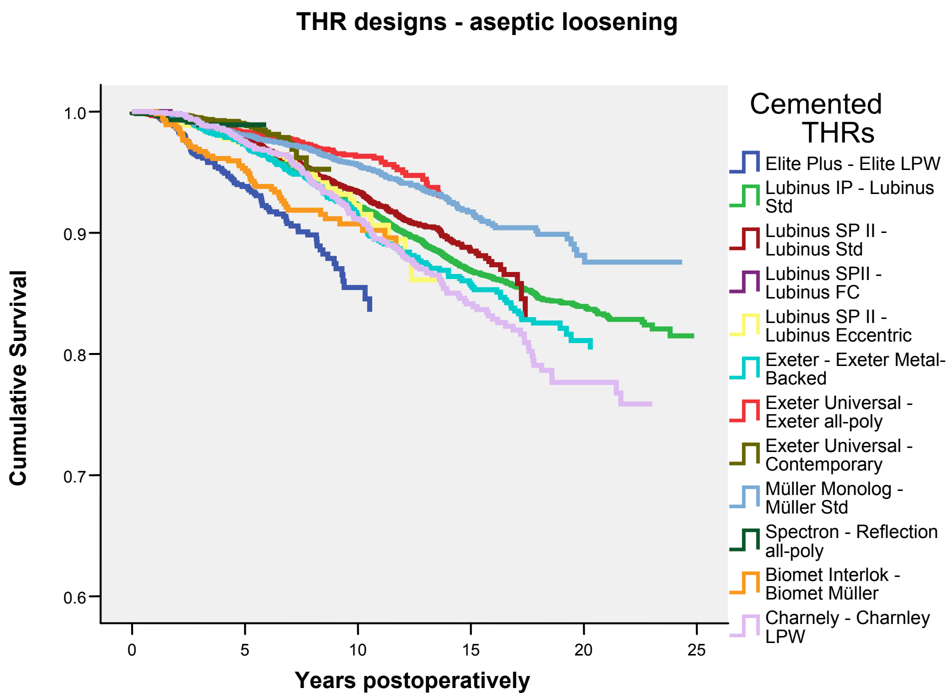

Figure 9. Cox-adjusted survival curves of 34 549 total hip replacements in patients aged 55 years or older in study II, with THR brands as the strata factor. The end-point was defined as cup and/or stem revision due to aseptic loosening. Adjustment has been made for age and gender.

9.1.3.2.2 Survival rate for any reason

At 15 years in study II, survival of the Exeter Universal/Exeter All-poly and the Müller prosthesis was 88 per cent (Table 25), when revision for any reason was considered as the end-point. The Cox model determined that five designs had a reduced risk of revision as compared to the Charnley prosthesis (Table 25). For patients aged 55 to 64 years, the Exeter Universal/Exeter All-poly had a 15-year survival rate for any reason of 80 per cent. For patients aged 65 to 74 years, the Exeter Universal/Exeter All-poly and the Müller prosthesis had 15-year survival rates exceeding 85 per cent. For patients aged 75 years or older, three designs had lower risks of revision than the Charnley prosthesis.

9.1.3.3 Cementless total hip replacements

9.1.3.3.1 Survival rate for aseptic loosening

When all patients aged 55 years or more were analysed as a single group, the 15-year survival rate for aseptic loosening of the PCA Standard/PCA Pegged was lower than that of the reference group. Cox regression analysis revealed that the PCA Standard/PCA Pegged design had a significantly increased risk of revision beyond seven years of follow-up. In contrast, all other cementless cup designs had lower risks of revision than the cemented reference group during the first seven years. These lower risks of revision even continued for the Bi-Metric/Press-Fit Universal, the Bi-Metric/Mallory and the ABG I/ABGII beyond seven years (Table 26, Figure 10). Beyond seven years, the number of the Bi-Metric/Vision THRs was scarce, however (Table 26).

For patients aged from 55 to 64 years, the 15-year survival rate of the Bi-Metric/Press-Fit Universal design was higher than that of the reference group [88% (CI 84-92) vs. 78% (CI 74-82)]. Moreover, for patients aged 65 to 74 years, the survival rate at 15 years for the Bi-Metric/Press-Fit Universal [95% (CI 93-98)] was higher than that of the reference group [87% (CI 86-89%)].

Age group	THR	N*	MF yr	AR 5 yr	% 5-year survival (95 % CI)	AR 10 yr	% 10-year survival (95 % CI)	AR 15 yr	% 15-year survival (95 % CI)	AR 20 yr	% 20-year survival (95 % CI)	Adjusted RR for revision (95 % CI)	p-value
All (≥ 55 years)	Elite Plus/ Elite Plus	885	6.3	622	92 (90-94)	134	81 (78-85)	0	-	0	-	1.49 (1.17-1.90)	<0.001
	Lubinus IP/ Lubinus IP	5790	12.0	5099	96 (96-97)	3690	89 (88-90)	2153	81 (80-82)	752	76 (74-77)	0.72 (0.61-0.84)	<0.001
	Lubinus SP II/ Lubinus IP	7240	8.1	5432	96 (95-96)	2996	91 (90-91)	611	84 (83-86)	0	-	0.74 (0.62-0.87)	<0.001
	Lubinus SP II/ Lubinus FC	701	2.6	94	97 (95-98)	0	-	0	-	0	-	0.95 (0.58-1.55)	NS (0.84)
	Lubinus SP II/ Lubinus Eccentric	2693	5.9	1830	96 (95-97)	252	90 (88-92)	9	-	0	-	0.82 (0.66-1.02)	NS (0.07)
	Exeter/ Exeter Metal-backed	876	11.6	760	96 (94-97)	543	86 (83-89)	309	76 (73-80)	84	68 (63-73)	0.89 (0.72-1.09)	NS (0.27)
	Exeter Universal/ Exeter All-poly	5048	5.9	3053	96 (96-97)	832	93 (91-94)	95	88 (85-91)	0	-	0.63 (0.52-0.76)	<0.001
	Exeter Universal/ Exeter Contemporary	5572	2.9	1237	97 (96-97)	3	-	0	-	0	-	0.78 (0.62-0.98)	=0.031
	Müller Straight/ Müller Std	2309	10.7	2011	97 (96-98)	1452	93 (92-95)	506	88 (86-90)	115	82 (78-86)	0.48 (0.39-0.59)	<0.001
	Spectron EF/ Reflection all-poly	1929	1.8	103	97 (96-98)	0	-	0	-	0	-	0.89 (0.61-1.29)	NS (0.53)
	Biomet Interlok/ Biomet Müller	581	7.5	454	95 (93-96)	180	88 (85-91)	0	-	0	-	1.04 (0.77-1.40)	NS (0.81)
	Charnley/ Charnley LPW	925	11.1	799	95 (94-96)	566	85 (83-88)	244	73 (70-77)	71	63 (57-68)	1.0	-

Table 25. Survival of cemented total hip replacements in study II. End-point is defined as the revision of the cup and/or the stem due to any reason. 5-, 10-, 15-, and 20-year survival rates obtained from the Kaplan-Meier analysis. *N = number of operations. MF = mean follow-up (years). AR = at risk. RR = risk ratio from the Cox regression analysis (other stem brands compared to the Charnley stem/Charnley LPW cup; adjustment made for age and gender). NS = non-significant.

Age group	THR	N*	MF yr	AR 7 yr	% 7-year survival (95% CI)	AR 10 yr	% 10-year survival (95% CI)	AR 15 yr	% 15-year survival (95% CI)	Adjusted RR for revision (95% CI)	p-value
All (≥ 55 years)	Anatomic Mesh/ HG-II	604	11.1	532	97 (96-98)	445	94 (92-96)	92	85 (80-89)	0.68 (0.51-0.90)	0.006
	FU ≤7 years									0.52 (0.32-0.86)	0.01
	FU > 7 years									0.75 (0.53-1.06)	0.11
	PCA Std/PCA Pegged	508	11.6	433	92 (90-95)	354	83 (80-87)	148	71 (66-76)	1.48 (1.19-1.83)	<0.001
	FU ≤7 years									1.37 (0.96-1.96)	0.09
	FU > 7 years									1.46 (1.11-1.92)	0.006
	Bi-Metric/PFU	2,687	8.8	2,035	98 (97-98)	1,192	96 (96-97)	145	90 (87-93)	0.37 (0.29-0.46)	<0.001
	FU ≤7 years									0.39 (0.29-0.54)	<0.001
	FU > 7 years									0.34 (0.25-0.47)	<0.001
	Bi-Metric/Mallory	637	8.8	517	99 (98-100)	275	96 (94-98)	10	-	0.36 (0.23-0.58)	<0.001
	FU ≤7 years									0.27 (0.13-0.55)	<0.001
	FU > 7 years									0.48 (0.26-0.88)	0.02
	Bi-Metric/Vision	2,055	3.4	152	99 (98-99)	0	-	0	-	0.37 (0.23-0.60)	<0.001
	FU ≤7 years									0.37 (0.23-0.62)	<0.001
	FU > 7 years									2.53 (0.35-18.38)	0.4
	ABG I/ABG I	565	9.1	455	97 (96-99)	330	92 (90-95)	0	-	0.75 (0.54-1.04)	0.09
	FU ≤7 years									0.51 (0.29-0.87)	0.01
	FU > 7 years									1.03 (0.68-1.55)	0.9
	ABG I/ABG II	1,765	5.9	700	99 (99-100)	14	-	0	-	0.12 (0.06-0.22)	<0.001
	FU ≤7 years									0.12 (0.06-0.24)	<0.001
	FU > 7 years									0.13 (0.02-0.93)	0.04
	ABG II/ABG II	1,489	2.5	0	-	0	-	0	-	0.33 (0.15-0.74)	0.007
	FU ≤7 years									0.34 (0.15-0.76)	0.009
	FU > 7 years									-	-
	Cemented reference	9,549	8.8	6,234	96 (96-96)	4,447	93 (93-94)	1,116	88 (87-89)	1.0	-
	FU ≤7 years									1.0	-
	FU > 7 years									1.0	-
	Total	19,859									

Table 26. Survival of cementless total hip replacements and the cemented reference group in study III. End-point is defined as revision due to aseptic loosening of the cup and/or the stem. 7-, 10-, and 15-year survival rates were obtained from the Kaplan-Meier analysis. Abbreviations: THR = total hip replacement, N* = number of operations, MF = mean follow-up (years), AR = at risk, RR = risk ratio from the Cox regression analysis (other brands compared to the cemented reference designs; adjustment made for age and gender), HG-II = Harris-Galante II, PCA = Porous Coated Anatomic, PFU = Press-Fit Universal and ABG = Anatomique Benoist Girard.

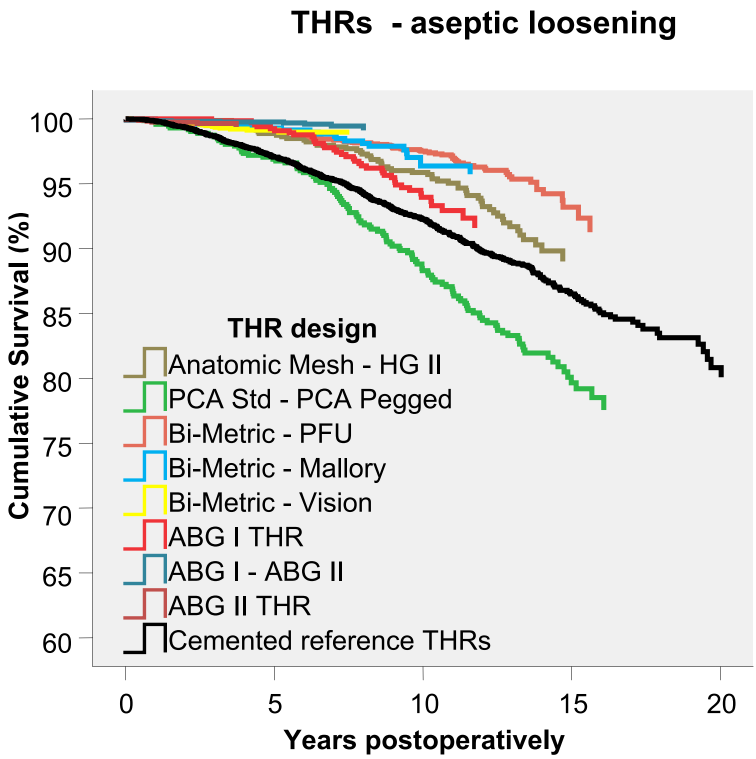

Figure 10. Cox-adjusted survival curves of 19,859 total hip replacements in patients aged 55 years or older with total hip replacement design as the strata factor in study III. The end point was defined as revision of the stem and/or the cup due to aseptic loosening. Adjustment was made for age and gender. Abbreviations; PCA = Porous Coated Anatomic, ABG = Anatomique Benoist Girard, PFU = Press-Fit Universal, THR = total hip replacement and HG II = Harris-Galante II.

9.1.3.3.2 Survival rate for any reason

When all patients aged 55 years or more were analysed as a single group, the survival rate at 15 years of the cementless designs was found to be lower than that of the reference group. Cox regression analysis revealed that during the first seven postoperative years the ABG I/ABGII had a significantly decreased risk of revision as compared to the cemented reference group (Table 27). Furthermore, the ABG II/ABG II combination was the only design which had an increased risk of revision during the first seven years after the primary operation (Table 27). Beyond seven years of follow-up, however, several cementless designs (the Anatomic Mesh/ HG-II, the PCA Standard/PCA Pegged, the ABG I/ABG I) showed higher risks of revision than the cemented reference group (Table 27, Figure 11), and none of the cementless designs had a lower risk of revision than the reference group beyond seven years. The numbers of the ABG I/ABG II THRs found beyond seven years was scarce (Table 27).

During the first seven postoperative years the risk ratio for revision due to any reason of cementless THRs for the 55-64 year group did not differ significantly from that of the cemented reference group. Beyond seven years of follow-up, however, the revision risks of the Anatomic Mesh/HG-II (RR 1.59, CI 1.15-2.20), the PCA Std/PCA Pegged (RR 1.53, CI 1.12-2.09), the Bi-Metric/PFU (RR 1.48, CI 1.13-1.93), the Bi-Metric/Mallory (RR 1.98, CI 1.27-3.08) and the ABG I/ABG I (RR 3.23, CI 2.26-4.63) were increased compared to the reference group.

During the first seven years, the risk ratio for revision due to any reason for cementless THRs did not differ significantly for the 65-74 year group from that of the cemented reference group, except for the ABG I/ABG II, which had a decreased risk of revision compared to that of the reference group (RR 0.45, CI 0.28-0.72). Except for the PCA Std/PCA Pegged (RR 2.02, CI 1.27-3.28) design, which had an increased risk of revision compared to the reference group beyond seven years of follow-up, the risk ratio for revision due to any reason for cementless THRs did not differ significantly from that of the cemented reference group.

Age group	THR	N*	MF yr	AR 7 yr	% 7-year survival (95% CI)	AR 10 yr	% 10-year survival (95% CI)	AR 15 yr	% 15-year survival (95% CI)	Adjusted RR for revision (95% CI)	p-value
All (≥ 55 years)	Anatomic Mesh/HG-II	604	11.1	532	94 (92-96)	446	89 (87-92)	93	72 (67-78)	1.19 (0.97-1.47)	0.1
	FU ≤7 years									0.91 (0.64-1.29)	0.6
	FU > 7 years									1.32 (1.01-1.72)	0.04
	PCA Std/PCA Pegged	508	11.6	433	91 (89-94)	354	82 (79-86)	149	67 (62-72)	1.51 (1.24-1.83)	<0.001
	FU ≤7 years									1.26 (0.91-1.75)	0.2
	FU > 7 years									1.52 (1.18-1.95)	0.001
	Bi-Metric/PFU	2,687	8.8	2,044	93 (92-94)	1,205	87 (86-89)	147	71 (67-75)	1.10 (0.95-1.27)	0.2
	FU ≤7 years									0.98 (0.80-1.20)	0.8
	FU > 7 years									1.18 (0.96-1.46)	0.1
	Bi-Metric/Mallory	637	8.8	519	95 (93-97)	277	89 (85-92)	10	-	1.05 (0.81-1.36)	0.7
	FU ≤7 years									0.76 (0.52-1.12)	0.2
	FU > 7 years									1.43 (1.00-2.05)	0.05
	Bi-Metric/Vision	2,055	3.4	153	95 (93-96)	0	-	0	-	0.99 (0.76-1.29)	0.9
	FU ≤7 years									0.98 (0.75-1.29)	0.9
	FU > 7 years									2.75 (0.38-19.85)	0.3
	ABG I/ABG I	565	9.1	458	91 (89-94)	336	81 (77-84)	0	-	1.74 (1.41-2.15)	<0.001
	FU ≤7 years									1.27 (0.92-1.74)	0.1

Age group	THR	N*	MF yr	AR 7 yr	% 7-year survival (95% CI)	AR 10 yr	% 10-year survival (95% CI)	AR 15 yr	% 15-year survival (95% CI)	Adjusted RR for revision (95% CI)	p-value
	FU > 7 years									2.30 (1.73-3.06)	<0.001
	ABG I/ABG II	1,765	5.9	701	96 (95-97)	14	-	0	-	0.66 (0.51-0.86)	0.002
	FU ≤7 years									0.63 (0.48-0.84)	0.001
	FU > 7 years									0.69 (0.28-1.69)	0.4
	ABG II/ABG II	1,489	2.5	0	-	0	-	0	-	1.52 (1.13-2.05)	0.006
	FU ≤7 years									1.46 (1.08-1.97)	0.01
	FU > 7 years									-	-
	Cemented reference	9,549	8.8	6,237	94 (94-95)	4,449	91 (91-92)	1,117	86 (84-87)	1.0	-
	FU ≤7 years									1.0	-
	FU > 7 years									1.0	-
	Total	19,859									

Table 27. Survival of cementless total hip replacements and the cemented reference group in study III. End-point is defined as revision of the cup and/or the stem due to any reason. 7-, 10-, and 15-year survival rates were obtained from the Kaplan-Meier analysis. Abbreviations: THR = total hip replacement, N* = number of operations, MF = mean follow-up (years), AR = at risk, RR = risk ratio from the Cox regression analysis (other brands compared to the cemented reference designs; adjustment made for age and gender), HG-II = Harris-Galante II, PCA = Porous Coated Anatomic, PFU = Press-Fit Universal and ABG = Anatomique Benoist Girard.

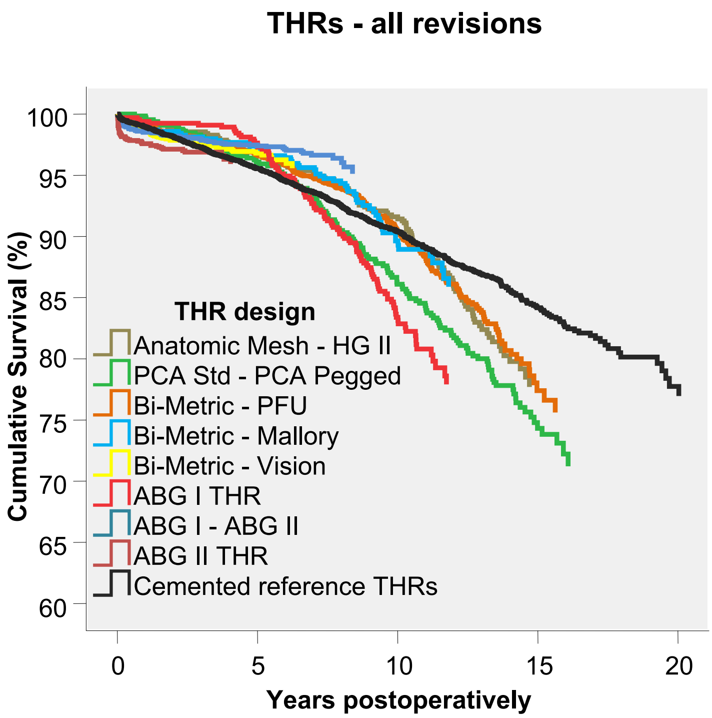

Figure 11. Cox-adjusted survival curves of 19,859 total hip replacements in patients aged 55 years or older with total hip replacement design as the strata factor in study III. The end point was defined as revision of the stem and/or the cup for any reason. Adjustment was made for age and gender. Abbreviations; PCA = Porous Coated Anatomic, ABG = Anatomique Benoist Girard, PFU = Press-Fit Universal, THR = total hip replacement and HG II = Harris-Galante II.

9.2 HOSPITAL DISCHARGE REGISTER-BASED STUDIES (IV AND V)

9.2.1 REGIONAL VARIATION IN THA RATES (STUDY IV)

Over the 1998 to 2005 period, 44 093 primary THAs were performed in Finland. Of these, 34 675 were performed due to primary OA (79% of all primary THAs) (Table 28). The number of primary THAs for primary OA increased by 67 per cent over the eight year period (Table 28). In 2005 the incidence per 100 000 inhabitants of primary THAs for primary OA was 112 (Table 29). There was a tendency for the proportion of men to increase towards the end of the study period (Table 28).

There was considerable geographical variation in THA incidence rates. The relative differences in rate between the highest and lowest scoring region adjusted for age and for gender was threefold in 1998, 1.9-fold in 2005 and from two to 2.3-fold in all other years studied (Table 29).

The adjusted incidence index for the capital, Helsinki, was continually below the average for the whole country (Figure 12, Tables 30 and 31).

9.2.2 VARIABLES POSSIBLY ASSOCIATED WITH REGIONAL VARIATION OF THA (STUDY IV)

When the ratio of THAs performed for primary OA to THAs performed for any reason was high, the absolute incidence of THAs was high ($p<0.001$). Similarly, high need-adjusted expenses of specialized care ($p<0.001$) were also associated with a high incidence rate of THA for primary OA.

In contrast, a large proportion of patients aged between 18 to 64 years who had permanent disability pension because of orthopaedic disorders or connective tissue disease was associated with a low incidence rate of THA for primary OA ($p<0.001$).

None of the following factors were associated with the incidence rate of THA for primary OA: the relative number of orthopaedic surgeons or anesthesiologists, population density, average distance of inhabitants of the region to the nearest hospital performing THAs, the average incomes in a region as evaluated by state taxation and morbidity index.

	1998	1999	2000	2001	2002	2003	2004	2005
The number of all primary THAs	4538	4660	4984	5197	5755	6153	5859	6947
The number of primary THAs for primary OA	3421	3506	3878	4099	4517	4891	4643	5720
Mean age (in years)	68.3	68.3	68.1	68.0	68.1	67.6	67.7	67.9
Gender (proportion of men, %)	40.2	42.2	42.5	42.4	41.5	43.8	44.9	44.9

Table 28. The number of all primary THAs, the number of all primary THAs for primary OA, the mean age of the patients (in years) and the proportion of men of all patients (%) operated on in Finland over the 1998-2005 period in study IV.

	1998	1999	2000	2001	2002	2003	2004	2005
Incidence in the whole country	67	69	76	80	89	96	91	112
The highest regional incidence	147	110	109	144	128	147	138	163
The lowest regional incidence	45	46	43	48	66	68	58	69
Adjusted incidence index in the whole country	100	101	110	114	124	133	124	150
The highest regional adjusted incidence index	219	160	156	169	176	200	184	190
The lowest regional adjusted incidence index	73	72	69	77	86	91	87	104

Table 29. The unadjusted incidence of primary THAs for primary OA per 100 000 inhabitants for the whole country, including the highest and the lowest regional incidences and the age- and gender adjusted incidence indices of primary THAs for primary OA for the whole country, including the highest and the lowest regional adjusted incidence indices for the 1998-2005 period in study IV. 100 is taken as the average for the whole country in 1998 and thus 1998 is taken as the base year.

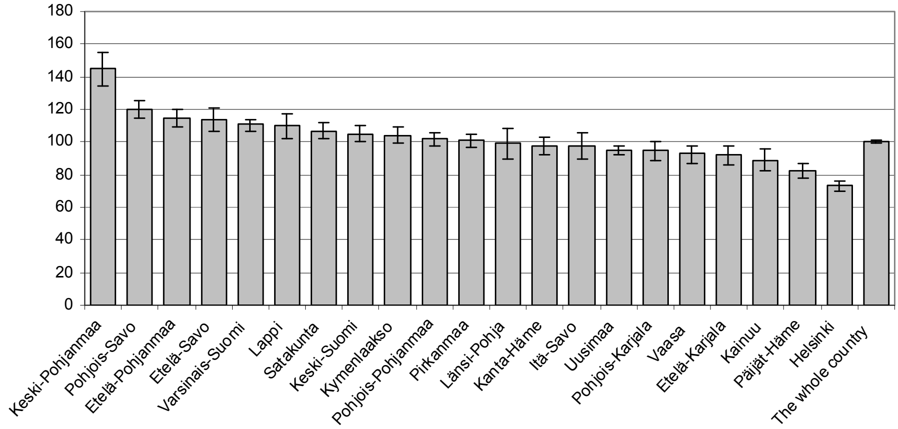

Figure 12. Districts, adjusted indices of regional incidence and 95% confidence intervals of the index, years 1998-2005 summed together in study IV. Adjusted indices were compared up to the level of the whole country in year 1998 (the whole country 1998-2005 = 100).

	1998			1999			2000			2001		
District	Index	95% CI	Incid.	Index	95% CI	Incid	Index	95% CI	Incid.	Index	95% CI	Incid.
Varsinais-Suomi	129	117-142	92.5	104	93-116	75.4	122	110-134	89	137	125-150	101.4
Satakunta	117	101-134	87.7	117	102-134	89.5	119	104-136	93.2	125	110-142	100.2
Kanta-Häme	100	83-119	74.6	93	77-111	70.2	123	104-144	93.8	108	91-128	84
Pirkanmaa	93	82-104	65.3	105	94-117	74.4	108	97-120	77.5	107	96-119	77.3
Päijät-Häme	80	66-96	57.5	96	81-113	70.6	87	73-103	65.3	96	81-112	73.4
Kymenlaakso	73	60-89	56.7	94	79-111	73.9	127	110-147	102.2	132	114-152	108.1
Etelä-Karjala	74	58-93	56.8	91	73-111	70.9	115	95-138	91	83	67-102	67.1
Etelä-Savo	91	72-113	73.2	120	98-145	97.9	128	106-154	106.9	169	143-198	144.4
Itä-Savo	118	92-151	99.1	112	86-143	95.7	121	94-153	106.3	139	110-173	124.5
Pohjois-Karjala	83	68-100	61.5	72	58-88	54.5	106	89-125	81.4	119	101-139	92.8
Pohjois-Savo	141	125-159	102.8	120	105-137	89.3	130	114-147	98.1	143	127-161	110.3
Keski-Suomi	110	95-126	77	111	96-127	78.5	117	103-134	84.3	120	105-136	87.4
Etelä-Pohjanmaa	119	102-138	89.4	113	96-131	85.7	111	95-129	85.7	145	127-166	113.9
Vaasa	108	91-128	79.1	87	72-105	64.4	111	94-132	83.1	119	100-139	89.8
Keski-Pohjanmaa	219	181-263	146.9	160	128-198	109.5	156	125-193	108.8	146	116-181	104.3
Pohjois-Pohjanmaa	84	73-98	49.3	105	92-119	61.9	116	102-131	69	99	87-113	60.2
Kainuu	85	64-111	61.5	73	53-96	54.1	84	63-109	64.2	95	73-122	75.7
Länsi-Pohja	84	60-114	57.2	105	78-138	73.7	118	89-152	84.6	119	91-154	88.5
Lappi	98	77-121	64	112	91-137	75.9	136	113-163	95	126	104-152	91.4
Helsinki	73	64-82	45	74	65-83	45.7	69	61-79	43	77	68-87	48.4
Uusimaa	91	82-101	47.6	103	93-113	54.4	101	92-111	54.6	95	87-105	52.6
The whole country	100	97-103	67.4	101	98-104	69	110	107-114	76.2	114	110-117	80.2

Table 30. Districts, adjusted indices of regional incidence (Index), 95% confidence intervals (95% CI) of the index and regional incidences per 100 000 inhabitants in 1998-2001 in study IV. Adjusted indices (Index) were compared to the level of the whole country in year 1998 (the whole country 1998 = 100).

	2002			2003			2004			2005		
District	Index	95% CI	Incid.	Index	95% CI	Incid	Index	95% CI	Incid.	Index	95% CI	Incid.
Varsinais-Suomi	146	133-159	109.1	132	120-145	100.3	136	124-149	105.2	163	150-176	127
Satakunta	114	99-131	93.1	147	130-165	121.8	120	105-136	101.5	170	152-189	146.7
Kanta-Häme	115	97-134	89.8	132	114-154	105	133	114-154	106.8	140	121-162	113.4
Pirkanmaa	116	105-128	84.7	134	122-147	98.8	139	127-152	103.7	163	150-177	122.3
Päijät-Häme	95	81-112	74.2	99	84-115	78.5	87	74-102	70.7	130	113-148	107.1
Kymenlaakso	130	113-150	107.9	139	121-159	117	138	120-158	118.2	172	152-194	149.9
Etelä-Karjala	86	69-105	70.3	126	106-149	105.3	113	94-135	96.4	189	165-217	163.3
Etelä-Savo	123	102-148	107.5	143	120-169	127.1	166	140-196	151	172	146-200	158.2
Itä-Savo	109	84-139	100.4	100	76-129	93.4	95	72-123	90.9	160	130-195	155.8
Pohjois-Karjala	125	107-145	99.2	154	134-177	124.7	98	82-116	80.4	167	147-190	140
Pohjois-Savo	137	121-155	107.2	156	139-174	123.3	140	124-157	112.7	190	171-209	155.6
Keski-Suomi	138	122-155	101.6	147	131-165	110.2	124	109-140	94.1	142	126-159	109.8
Etelä-Pohjanmaa	145	127-166	115.1	179	159-201	143.5	146	128-166	118.7	171	152-193	140.5
Vaasa	103	86-122	78.4	91	75-109	70.5	118	100-139	92.7	177	155-201	139.5
Keski-Pohjanmaa	176	143-214	127.8	200	165-240	147.3	184	151-223	138.4	163	132-199	123.9
Pohjois-Pohjanmaa	145	130-161	89.1	134	120-150	83.6	135	121-151	85.6	147	132-163	94.3
Kainuu	147	120-179	119.8	134	108-164	111.2	107	84-134	91.2	126	101-154	109.1
Länsi-Pohja	94	69-125	71.5	162	129-201	125.6	139	109-174	109.6	125	97-159	100.7
Lappi	141	118-168	105.3	156	131-183	119.2	132	110-157	103.5	143	120-169	114.9
Helsinki	112	101-123	70.9	105	95-117	67.8	89	79-99	58.1	104	94-115	68.8
Uusimaa	118	109-128	66.4	118	108-128	67.6	118	109-128	69.4	122	112-131	73
The whole country	124	121-128	88.8	133	129-136	96.1	124	120-157	91.3	150	146-153	111.9

Table 31. Districts, adjusted indices of regional incidence (Index), 95% confidence intervals (95% CI) of the index and regional incidences per 100 000 inhabitants in 2002-2005 in study IV. Adjusted indices (Index) were compared to the level of the whole country in year 1998 (the whole country 1998 = 100).

9.2.3 LOS, LUIC AND COSTS (STUDY V)

LOS was significantly longer for Group 1 than for Group 4 (p=0.0001) and for Group 3 (p=0.0006). However, the LOS was shorter for the Group 1 than for the Group 2 (p=0.0001). The mean annual LOS in hospital volume groups are presented in Table 32.

The LUIC was shorter for Group 4 than for Group 1 (p=0.0001). Nonetheless LUIC was longer for Group 3 (p=0.0001) and for Group 2 (p=0.0001) than for Group 1. The mean annual LUIC-LOS in hospital volume groups are presented in Table 33.

If all THRs of the study period in Finland had been performed in the very high volume hospitals with the shortest length of stay, theoretically 39 650 days would have been saved (1.41 days per patient) (Table 32). Thus, theoretically costs would have been decreased by 20 895 550 euros. The effect of difference in LUIC-LOS to saving days was minor (Table 33).

If all THRs of the study period in Finland had been performed in the very high volume hospitals, then this would have lead to a total of 583 extra re-admissions at 14 days. The increased cost resulting from these re-admissions would have been 162 074 euros.

If the putative increased costs due the higher number of re-admissions (162 074 euros) were subtracted from the total savings for the LOS reduction (20 895 550 euros), then the net savings during the follow-up time would be 20 733 476 euros.

	1998				1999				2000				2001			
	LOS	N	Difference in LOS	Days saved	LOS	N	Difference in LOS	Days saved	LOS	N	Difference in LOS	Days saved	LOS	N	Difference in LOS	Days saved
Group 1 (0-50)	10.98	452	3.56	1609	10.07	270	1.13	305	9.10	420	1.73	727	8.26	482	0.75	362
Group 2 (51-150)	10.22	1438	2.80	4026	10.02	1576	1.08	1702	9.78	1360	2.41	3278	9.66	1302	2.15	2800
Group 3 (151-300)	9.33	1015	1.91	1939	8.94	1187	-	-	8.76	1079	1.39	1500	8.50	1118	0.99	1107
Group 4 (301+)	7.42	172	-	-	-	0	-	-	7.37	325	-	-	7.51	435	-	-
Totally		3077		7574		3033		2007		3184		5505		3337		4269

	2002				2003				2004				2005				1998-2005
	LOS	N	Difference in LOS	Days saved	LOS	N	Difference in LOS	Days saved	LOS	N	Difference in LOS	Days saved	LOS	N	Difference in LOS	Days saved	Days saved
Group 1 (0-50)	7.83	391	0.56	219	6.74	182	0.77	140	6.22	212	0.88	187	6.29	217	0.84	182	-
Group 2 (51-150)	9.26	1456	1.99	2897	8.63	1275	2.66	3391	8.42	1260	3.08	3881	7.69	1227	2.24	2748	-
Group 3 (151-300)	7.91	1077	0.64	689	8.24	886	2.27	2011	7.49	1150	2.15	2473	6.99	959	1.54	1477	-
Group 4 (301+)	7.27	666	-	-	5.97	1553	-	-	5.34	1051	-	-	5.45	2025	-	-	
Totally		3590		3805		3896		5542		3673		6541		4428		4407	39650

Table 32. The average annual length of stay and the number of days saved if patients were treated in hospitals with the shortest length of stay. LOS = annual mean length of stay (surgical treatment period) in days. N = number of patients. Difference in LOS = Difference between the shortest length of stay and that of other hospital groups in days. Days saved = number of days saved if patients were operated in hospitals with the shortest length of stay (Days saved = Difference in LOS multiplied with N).

	1998				1999				2000				2001				
	LUIC-LOS	N	Difference in LUIC-LOS	Days saved	LUIC-LOS	N	Difference in LUIC-LOS	Days saved	LUIC-LOS	N	Difference in LUIC-LOS	Days saved	LUIC-LOS	N	Difference in LUIC-LOS	Days saved	
Group 1 (0-50)	3.46	452	0,47	212	3.71	270	-0.45	-122	2.78	420	-0.64	-269	2.90	482	-0.28	-135	
Group 2 (51-150)	3.19	1438	0.20	288	3.34	1576	-0,82	-1292	3,51	1360	0.09	122	3.23	1302	0.05	65	
Group 3 (151-300)	4.59	1015	1,60	1624	4,16	1187	-	-	4,74	1079	1.32	1424	4,52	1118	1.34	1498	
Group 4 (301+)	2.99	172	-	-	-	0	-	-	3,42	325	-	-	3,18	435	-	-	
Totally		3077		2124		3033		-1414		3184		1277		3337		1428	
	2002				2003				2004				2005				1998-2005
	LUIC-LOS	N	Difference in LUIC-LOS	Days saved	LUIC-LOS	N	Difference in LUIC-LOS	Days saved	LUIC-LOS	N	Difference in LUIC-LOS	Days saved	LUIC-LOS	N	Difference in LUIC-LOS		Days saved
Group 1 (0-50)	3.60	391	0.21	82	2.84	182	-1.42	-258	2.82	212	-0.32	-68	2.75	217	-1.69	-367	-
Group 2 (51-150)	3.26	1456	-0.13	-189	3.47	1275	-0.79	-1007	3.58	1260	0.44	554	2.90	1227	-1.54	-1890	-
Group 3 (151-300)	4,56	1077	1.17	1260	2,91	886	-1.35	-1196	4,61	1150	1.47	1691	3.34	959	-1.10	-1055	-
Group 4 (301+)	3,39	666	-	-	4,26	1553	-	-	3,14	1051	-	-	4,44	2025	-	-	-
Totally		3590		1153		3896		-2461		3673		2177		4428		-3312	972

Table 33. The average length of institutional care after the surgical treatment period by hospital volume groups and the number of days saved if patients were treated in highest volume hospitals. LUIC-LOS = length of institutional care after the surgical treatment period on average. N = number of patients. Difference in LUIC-LOS = difference in the length of institutional care after the surgical treatment period compared to the Group 4 (with the exception year 1999, when the comparison was made to the Group 3). If the Difference of LUIC-LOS had a negative value, the LUIC-LOS was shorter in the hospital volume group involved than in the Group 4. Days saved = the number of days saved if patients were operated in the highest volume hospitals (Days saved = Difference in LUIC-LOS multiplied with N).

	Re-ads 14 days		Re-ads 42 days		Dis-locations		Re-operations		Infections	
Groups	OR	95% Wald Confidence Limits	OR	95% Wald Confidence Limits	OR	95% Wald Confidence Limits	OR	95% Wald Confidence Limits	OR	95% Wald Confidence Limits
2 vs 1	1.21	1.00-1.46	0.98	0.85-1.12	0.88	0.70-1.11	1.05	0.83-1.33	1.07	0.67-1.70
3vs 1	1.35	1.12-1.64	0.96	0.84-1.11	0.70	0.55-0.90	0.96	0.75-1.23	0.88	0.54-1.45
4 vs 1	1.43	1.18-1.74	1.17	1.02-1.36	1.09	0.85-1.41	0.94	0.72-1.23	0.80	0.48-1.35

Table 34. Adjusted odds ratios for unscheduled re-admissions in 14 and in 42 days, dislocations, re-operations and infections in study V. Abbreviations: OR = odds ratio and Re-ads = re-admissions. Group 1 = 1-50 (low volume hospitals), Group 2 = 51-150 (average volume hospitals), Group 3 = 151-300 (high volume hospitals) and Group 4 = 301 or over (very high volume hospitals) primary and revision knee and hip replacements performed annually.

9.2.4 UNSCHEDULED RE-ADMISSIONS AND COMPLICATIONS (STUDY V)

Adjusted odds ratios of hospital groups for unscheduled re-admissions at 14 and at 42 days, dislocations, re-operations and infections are presented in Table 34. There were significantly fewer re-admissions within 14 days for Group 1 than for all other hospital groups. There were significantly more dislocations for Group 1 than for Group 3. Hospital volume was not associated with re-operation rates or with infection rates.

10. DISCUSSION

10.1 VALIDITY OF THE DATA

10.1.1 THE FINNISH ARTHROPLASTY REGISTER-BASED STUDIES (I, II AND III)

Register-based studies have certain limitations. Prior to 1994, 10 per cent of total hip replacements performed in Finland were missing from the Finnish Arthroplasty Register (Puolakka et al. 2001a). These THRs were lost to follow-up and could have been failures that would have caused bias in our study. It is also possible that few centres performed the majority of the replacements and certain complications could have occurred more often at certain centres. However, a single centre or an implant giving poor results does not have a major effect on the overall results in a register-based study involving very high numbers. It is actually the purpose of register studies to evaluate population-based results for hospitals and implants of variable standards. A limitation of register-based studies is that only a revision operation *per se* is defined as a failure. There might be patients with polyethylene failure, osteolysis or loosened implants who are too ill to undergo revision surgery, or those who simply prefer not to do so, or other patients who are not even aware of having a problem associated with their implants. Furthermore, selection bias may occur, if some surgeons do not use cementless implants under certain circumstances. One such circumstance could be severe osteoporosis (study I and III). However, this kind of selection bias can in theory only be avoided by conducting a randomized controlled trial. Recently, it was stated that well designed observational studies provide reliable information on treatment effects, and that the role of single randomized controlled studies should not be overemphasized in clinical decisions (Benson and Hartz 2000, Concato et al. 2000).

In studies II and III, the implantation of different designs varied over the years (Tables 6 and 9, respectively). In some studies, modern cementing techniques have resulted in higher long-term survival (Herberts and Malchau 2000, Malchau et al. 2002) compared to earlier techniques. However, this has not been verified in all studies (Puolakka et al. 2001a). In study III, some of the three cemented designs used as the reference group were implanted over the whole study period starting in 1980. Any recent developments in cementing techniques adopted may result in higher long-term survival rates for those prostheses, which were implanted later in the study period (Herberts and Malchau 2000, Malchau et al. 2002). Nevertheless, the cemented implants chosen in study III were the best performing designs found in study II.

In study III, the proportional hazards assumption of the Cox model (meaning that the relative difference between revision rates should be constant over the elapse of time since the primary operation) was not reached in some analyses performed. Therefore, adjusted risk ratios were also established within defined time intervals (0-7 years, >7 years after the primary operation). Follow-up beyond seven years revealed that the results regarding cementless cups, and therefore regarding cementless THRs, do deteriorate over time.

10.1.2 HOSPITAL DISCHARGE REGISTER-BASED STUDIES (IV AND V)

The main strength of studies IV and V was the access to a nationwide database with previously documented high data validity that allowed a population-based approach for this study. The reliability of the Discharge Register for reporting surgical operations is high. As early as the late 1980's at least 95 per cent of operations were recorded in the Discharge Register (Keskimäki and Aro 1991). The correlation between Nordic discharge registers and Nordic arthroplasty registers is high (Söderman et al. 2000, Pedersen et al. 2004, Arthursson et al. 2005, Peltola 2008). It is also notable that the data of studies IV and V also include all private hospitals. Thus these data are comprehensive.

One limitation of the study IV was that no information on waiting times was available. The data in the Discharge Register in Finland regarding waiting times are considered incomplete (Järvelin and Linna 2004). Long waiting lists and a high rate of surgery can result from a high demand for surgery, which in turn is influenced by decisions taken by physicians (Nordberg et al. 1994). We had no information on the preference of patients or of physicians for surgery. Similarly we had no information about local guidelines for clinical decision-making, or the number of specialist nurses available. The method of extreme quotients in estimating variation is susceptible to potential skewing effect of outliers because it does not exclude the variance attributable to outlying random variation (Keskimäki et al. 1994). However, in a previous report on data obtained from the Finnish Discharge Register, it was concluded that the method of extreme quotient produces reliable results for THAs (Keskimäki et al. 1994).

Patient age, sex and surgical and medical diagnoses were adjusted in study V. Calculations were also performed using head size of the prosthesis in the adjustments to eliminate the effect of head size to dislocation rate. However, the data of head size of the prosthesis was missing in 1402 of all THRs studied (5%). The head size of 28 mm was used in 86 per cent of those THRs for which such information was available. The effects of hospital volume on dislocation rates were very similar with or without adjustment of the head size. However, not all factors associated with dislocation rate, such as the surgical approach used, could be adjusted in study V.

Data on the effect of surgeon's volume on results of THR separate from the effect of hospital volume were not available in study V. However, it has already been reported that surgeon volume is a very good indicator of orthopaedic adverse events in THR surgery (Solomon et al. 2002). Surgeon volume in a single hospital is basically a question of organizational choice and capability of reasonable orthopaedic decision-making in that hospital. A limitation of our study is that a single hospital may have a major effect on results when there were only a few hospitals in a particular group. The length of the follow-up in the current study was short and we were not able to evaluate the relationship between hospital volume and long-term survival of replacements. Furthermore, we did not have data on the numbers of unscheduled visits to unspecialized public primary health care or to private physicians after THR. Telephone contacts were not recorded either.

10.2 GENERAL DISCUSSION

10.2.1 THE FINNISH ARTHROPLASTY REGISTER-BASED STUDIES (I, II AND III)

10.2.1.1 Implant groups

Recent Scandinavian national register-based studies have shown excellent long-term survivorship for cemented THRs in patients with primary OA (Havelin et al. 2000, Malchau et al. 2002, Espehaug et al. 2009, Havelin et al. 2009). Survival of cemented implants was shown to be better than survival of cementless implants (Malchau et al. 2002). When our data were compared with those of other Nordic registries, the differences in survivorship between cementless and cemented implants in elderly patients are interesting. In Finland, the tradition of cementless total hip arthroplasty is strong. In Sweden and in Norway, the use of cementless implants has not been as common as in Finland (Herberts and Malchau 2000, Malchau et al. 2002, Havelin et al. 2009). In our opinion, reports from the Swedish Arthroplasty Register have not taken into account substantial differences between cementless hip replacements, some of which have proved to have excellent (Archibeck et al. 2001, Bojescul et al. 2003, Jacobsen et al. 2003, Marshall et al. 2004, Meding et al. 2004, Oosterbos et al. 2004, Parvizi et al. 2004a, Eskelinen et al. 2005, Eskelinen et al. 2006) and others catastrophic (Engh et al. 1990, Tallroth et al. 1993, Simank et al. 1997) results. We think that the survival data of cementless implants should be analysed by implant groups and be presented as such. On the other hand, systematic instructions for cementing techniques and reporting of the results were started very early in Sweden, which has certainly aided in achieving the high long-term survivorship of cemented replacements reported from the Swedish register. In study I, survivorship of cementless stems for aseptic loosening was superior to that of cemented stems for patients aged 55 to 74 years. To the best of our knowledge, this finding has not been reported previously. The results of the study I also suggest that the survivorship of cementless cups for aseptic loosening can be as good as those of the cemented types in elderly patients. However, a large number of wear-related revisions of modular cementless cups are an alarming finding, which clearly emphasizes the need for more wear-resistant articulations for cementless cups. The problem or cup/liner incongruity of the two-piece acetabular designs with an incomplete locking mechanism was emphasized in study I. This problem was due to the large proportion of those cups designs that have been reported to have a high incidence of liner problems.

10.2.1.2 Cemented THA

10.2.1.2.1 The Charnley prosthesis

In study II, results of the Charnley prosthesis were not as good as those in other studies (Berry et al. 2002, Wroblewski et al. 2002, Buckwalter et al. 2006, Espehaug et al. 2009). Only the Elite Plus prosthesis, which is a modification of the Charnley prosthesis, had a poorer outcome than the Charnley prosthesis. However, the number of Charnley prostheses implanted in Finland was small (925) compared to the Exeter Universal/ Exeter All-poly prosthesis (5,048). There may be a bias concerning the centre in which the operations took place. The Charnley prosthesis may also have been affected by the cohort. The use of the Exeter Universal/ Exeter All-poly prosthesis in Finland was started nine years later than the use of the Charnley prosthesis. Furthermore, when we analysed the 12 most common THR designs, only those Charnley stems that were implanted together with the LPW (=long posterior wall) cup were included. Combinations with other cups such as the Charnley Standard were not included, because these were not among the 12 most common replacements used in Finland. The LPW socket can generate twice as much torque as the standard socket and therefore is more likely to loosen (Murray 1992). The poor results of the cup component may have had a detrimental effect on the results of the Charnley stem.

10.2.1.2.2 The Lubinus prosthesis

The Lubinus prosthesis has been used widely in Finland, Sweden and Norway (Puolakka et al. 2001, Malchau et al. 2002, Espehaug et al. 2009). However, long-term survival rates of the Lubinus prosthesis have been contradictory (Partio et al. 1994, Alho et al. 2000, Havelin et al. 2000, Puolakka et al. 2001a, Malchau et al. 2002, Espehaug et al. 2009). In study II, survival of the Lubinus replacements were not as good as those of the best-performing designs. For any reason, the 10-year survival rate of the Lubinus SP II/ Lubinus IP prosthesis for patients aged 55 to 64 years was 88 per cent, but at 15-years it had declined to only 73 per cent. This finding emphasizes the importance of continual surveillance and reporting beyond 10-years of follow-up.

10.2.1.2.3 The Exeter prosthesis

In study II, the overall survival of the matte-finished Exeter stem combined with the metal-backed cemented cup was poor. The overall survival of the Exeter Universal/ Exeter All-poly was good. These results are in accordance with previous reports (Howie et al. 1998, Malchau et al. 2002, Williams et al. 2002, Hook et al. 2006, Carrington et al. 2009, Espehaug et al. 2009).

10.2.1.2.4 The Müller prosthesis

In study II, the survivorship of the Müller prosthesis was good regarding those patients who were older than 64 years. Good long-term results for the Müller stem have also been published previously (Räber et al. 2001, Riede et al. 2007, Clauss et al. 2009).

10.2.1.2.5 The Elite Plus prosthesis

The survival of the Elite Plus prosthesis was found to be poor in study II. Reports of the poor performance of the Elite Plus prosthesis have also been published previously (Walton et al. 2005, Hauptfleisch et al. 2006). Changes to the Elite Plus stem but not to the Charnley stem included: a modification of the shoulder flange designed to reduce subsidence (Wroblewski et al. 1998), an altered surface finish, improved material, and new instrumentation (Elite Plus Total Hip System). Furthermore, catastrophic failures of the Elite Plus prosthesis with the Hylamer acetabulum and zirconia ceramic femoral head have been reported (Norton et al. 2002). However, the all-poly Hylamer cups have not been used in Finland. There seems to be no reason to continue performing Elite Plus replacements.

10.2.1.2.6 The Spectron EF/the Reflection All-poly

The combination of the Spectron EF stem and the Reflection All-poly cup has become very popular in Finland, despite the fact that long-term results for this design have not yet become available. In study II, the short-term results for this design were promising. This is in accordance with previous data for the older version of the stem, the satin Spectron stem (Garellick et al. 1999, Malchau et al. 2002, Kale et al. 2003). A modified version of the Spectron stem, the Spectron EF, was introduced in 1989 with the addition of a distal centraliser, head modularity, and a rough surface finish in the proximal third (Grose et al. 2006). In Finland, only the roughened version has been used. High failure rates of the Spectron EF stem have recently been published (Gonzales Della Valle et al. 2006, Grose et al. 2006). Nevertheless, this aseptic failure, which is characterized by debonding, subsidence, and metallic shedding with femoral osteolysis and metallosis, has not been reported for the satin finish Spectron stem (Gonzales Della Valle et al. 2006). In a study based on data from the Norwegian Arthroplasty Register, it was stated that beyond five years follow-up, the Reflection All-Poly cup had a 14 times higher revision rate than the Charnley cup. Moreover, the Spectron EF stem had higher revision rate due to aseptic loosening than the Charnley stem, RR = 6.1 (Espehaug et al. 2009). Time will tell if there is difference in survival of the satin finished Spectron stem and the Spectron EF stem. It is interesting to see, if the good results in the current study in the short term will remain in longer term, or shall there be more aseptic loosenings as suggested in above mentioned studies.

In study II, the survival of cemented prostheses for the age groups of 55 to 64 years and 64 to 74 years was not excellent. However, almost all cemented designs performed well for the age group of 75 years and older. In study I it was found that cemented prostheses have higher risks of revision for aseptic loosening than their cementless counterparts for patients aged 55 to 74 years with OA. The causes of these relatively poor survival rates of cemented designs in Finland are unclear. Hip replacements have been performed in numerous low-volume hospitals in Finland until recently. Furthermore, third-generation cementing techniques may not have been widely adopted among Finnish orthopaedic surgeons during the 1990s. Moreover, cementing techniques have only been categorically documented in the Finnish Register since 1996.

In study I, composite-beam stems (Shen 1998, Scheerlinck and Casteleyn 2006) were found to have a significantly increased risk of revision for aseptic loosening compared to the loaded-taper stems (Ong et al. 2002, Scheerlinck and Casteleyn 2006). The Exeter Universal stem, which is a loaded-taper stem, also had a good survival in individuals of the youngest age-group in study II. It cannot be categorically stated that the survival of cemented prostheses in Finland is poor. However, the long-term survival of cemented composite-beam stems was found to be poor, and the survival of cemented all-poly cups was not excellent either.

10.2.1.3 Cementless THA

10.2.1.3.1 The Biomet prostheses

Survival rates of 95 to 100 per cent for follow-ups of between five to 15 years have been reported for the Bi-Metric stem (Jacobsen et al. 2003, Marshall et al. 2004, Eskelinen et al. 2006). In study III, we found a higher survival rate for aseptic loosening of the Bi-Metric stem than that of the reference stems in patients aged 55 to 74 years. When revisions for aseptic loosening were analysed, the Press-Fit Universal cup was found to have a comparable survival rate to those of the reference cups in patients aged 55 to 74 years. In Finland, Biomet cups were used with Hexloc liners until 1995 and have been used with Ringloc liners since then. In an earlier study based on data from the Finnish Register, survivorship of the Press-Fit Universal cups with Hexloc-liners was poor (Puolakka et al. 1999). Reasons for increased wear of Hexloc liners were thin polyethylene, poor quality of the polyethylene, the cylindrical design and a poor locking mechanism (Puolakka et al. 1999, Puolakka et al. 2001b). Furthermore, screw-holes of Press-Fit Universal cups were unplugged. In the present study, the survival rate of the Bi-Metric/Press-Fit Universal at 15 years was lower than that of the cemented reference group when all revisions were taken into account. However, the adjusted risk of revision for any reason for the Bi-Metric/Press-Fit Universal was similar to that of the reference group. This finding is probably influenced by the positive impact of Ringloc liners (beginning 1995) on results of the Bi-Metric/Press-Fit Universal. Unfortunately, it is not possible to analyse the survival rate of the Press-Fit Universal cups with Hexloc liners separately from the Ringloc liners in the Finnish Register data. Revision risk of the Bi-Metric/Vision for any reason was similar to that of the cemented reference group (Table 27, Figure 11). However, survival rates at 10-years of the Vision cup with Ringloc liners and plugged screw-holes are not yet available.

10.2.1.3.2 The Anatomic Mesh/Harris-Galante II

Survival rates at 10 years ranging from 96 to 99 per cent have been reported for the Harris-Galante II cup (Archibeck et al. 2001, Firestone et al. 2007, Surdam et al. 2007,) and 100 per cent survival rates for the Anatomic stem (Archibeck et al. 2001), respectively. In study III, the survival rate for aseptic loosening of the Anatomic Mesh/Harris-Galante II at 15 years did not differ from that of the cemented reference group. Nonetheless, the survival rate for any reason of the Anatomic Mesh/HG-II at 15 years was poor. Again, this finding can be attributed to wear-related factors. The Anatomic Mesh/Harris-Galante II is no longer being implanted into patients in Finland.

10.2.1.3.3 The PCA prosthesis

Mid- to long-term survival rates ranging from 91 to 97 per cent of the PCA Standard stem have previously been reported (Thanner et al. 1999, Xenos et al. 1999, Bojescul et al. 2003, Moskal et al. 2004, Kim 2005). The 15-year survival rate of the PCA Standard stem in study III was comparable to that reported earlier, but lower than those of the best-performing stems. Survival rates ranging from 85 to 94 per cent for seven to 13 years (Malchau et al. 1997, Thanner et al. 1999, Xenos et al. 1999, Moskal et al. 2004) and from 79 to 83 per cent for 15 to 20 years (Bojescul et al. 2003, Kim 2005) have been published for the PCA Pegged cup with high revision rates associated with osteolysis. In the current study, the survival rate of the PCA Pegged cup at 15 years was poor. The PCA Standard/PCA Pegged prosthesis is no longer being implanted into patients in Finland.

10.2.1.3.4 The ABG prosthesis

Survival rates of the ABG I/ABG I arthroplasty have been reported to range from 92 to 100 per cent between two to 13 years (Giannikas et al. 2002, Herrera et al. 2004, Oosterbos et al. 2004, Castoldi et al. 2007), though the incidence of polyethylene wear is alarming (Duffy et al. 2004). In study III, the survival rate for any reason of the ABG I/ABG I at 10 years was lower than that of the reference group. However, the survival rate of the ABG I stem at 10 years for aseptic loosening was higher than that of the reference group. For this reason and because of the poor liners of the ABG I cup design, in Finland the ABG I stem has been widely used along with the ABG II cup with plugged screw-holes and thicker Duration liners consisting of stabilised polyethylene (Stryker, Mahwah, NJ). In our study, the risk of revision for any reason of the ABG I/ABG II in patients aged 65 to 74 was lower than that of the reference group when all revisions were taken into account. However, survival rates of the ABG I/ABG II at 10 years are not yet available. Survivorship of modular cementless cups may dramatically worsen after seven to 10 years of follow-up due to excessive wear and osteolysis, as indicated by the beyond seven year survival analysis of study III. Thus, it is too early to draw any reliable conclusions about the long-term success of this hip implant.

The ABG II stem differs from the ABG I stem with regard to its composition of titanium alloy, stem geometry, macrotexture, conus size and an option for zirkonia heads (ABG II Cement Free Hip System). The risk of revision for any reason of the ABG II/ABG II was higher than that of the reference group. The mean follow-up time of the ABG II/ABG II design was short, only 2.5 years (Table 9). The proportion of periprothetic fractures of all revisions for the ABG II/ABG II was high, at 37 per cent (Table 11). This finding is in accordance with clinical experience in Finland. The ABG II stem seems to be vulnerable to perioperative periprothetic femoral fractures due to its anatomical and conical shape. There were only three aseptic loosenings of the ABG II stem found during the study period (Table 11). The problem with an early aseptic loosening of a cementless stem is that there may not have been any osteointegration at all at the beginning due to undersizing or other technical failure. Therefore, strictly speaking any associated loosening could not have happened either. A longer follow-up time is needed to see, whether either the ABG I/ABG II or the ABG II/ABG II provide a long-term solution to the wear problem. Only a few zirkonia head or liner fractures have been reported in Finland (Table 11).

10.2.1.3.5 Patients aged 75 years or older

In study III the survival rates for patients aged 75 years and older were similar between cementless implants and the cemented reference group, except that the PCA Pegged cup had an increased risk of revision compared to the cemented reference group. This is in accordance with results of study I. However, in another recent report from the Finnish Arthroplasty Register (Ogino et al. 2008) it was concluded that hybrid fixation (a cemented stem with a cementless cup) was significantly better than cementless fixation in patients 80 years of age and older. In study I, we concluded that the survival of the hybrid total hip for any reason for patients aged 75 years and older was not significantly different from that of cemented or cementless groups. Even so, we think that these two findings on hybrid hip implantations in elderly patients based on data from the Finnish Arthroplasty Register are not contradictory. In the study by Ogino et al., 100 stems and 101 cups were used in 393 combinations. The most commonly used stems were the Exeter Universal and the Lubinus SP II and the most commonly used cups were the Lubinus STD, the Exeter

All-Poly and the Exeter Contemporary, all of which are cemented implants. The cementless designs were not specified. In contrast, in study I we analysed survival rates of implant groups consisting of designs that had been used in more than 50 operations during the study period. Implants associated with well-documented poor results and implants that did not belong to any of the groups of interest were excluded from that study. Thus, the data analysed in those two studies were remarkably different. In register-based studies it is extremely important to scrutinize closely the inclusion and exclusion criteria. In the current study, survival rates of the eight most common total hip replacements in elderly patients in Finland were analysed separately. However, the number of cementless implants in patients aged 75 years and older is low compared to the number of cemented implants. Therefore, one should be careful in drawing conclusions from such low numbers.

10.2.2 HOSPITAL DISCHARGE REGISTER-BASED STUDIES (IV AND V)

10.2.2.1 Regional variation in THA rates

In Denmark the ratio for variation in THA was 1.4 between counties (Pedersen et al. 2005). The ratio of the highest to lowest regional rate for THAs was 4.7-fold in the Medicare population in the USA (Birkmeyer et al. 1998). In England, the rate of THA implantation varied between 25 to 30 per cent (Dixon et al. 2006). In a previous study on data obtained from the Finnish Hospital Discharge Register, the variation in the incidence of THA was threefold (Keskimäki et al. 1994). The 1.9- to threefold difference in the incidence of THA in study IV was lower than that reported previously from Finland but higher than those reported for other European countries.

10.2.2.2 Variables associated with regional variation of THA

10.2.2.2.1 Surgeon density and population density

In study IV, variations in relative orthopaedic surgeon or anesthesiologist numbers were not associated with THA incidence rates. Results from previous studies of surgeon or population densities have been contradictory (Peterson et al. 1992, Pedersen et al. 2005, Dixon et al. 2006). Despite the sparsely distributed population in Finland, the population density or the average distance of the inhabitants to the nearest hospital providing THAs were not associated with any regional variation in the current study. However, the incidence of THA in Helsinki was low. Accordingly, the incidence rate has also been reported to be low in other large cities including London, Copenhagen, Stockholm, Gothenburg and Malmö (Söderman et al. 2000, Pedersen et al. 2005, Dixon et al. 2006). THAs are most often performed on the elderly. Good infrastructure with services and efficient public transport systems may help elderly patients to manage for longer in these very large cities. However, the data in study IV was age adjusted accordingly. It is also likely that occupational needs are different in urban areas and that one can manage for longer without a THA in urban than if one lived in a rural area.

10.2.2.2.2 The ratio of primary THA for primary OA to primary THA for any reason

In contrast to our findings, the proportion of patients with primary OA in Denmark was not associated with the variation in the THA rate (Pedersen et al. 2005). It is important to note that no regional variation in the prevalence of clinical hip OA between different parts of Finland has been shown to exist (Heliövaara et al. 1993a, Baseline results of the Health 2000 examination survey). In Finland there are 20 hospital districts responsible for the management of hip surgery. However, in study IV the data are given for 21 hospital districts, not 20. This is because of its size Helsinki and its greater metropolitan area, Uusimaa, were counted as two and presented separately. The effect of the surgeon enthusiasm as an explanatory factor for area variation in arthroplasty (Chassin 1993, Wright et al. 1999) may become significant, if there are only a few surgeons responsible for performing THAs.

10.2.2.2.3 The need-adjusted expenses of specialized care

It has been estimated that the relative need of services has remained quite stable between the municipalities and regions in Finland over the period from 1993 to 2004 (Hujanen et al. 2006). The difference in the need-adjusted expenses ratio between the most and the least expensive municipality has been reported to be 2.5-fold (Hujanen et al. 2006). The need-adjusted expenses of specialized care have increased rapidly in the beginning of this century. Therefore, we wanted to find whether these increasing expenses were associated with the variation of regional THA incidence. In study IV, the high need-adjusted expenses of specialized care of a district were significantly associated with a high incidence of THAs. More money per capita "than needed" is spent in specialized care in districts where need-adjusted expenses are high. It is likely that some of this money is used to perform a high rate of THAs. When there are numerous small districts investing variable amounts in different forms of care, the risk of high regional variation of treatments would be expected to increase.

10.2.2.2.4 Proportion of working-aged patients having permanent disability pension because of orthopedic disorders

A high proportion of patients aged between 18 and 64 years who have permanent disability pension because of orthopaedic disorders was associated with a lower incidence of THA. It is likely that those with a permanent disability pension also have multiple orthopaedic disorders. Consequently, the willingness to perform a THA on such individuals is less, than it is for those with a single orthopaedic disorder, as the expected benefit from the procedure *per se* is also less.

10.2.2.2.5 Relative number of long-term illnesses

Similar to our findings in study IV, Dixon et al. (2006) found that the number of limiting long-term illnesses and standardized mortality rates in a region providing THAs were not associated with the actual incidence of THAs in that region. A limitation of the morbidity-index used in study IV is that it was not possible to divide it into parts.

10.2.2.2.6 Socio-economic status

An association between incidences of THA and socio-economic status was found in both England and in Finland (Keskimäki et al. 1996, Dixon et al. 2004, Milner et al. 2004). In more recent studies, however, this association has not been detected (Pedersen et al. 2005, Dixon et al. 2006). In study IV, the average incomes in a hospital district were not correlated with the incidence of THA. However, socio-economic status of the patient has been associated with arthroplasty rates in USA (Mahomed et al. 2003, Skinner et al. 2003). We are not aware of any reports of this subject from developing countries, but one might assume that such an association would be strong in these countries. We think that our results can influence THA rates emanating from developed countries by stating that socio-economic status of the patient does not limit patients access to THA. In developing countries and developed countries with large heterogenous populations socio-economic factors are probably of very high importance.

10.2.2.3 The association of hospital volume with results of THA

10.2.2.3.1 LOS and costs

In study V, very high hospital volume was associated not only with shorter surgical treatment periods but also with shorter uninterrupted institutional care. If all THRs during the study period were performed in the very high volume hospitals in Finland, 743 euros/953 US dollars per patient could have been saved. However, when the post-operative care is made more effective, the easiest and cheapest days are dropped off, not the most demanding days, which include the first post-operative day and the discharge day. Costs will not be reduced, if the turnover of hospital wards does not increase and/or the number of personal decrease. In the near future in Finland, the baby boom generation, born in the late 40's and early 50's, will retire. Because of the demographically aging population and decreasing numbers of nurses, more patients will have to be treated in the future with the same levels of resources as that allocated today by optimizing activities and also the use of assets.

10.2.2.3.2 Unscheduled re-admissions

In study V, the rate of re-admissions in the low volume hospitals was lower than in all other hospital groups. When the LOS is longer, early problems manifest in the hospital and are treated immediately *in situ,* thus re-admissions are less likely to occur than in shorter stay facilities. The costs of re-admissions were low compared to the costs of longer LOS.

10.2.2.3.3 Dislocations

In study V, the low volume hospitals had significantly higher dislocation rates than the high volume hospital groups. However, the dislocation rate of the very highest volume hospital (group 4) was not lower than that of the low volume hospitals (group 1). Very high volume hospitals are mainly university hospitals with junior surgeons performing replacements as part of their training. Furthermore, not all conditions such as obesity and alcoholism or the condition of the bone and soft tissues can be adjusted and it is likely that even after adjustments there are more demanding patients to be found in university hospitals that would have an adverse effect on dislocation rates. On the other hand, only a few surgeons may also have an impact on the results of a high volume unit when encountering problems with rare complications. Thus the importance of recording surgeon volume besides hospital volume is obvious.

The number of private hospitals in the low volume hospitals (Group 1) was high (Table 14). The high dislocation rate in these low volume hospitals is worrisome, because THAs in small private hospitals are performed by specialists only. To the best of our knowledge, the current study is the first in which the association between high dislocation rates and low volume hospitals consisting of considerable numbers of small private hospitals has been found and reported.

10.2.2.3.4 Infections

Nowadays, deep prosthetic infections after THR are rare and the capability of population-based studies to determine significant differences between hospitals is limited. In study V, patient age, gender, surgical and medical diagnoses factors were adjusted. Thus, it was not surprising that there was no association found between the infection rate and hospital volume.

10.2.2.3.5 Re-operations

Because the follow-up time in study V was short, it was assumed that many re-operations were performed because of infections and instability. Early dislocations after THR are most often treated by closed reduction, which were analysed separately. Open reductions and revision operations as treatments for dislocated hip prosthesis are rare. The influence of open reductions and early revisions on the re-operation rate between hospital volume groups, if any, was not detected in study V. It seems that the variations in outcome of THAs are more closely linked to surgeon volume than to hospital volume, whereas the use of resources (costs) is more closely related to hospital volume.

11. CONCLUSIONS

1. For patients who were 55 years of age and older, the long-term survival of cementless total hip replacements was as good as that of cemented replacements. For patients who were 55 to 74 years old, straight porous-coated cementless stems had better long-term survival than the cemented stems. For patients who were 75 years of age and older, there were no significant differences in the results. Multiple wear-related revisions of the cementless cups indicate that excessive polyethylene wear was a major clinical problem with modular cementless cups for all age groups.

2. There were considerable differences in the long-term survival of cemented stems in patients aged 55 years and older on a nation-wide level. The Exeter Universal/ Exeter All-poly had the best long-term outcomes of cemented replacements in Finland. However, none of the cemented prostheses provided the youngest age group of patients with excellent long-term survival. All cemented designs produced a reliable outcome in patients older than 74 years.

3. Cementless proximal porous-coated stems are a good option for patients aged 55 years and older. Even though biological fixation of the prosthesis is a reliable implantation method for THA, polyethylene wear and osteolysis remain a serious problem for cementless cups.

4. When hip surgery was performed on with a large repertoire, the indications to perform THAs due to primary OA were tight. Socio-economic status of the patient had no apparent effect on the THA rate.

5. The specialization of hip replacements in high volume hospitals should reduce costs by significantly shortening the length of stay, and may reduce the dislocation rate.

Personal Conclusions

Cementless fixation is more durable against aseptic loosening than cement fixation in THA patiets aged 55 years and older. Alternative bearings like ceramic-on-ceramic, metal-on-metal and highly cross-linked polyethylene bearings may help to reduce osteolysis and wear. However, for a single patient each re-operation – including a liner-exchange - is a major incident. Therefore, revisions for all reasons should be emphasized in survival analyses. Surgeon decision-making related factors influence THA rates when there were only a few surgeons responsible for performing THAs in a particular region. According to the existing known literature, elective THAs should be performed at high volume centres in order to reduce mortality and complication rates.

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