Cemented revision hip arthroplasty.

A multicenter 5–9-year study of 204 first revisions for loosening

Christer N. Strömberg[1], Peter Herberts[1] and Bo Palmertz[2]

In a prospective study of total hip replacements in Sweden, the epidemiology of all the reoperations has been documented since 1979. From this nationwide register, the results of initial revision arthroplasty for aseptic loosening were evaluated in a well-described patient population, aged 55 to 70 years at the time of revision. Totally, 202 patients (204 hips) were available for clinical and radiographic analysis. The average follow-up time was 7 years. A rerevision or radiographically loose components occurred in 38 percent of the hips. The survival rate, with rerevision as the end point, was 75 percent at 8 years. We concluded that the initial revision on still active patients, using previous cementing techniques, provided poor results with a high risk of mechanical loosening and rerevisions.

The results of this study, obtained in a well-described patient population, can be contemplated as a baseline that provides an opportunity for valid comparisons of new techniques.

University of Gothenburg Departments of [1]Orthopedics, Sahlgren Hospital, and [2]Radiology, East Hospital, Gothenburg, Sweden
Tel +46-31 601000. Fax +46-31 602630
Submitted 91-10-03. Accepted 92-02-03

Multicenter clinical trials have an important role in the assessment of total joint arthroplasty (Herberts et al. 1989). In Sweden, failure after total hip arthroplasty has been recorded prospectively since 1979 (Ahnfelt et al. 1990). Medical records from every reoperation have been documented and analyzed by computer. Aseptic loosening has emerged as the main problem; it has caused 74 percent of all the revisions.

Until it is proven otherwise, it must be assumed that the younger the patient is undergoing arthroplasty, the more likely an exchange will be required despite the use of good surgical technique, prosthetic design, and implant material. Patients with failed cemented total hip arthroplasties develop minor-to-massive bone loss. Because of this and because of the change in character of the remaining bone, the cement-microinterlock necessary for long-term stability is lost. Shear strength at the bone-cement interface is reduced (Dohmae et al. 1988), leading to deterioration of results in the course of time. Only a few series have reported on the long-term results after cemented revisions in active and middle-aged patients. Further, most reports have originated from hospitals that are highly specialized in revision surgery (Pellici et al. 1985, Turner et al. 1987, Rubash and Harris 1988, Engelbrecht et al. 1990).

The aim of our study was 1) to analyze the long-term clinical and radiographic results achieved nationwide in Sweden after initial revision THA using cement, and 2) to provide a baseline, obtained in a well-described patient population, providing the opportunity for valid comparisons of new techniques.

Patients and methods

Of all the initial revisions performed in Sweden between 1979 and 1982, 254 hips in 252 patients met the following criteria: aged 55 to 70 years at the time of revision, there were no rheumatoid arthropathies, the index procedure was a cemented THA, the reason for revision was aseptic loosening including fracture of the prosthesis and femoral fracture, and the revision was performed with one of the six most frequently used prostheses during that time period (Table 1).

Table 1. Types of prostheses used in revision arthroplasty

Lubinus	94
Charnley	60
Brunswik	20
Charnley-Müller	15
Müller	9
Stanmore	6
Total	204

43 patients subsequently died, and 7 patients were lost for follow-up; all 7 of these latter patients were contacted, but they were unable or unwilling to be radiographed at the time of the final evaluation. The remaining 202 patients (75 women and 127 men), with 204 revised hips, were included in this study. The mean follow-up time was 7 (5–9) years. The mean age at the primary THA was 59 (48–68) years and at the revision 64 (55–70) years. The mean time between the initial arthroplasty and the revision was 5 (0.2–13) years.

The diagnoses for which the primary arthroplasty was performed were primary arthrosis in 175 hips, failed hip fracture in 18, congenital dislocation in 5, pediatric hip disorders in 5, and osteonecrosis in 1 hip. In 55 hips, one or more previous operations had been performed before the primary arthroplasty: 21 hips had been subjected to femoral osteotomy, 11 to insertion of an uncemented hemi-endoprosthesis, 4 to an arthrodesis, and 19 to internal fixation of a fracture.

The revisions were performed in 35 hospitals, distributed throughout Sweden. The mean number of revisions per hospital was 6 (1–19). The number of surgeons was not coded. The Lubinus and the Charnley prostheses were used in the majority of the cases: respectively 94 and 60 (Table 1). A long stem was used in half of the cases. In 129 hips (59 percent) both components were revised, in eight (4 percent) the acetabular component, and 75 (37 percent) the femoral component only. A trochanteric osteotomy was performed in 68 hips (33 percent). A high-viscosity cement with gentamycin was used in all the cases, but contemporary techniques of bone preparation and cementation were not used.

Clinical evaluation

Clinical information was obtained by a questionnaire that was sent to the patients. Using the D'Aubigné and Postel grading system as modified by Charnley (1979), each patient was assigned a pain and walking score based on a 6-point scale. In addition, the questionnaire included information about hip function, hip motion, ability to put on shoes and stockings, activity level, and the patient category according to Charnley (1979). In all, 193 patients were classified as regards patient category. Fifty-eight patients were Category A (unilateral hip disease), 19 were Category B (bilateral hip disease), 71 were Category BB (bilateral hip disease, previously operated on one side), and 45 were Category C (disease other than the hip function impairing the function of walking).

Radiographic analysis

Radiographs made at the local hospitals were sent to us for review; all of them were evaluated by two of the authors (C. S. and B. P.). Anteroposterior and lateral projections of the hips were obtained in each patient. Anteroposterior views of the pelvis, when available, were also used for the analysis. Radiographic assessment of femoral and acetabular bone stock was made on the radiographs taken immediately before the revision, and the deficiencies were classified into four types according to Gustilo and Pasternak (1988; Figure 1). In 182 hips the radiographs permitted classification of the prerevision bony defects. On the femoral side, 142 were Type I, 34 Type II, 6 Type III, and none Type IV. For the acetabulum, 137 hips were Type I, 30 Type II, 12 Type III, and 3 Type IV.

Radiographic loosening was evaluated by comparing the postoperative radiographs with those taken at 1 year and at the final follow-up examination. As proposed by Harris (1982, 1987), the acetabular and femoral components were considered *definitely* loose if migration could be demonstrated (≥ 5 mm in this study). There was *probable* loosening in those components surrounded by a continuous, progressive, radiolucent line (≥ 2 mm for the acetabular components in our present study; Harris et al. 1982, Harris and Penenberg 1987).

Because of the multicenter character of this study, the radiographs were of varying quality. The degree of rotation of the femur and the pelvis, as well as the magnification, was taken into consideration. All the measurements were corrected for magnification by multiplication by the true diameter of the prosthetic head and division by the measured diameter. Rotational differences of the pelvis were assessed by comparing the configuration of the obturator foramina and the pelvic inlet. The shape of the minor trochanter was used to compare rotation of the femur. Only almost identical radiographs were compared. However, lack of radiographic standardization, notably varying exposure and rotation of the hip, unavoidably introduced a source of error into our analysis. Therefore, 5 mm was regarded as the lower limit for migration (Nunn et al. 1989). Heterotopic ossification was graded according to Brooker et al. (1973).

Surgical and technical parameters evaluated radiographically (Table 3) were surgical approach, stem length, position of the acetabular and the femoral component, acetabular roof bony coverage, and cementing technique. Cementing technique was estimated to be adequate if the prosthetic component was surrounded by a homogeneous, at least 2-mm-thick, cement layer.

Statistics

We used Fischer's exact test, a semi-trend test, and a test for trend in the contingency table. Survival curves with respect to revision were constructed, and hazard function was estimated as described by Kaplan and Meier (1958). All the calculations were made with rerevision as the end-point definition of failure.

Results

78 hips (38 percent) were rerevised or showed definite, probable loosenings (Tables 2 and 3). Taking both the clinical and radiographic results into account, 107 hips (52 percent) were radiographically loose *or* rerevised *and/or* painful.

Adequate cementing was found in 45 percent of the acetabular components, and in only 17 percent of the femoral components. 162 hips (79 percent) had either no or only Class I heterotopic ossification. 13 hips (6 percent) had Class IV ossification. There were 24/63 trochanteric nonunions.

Table 2. Results after first revision in 204 patients 55–70 years old, with a minimum of 5-year follow-up

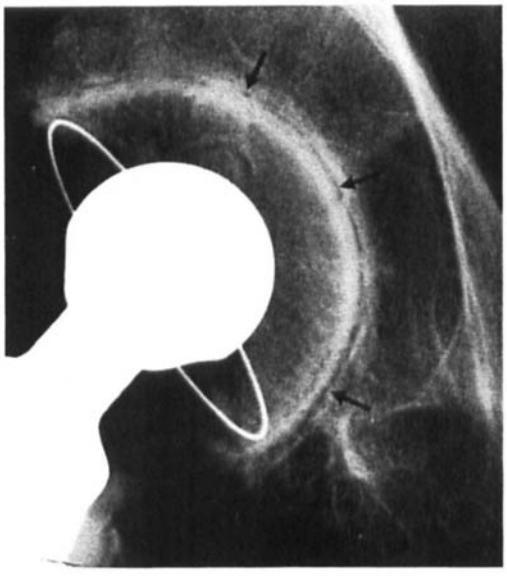
	No. of hips	No. rerevised
Definite or probable loosening		
Acetabular	13	2
Femoral	52	18
Both	4	3
Other causes for rerevision	9	9
Pain without rerevision or loosening	29	
No complications	97	
Total	204	32

Mechanical loosening

Definite or probable loosening was found radiographically in 69 hips with 13 acetabular, 52 femoral, and 4 with both components. Two loosenings occurred in combination with a femoral fracture. 23 hips have been rerevised (Tables 2 and 3). Acetabular radiolucencies were very common, especially in zone I; there were only 10 cases without demarcation.

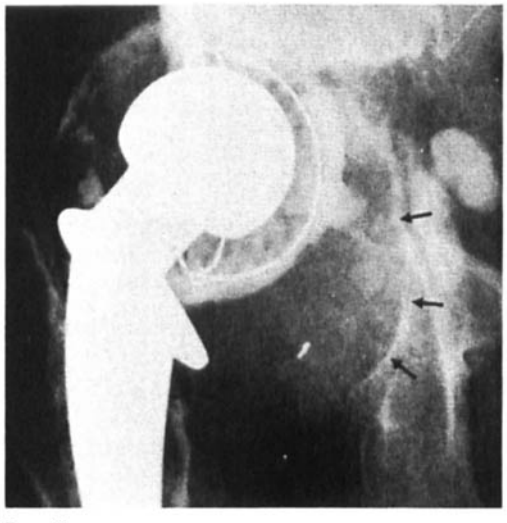
Table 3. Radiographic observations in revised hip arthroplasties

Femoral component	
Stem length (n 193)	
Standard	96
Long stem	97
Position (n 193)	
Neutral	118
Varus	27
Valgus	48
Trochanteric osteotomy	
Yes	63
Bony union	39
Cementing technique (n 204)	
Acceptable	34
Nonacceptable	170
Prerevision defects (n 182)	
Type I	142
Type II	34
Type III	6
Type IV	0
Ectopic ossification (n 86)	
Brooker I	44
Brooker II	13
Brooker III	16
Brooker IV	13
Definite radiographic loosening (n 48)	
Subsidence	38
Cement fracture	10
Osteolysis	26
Prosthesis-cement radiolucency ≥ 2 mm	25
Radiolucency complete and ≥ 2 mm	4
Radiolucency complete	20
Radiolucency 50–100 percent	17
Probable loosening (n 8)	
Osteolysis	4
Radiolucency complete	8
Acetabular component	
Inclination of socket (n 150)	
35–60 degrees	117
> 60 degrees	20
< 35 degrees	13
Location of center of rotation too high	
(> 15mm above teardrop)	21
Poor bone coverage	37
Protrusion	37
Cementing technique (n 204)	
Acceptable	92
Nonacceptable	112
Prerevision defects (n 182)	
Type I	137
Type II	30
Type III	12
Type IV	3
Definite loosening (n 17)	
Migration	17
Radiolucency complete and ≥ 2 mm	3
Probable loosening (n 0)	



Type I

Type II



Type III

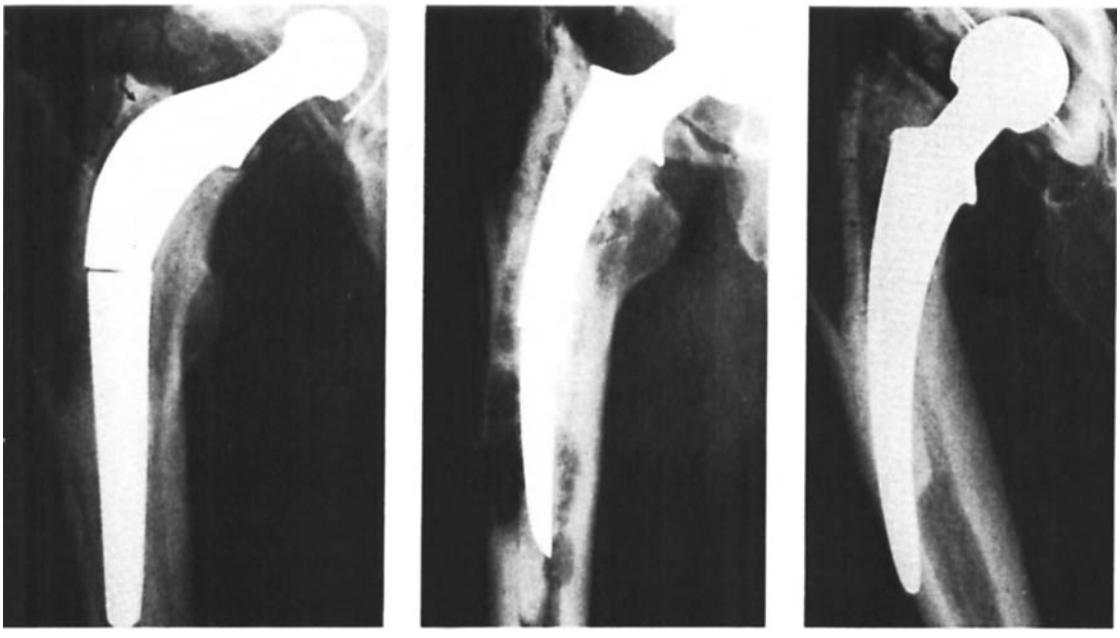
Type IV

The loosening rate was higher for the acetabular component in the hips with obvious prerevision bony defects as compared with hips with only minor bone loss ($P < 0001$; Figure 3). No such relationship was found for the femoral side, where, on the other hand, very few Type III defects were present.

Clinical, surgical, and technical parameters, as well as the orthopedic departments participating in this study, were compared for definite, probable loose hips and hips without such radiographic signs of loosening. No significant differences were found.

Rerevisions

The overall rerevision rate for the entire series was 16 percent (32 hips). 23 hips were definitely or probably loose. An additional 9 hips were rerevised for another reason. According to the case records and operative reports, 3 hips have been rerevised because of mechanical loosening, but radiographically these hips did not fulfill our radiographic criteria for loosening. Further, rerevision was done because of recurrent dislocation in 2 hips, femoral fracture in 1 hip, and a deep infection in 3 hips. At the final follow-up evaluation of



Type I Type II Type III

Figure 1. Classification of bone-stock loss according Gustilo and Pasternak (1988).

Type I. Minimal enlargement of the acetabular wall and loosening at the cement-prosthesis interface. Femoral bone loss, with minimal endosteal or inner cortical bone bone loss, i.e., loosening from the cement-metal-bone interface or a broken stem.

Type II. Acetabular bone loss with marked enlargement and thinning of the acetabular wall (but no wall defect) and loosening at the cement-bone interface. Proximal femoral canal enlargement with cortical thinning of 50 percent or more, and sometimes there is a lateral wall defect with an intact circumferential wall. The most important difference between Types I and II acetabular and femoral deficiencies are the loss of almost all the trabecular bone in Type II.

Type III. Acetabular bone loss with local quadrant wall defects: viz., anterior, posterior, superior, or central. On the femoral side, posteromedial wall defects involve the lesser trochanter indicating instability.

Type IV. Massive and global collapse involving two or more acetabular walls, and total proximal circumferential loss varying distances below the lesser trochanter. No Type IV femoral bone defect was found in this material.

these rerevised hips, 4 subsequently underwent a Girdlestone procedure, 4 were radiographically loose, and 5 hips had radiographic signs indicating a risk of loosening in the future. In all, 8/32 hips failed rapidly after the second revision.

Survival analysis

Rerevision was the definition of failure. The survival rate was 91 percent after 5 years and 75 percent after 8 years (Figure 2). No difference in prosthetic survival was found between the male and the female patients.

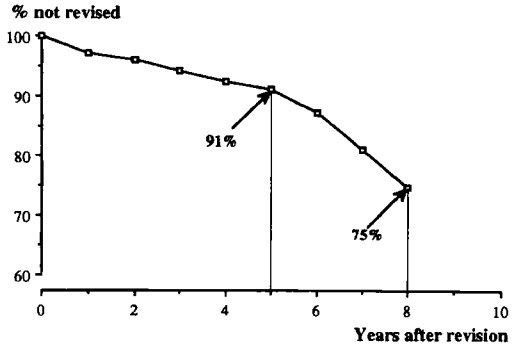


Figure 2. Survival rate with rerevision as end point and definition of failure.

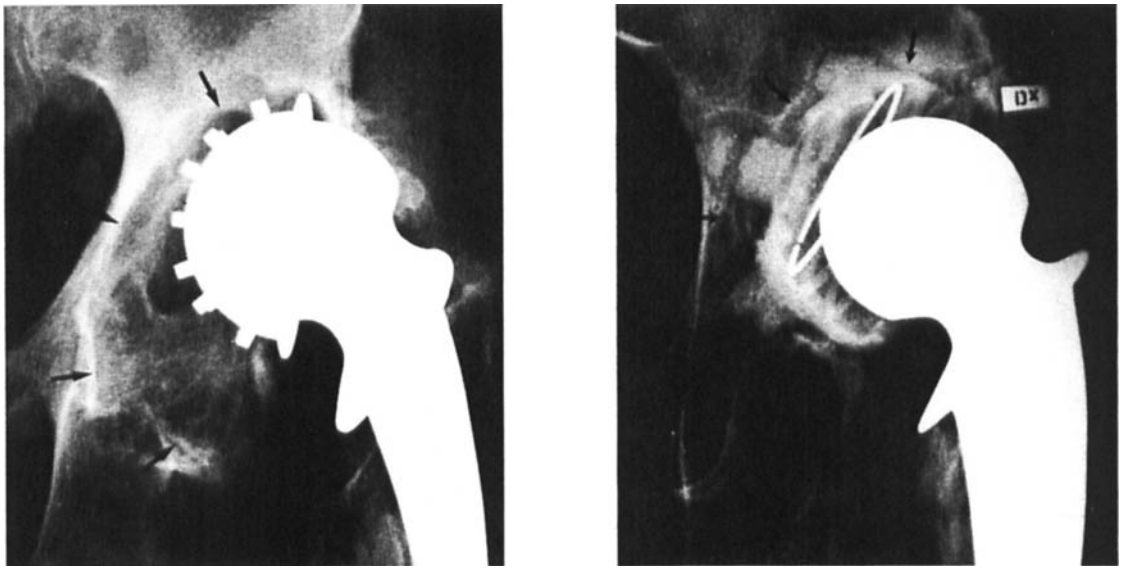


Figure 3. There is an increased risk for mechanical loosening of the acetabular component following revision of the hip to the left (Type III) compared with the right hip (Type II). The left AP radiograph shows a defective superior wall, probably requiring a bone graft. In the right radiograph, there is marked enlargement and thinning of the acetabular wall, but no wall defect. The lateral projections, not shown here, did not reveal any wall defects.

Clinical results

The various clinical parameters were filled in by 190 to 198 patients. The clinical results were evaluated separately for Charnley Category A patients (n 58), and the corresponding figures are given in parenthesis after the overall result.

71 (73) percent lived a semi-sedentary life and were able to perform light daily chores, such as yard work and light housekeeping. 2 (0) percent were confined to a wheelchair and 10 (7) percent were sedentary. 17 (20) percent lived an active life, with moderate manual labor, walks, or dancing. No patients were engaged in vigorous sports activities or performed heavy manual labor.

39 (25) percent of the patients were bedridden or were limited as regards the distance that they could walk with or without canes. 41 (57) percent were able to walk long distances with or without canes, and of these 81 patients, 41 walked normally. Approximately 40 (50) percent of the patients felt that they had good motion in the operated on hip, and had no difficulty putting on their shoes and stockings.

Pain was graded as none or slight in 74 (82) percent of the patients, corresponding to pain scores of 4, 5, or 6. Patients assessed hip function as excellent in 18 (32) percent, good in 29 (27) percent, fair in 42 (36) percent, and poor in 11 (5) percent.

Complications

32 patients (16 percent) had peroperative or immediate postoperative local complications: 7 had dislocations, 3 had deep infections, 10 had superficial infections, 4 had femoral fractures, 5 had penetrations of the femoral shaft, 1 had loosening of the cup, and 2 patients had profuse bleedings.

Systemic complications were found in 17 (8 percent) patients: 5 had urinary retention, 2 urinary infection, 3 deep vein thrombosis, 4 pulmonary embolism, 1 pneumonia, 1 gastric ulcer with melena, and 1 urticaria.

Discussion

Only a few revision series have reported on long-term results, and most reported series were obtained from hospitals that were highly specialized in revision surgery (Table 4). Pellici et al. (1985), in a later follow-up on their 110 hips, reported a 29 percent failure rate with 19 percent rerevisions after an average of 8 years. Turner et al. (1987) reported 12 percent failures with 5 percent rerevisions after an average of 7 years using a long-stem femoral component. Rubash and Harris (1988) had 12 percent failures with 2 percent

Table 4. Previous reports on long-term results after revision hip arthroplasty

Author	No. of hips	Average age at the revision	Follow-up time (years)	Observed failure (mechanical loosening, infections, technical errors)	Rerevised
Pellici et al. (1985)	99	64	8	29	19
Turner et al. (1987)[a]	139	62	7	17	7
Rubash and Harris(1988)[a]	43	57	6	5	1
Marti et al. (1990)	60	71	9	32	6
Engelbrecht et al. (1990)	138	59	7	43 stems, 53 cups	17/193
This report	204	64	7	78	32

[a] Femoral components reviewed.

rerevisions an average of 6 years after the revision of loose femoral components with modern cementing technique. Marti et al. (1990) in their series of relatively old patients, reported 53 percent failures after 9 years with 10 percent rerevisions. Engelbrecht et al. (1990) had 9 percent rerevisions after an average of 7 years.

When evaluating a multicenter material, distance may preclude direct examination at the time of follow-up, and sometimes detailed information after discharge from the hospital is difficult to obtain. However, as pointed out by Galante (1985), a questionnaire or telephone contact can provide fairly accurate answers to most of the items on the evaluation form. Clinical assessment of the hips in this series demonstrate inferior results, particularly when compared with long-term results after primary THA (Older 1986, Wejkner and Stenport 1988). Depending on the proportion of different Charnley categories in the studies, various clinical results and rating scores can be expected. It is especially important to report separately the results of patient Category A, which shows the true result of hip surgery without associated factors influencing the clinical assessment. This study showed a slightly better result in Category A when compared with the overall results.

Femoral component loosening occurred four times more often than that of the acetabular component (52/13). With current knowledge after 7 years' follow-up, this was an expected ratio. Good cementation was difficult to achieve, reflected in this study as inadequate cementation on the radiograph for 83 percent of the femoral components and for 55 percent of the acetabular components. Cementation on the acetabular side was difficult to evaluate radiographically, and probably this figure was underestimated; radiolucent lines were very common on the acetabular side, probably representing indirect signs of poor technique.

No statistical relationship was found for radiographic signs of loosening and pain, which was in agreement with other authors (Kavanagh et al. 1985, Ejstedt and Olsen 1987).

There is a need to report and classify bony defects. During the last few years, several classifications of bony defects have been proposed (Engh et al. 1988, Gustilo and Pasternak 1988, Chandler and Penenberg 1989). We have found the classification of Gustilo and Pasterank (1988) the most useful classifications just in that a sophisticated radiographic examination can be dispensed with. Bone loss influences the type of reconstructive surgery to be undertaken; and according to the results in this study, acetabular components with obvious prerevision bony defects had a higher loosening rate as compared with those with only minor bone loss. Contrary to the findings of Turner et al. (1987), no such relation was found for the femoral component. Engelbrecht et al. (1990), in their series on cemented revisions, found that the extent of bone damage to the acetabulum substantially influenced the radiographic results. The reason for the better results in Type I bony defects, where trabecular bone still exists, is, of course, the ability to achieve a microinterlock during the recementing procedure. It is unfortunate that reviews of the results of revision have not, to date, used a common standard classification of bone stock loss.

When planning a revision, careful consideration should be made of the possible need of further revision. In the presence of marked bone destruction, it seems that attempts to restore bone stock should be made at the time of revision; the situation must be looked upon as healing problems in fracture treatment with bone loss. It therefore seems logical that an uncemented prosthesis is the correct option. Midterm results after cementless revision have been promising (Gustilo and Pasternak 1988, Harris et al. 1988), but there is insufficient evidence to conclude that uncemented revisions perform better than cemented ones. Recent reports on the results after primary THA using modern cementing techniques have demonstrated

marked improvement in the longevity of fixation of the femoral component (Roberts et al. 1986, Russotti et al. 1988). However, there are few data at this time to show that modern cementing techniques improve the results of revision surgery in a manner similar to that for primary THAs (Rubash and Harris 1988).

At the present time, our indications for revision are symptomatic fixation failure, or, in the absence of symptoms, ongoing bone-stock loss together with the radiographic appearance of definite loosening. As pointed out by Hofman et al. (1989), the increased rate of femoral medullary canal expansion after the onset of symptoms demonstrates the need for early surgical intervention to avoid excessive bone loss.

The rapid evolution of total hip arthroplasty, with new expensive designs and methods of fixation, necessitates a continuous registration and a close scientific evaluation. The Swedish multicenter clinical trial has recorded all the reoperations after failed THAs since January 1979, and has thus created a unique computer-based data bank for further evaluation of the results of revision surgery. This series constitutes all the revisions in Sweden fulfilling our criteria. It reflects the results achieved nationwide in Sweden, in all the 35 hospitals distributed throughout the country, which is probably a more correct estimate of the outcome after revision, performed by the average orthopedic surgeon.

Our study has clearly shown that initial revision surgery in patients 55–70 years of age has failed in Sweden when previous cementing techniques have been used. These results can be looked upon as a baseline obtained on a well-described patient population giving the opportunity for valid comparisons of new techniques.

Acknowledgements

The authors wish to thank all the participating orthopedic surgeons; their help has been essential for this study.

The Swedish National Study for Registration of Total Hip Arthroplasties was financially supported by the Federation of County Councils.

Further financial support was obtained from The Greta and Einar Askers Stiftelse, The Gun and Bertil Stohnes Stiftelser, The Konung Gustav V:s 80-årsfond, The Konrad and Helfrid Johanssons Foundation, The Gothenburg Medical Society, The Swedish Society of Medicine, and The University of Gothenburg.

References

Ahnfelt L, Herberts P, Malchau H, Andersson G B. Prognosis of total hip replacement. A Swedish multicenter study of 4,664 revisions. *Acta Orthop Scand* (Suppl 238) 1990; 61: 1–26.

Brooker A F, Bowerman J W, Robinson R A, Riley L H Jr. Ectopic ossification following total hip replacement. Incidence and a method of classification. *J Bone Joint Surg* (Am) 1973; 55 (8): 1629–32.

Chandler H, Penenberg B. *Acetabular reconstruction. In: Bone stock deficiency in total hip replacement. Classification and management.* SLACK incorporated 1989: 47–102.

Charnley J. Numerical gradings of clinical results. In: *Low friction arthroplasty of the hip: Theory and practice* (Ed, Chandley, J) Springer Verlag, Berlin 1979: 20–4.

Dohmae Y, Bechtold J E, Sherman R E, Puno R M, Gustilo R B. Reduction in cement-bone interface shear strength between primary and revision arthroplasty. *Clin Orthop* 1988; 236: 214–20.

Ejsted R, Olsen N J. Revision of failed total hip arthroplasty. *J Bone Joint Surg* (Br) 1987; 69 (1): 57–60.

Engh C A, Glassman A H, Griffin W L, Mayer J G. Results of cementless revision for failed cemented total hip arthroplasty. *Clin Orthop* 1988; 235: 91–110.

Engelbrecht D J, Weber F A, Sweet M B, Jakim I. Long-term results of revision total hip arthroplasty. *J Bone Joint Surg* (Br) 1990; 72 (1): 41–5.

Galante J. The need for a standardized system for evaluating results of total hip surgery (editorial). *J Bone Joint Surg* (Am) 1985; 67 (4): 511–2.

Gustilo R B, Pasternak H S. Revision total hip arthroplasty with titanium ingrowth prosthesis and bone grafting for failed cemented femoral component loosening. *Clin Orthop* 1988; 235: 111–9.

Harris W H, McCarthy J C Jr, O Neill D A. Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg* (Am) 1982; 64 (7): 1063–7.

Harris W H, Penenberg B L. Further follow-up on socket fixation using a metal backed acetabular component for total hip replacement. A minimum ten-year follow-up study. *J Bone Joint Surg* (Am) 1987; 69 (8): 1140–3.

Harris W H, Krushell R J, Galante J O. Results of cementless revisions of total hip arthroplasties using the Harris-Galante prosthesis. *Clin Orthop* 1988; 235: 120–6.

Herberts P, Ahnfelt L, Malchau H, Stromberg C, Andersson G B. Multicenter clinical trials and their value in assessing total joint arthroplasty. *Clin Orthop* 1989; 249: 48–55.

Hofmann A A, Wyatt R W, France E P, Bigler G T, Daniels A U, Hess W E. Endosteal bone loss after total hip arthroplasty. *Clin Orthop* 1989; 245: 138–44.

Kaplan E L, Meier P. Nonparametric estimation from incomplete observations. *Amer Stat Assn J* 1958; 53: 457–81.

Kavanagh B F, Ilstrup D M, Fitzgerald R H Jr. Revision total hip arthroplasty. *J Bone Joint Surg* (Am) 1985; 67 (4): 517–26.

Marti R K, Schüller H M, Besselaar P P, Vanfrank Haasnoot E L. Results of revision of hip arthroplasty with cement. A five to fourteen-year follow-up study. *J Bone Joint Surg* (Am) 1990; 72 (3): 346–54.

Nunn D, Freeman M A, Hill P F, Evans S J. The measurement of migration of the acetabular component of hip prostheses. *J Bone Joint Surg* (Br) 1989; 71 (4): 629–31.

Older J. Low friction arthroplasty of the hip. A 10–12 year follow up study. *Clin Orthop* 1986; 211: 36–42.

Pellicci P M, Wilson P D Jr, Sledge C B, Salvati E A, Ranawat C S, Poss R, Callaghan J J. Long-term results of revision total hip replacement. A follow-up report. *J Bone Joint Surg* (Am) 1985; 67 (4): 513–6.

Russotti G M, Coventry M B, Stauffer R N. Cemented total hip arthroplasty with contemporary techniques. A five-year minimum follow-up study. *Clin Orthop* 1988; 235: 141–7.

Roberts D W, Poss R, Kelley K. Radiographic comparison of cementing techniques in total hip arthroplasty. *J Arthroplasty* 1986; 1 (4): 241–7.

Rubash H E, Harris W H. Revision of nonseptic, loose, cemented femoral components using modern cementing techniques. *J Arthroplasty* 1988; 3 (3): 241–8.

Turner R H, Mattingly D A, Scheller A. Femoral revision total hip arthroplasty using a long stem femoral component. Clinical and radiographic analysis. *J Arthroplasty* 1987; 2 (3): 247–58.

Wejkner B, Stenport J. Charnley total hip arthroplasty. A ten to 14-year follow-up study. *Clin Orthop* 1988; 231: 113–9.