Radiographic risk signs for loosening after cemented THA

61 loose stems and 23 loose sockets compared with 42 controls

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

The 1-year radiographs in 61 stems and 23 sockets, later revised because of aseptic loosening, were carefully examined for changes such as 1) separation of the lateral side of the stem from the cement, 2) radiolucent zones at the bone-cement interface, 3) fracture of the cement, 4) endosteal cavitation and 5) migration. They were compared with 42 clinically and radiographically successful primary total hip arthroplasties with 12–16 years follow-up. We found an increased risk of loosening in hips where radiolucencies appeared within the first postoperative year, whereas an unchanged radiographic appearance after 1 year strongly indicated that the risk of later loosening was small.

Patients at risk should be followed indefinitely to detect progressive loosening and concomitant bone resorption in time.

Departments of [1]Orthopedics, Institute of Surgical Sciences, Göteborg University, Sahlgrenska University Hospital, and [2]Radiology, East Hospital, Göteborg, Sweden. Correspondance: Dr. C.N. Strömberg, Department of Orthopedics, Uddevalla Hospital, S-451 80 Uddevalla, Sweden. Tel +46 522-92000. Fax +46 522-93360
Submitted 94-12-30. Accepted 95-09-17

It is important to perform revision hip arthroplasty while there is still some good bonestock (Gustilo and Pasternak 1988, Strömberg et al. 1992). Regular radiographic follow-up is the only way to detect ongoing bone loss in time, because progressive bone destruction may be asymptomatic (Charnley 1979, Carlsson and Gentz 1980, Stauffer 1982, Strömberg et al. 1988). If hips at risk for loosening could be identified early on conventional radiographs, then our radiographic resources could be concentrated on these cases. A previous study by Pacheco et al. (1988) showed that early demarcation of the distal cement and fracture of the cement near the tip of the stem were associated with later loosening.

We evaluated early radiographic risk factors for subsequent loosening of the stem and socket.

Patients and methods

All reoperations after total hip arthroplasty performed in Sweden have been recorded prospectively since 1979 (Ahnfelt et al. 1990, Malchau et al. 1993). In a previous study, the results of initial revision arthroplasty for aseptic loosening were evaluated in 202 patients (Strömberg et al. 1992). Most patients were primarily operated on because of primary arthrosis. Inflammatory arthropathies were excluded. All primary total hip arthroplasties (THA) were performed with first-generation cementing techniques. We used this material about revisions to assess radiographic risk factors for mechanical loosening, following a primary cemented THA. We compared the 1-year radiographs of the hips that were later revised for aseptic loosening (Harris et al. 1982, Harris and Penenburg 1987, Hodgkinson et al. 1988) with a group of 42 clinically and radiographically successful primary THAs with a long follow-up (12–16 years) operated on at our own institution.

61 stems and 23 sockets from the revision series had adequate radiographs following the primary THA in accordance with our requirements for the radiographic analysis (Table 1).

The mean time between the primary THA and the 61 stem revisions was 5 (2–11) years. There were 42 men and 19 women. Average age at the time of the primary surgery was 60 (49–68) years.

The mean time between the primary THA and the 23 socket revisions was 5 (2–12) years. There were 13 men and 10 women. Average age at the time of the primary surgery was 62 (55–68) years.

Between 1973 and 1977, a total of 95 primary Charnley low-friction arthroplasties (90 patients) were performed at Sahlgrenska Hospital, Gothenburg. The diagnosis was in most cases primary arthrosis. 53 unrevised THAs were available for

Table 1. Prostheses used at the primary arthroplasty in the revision series

	Sockets n 23	Stems n 61
Brunswik	5	17
Charnley	1	21
Charnley-Müller	2	13
Christiansen	8	2
Lubinus	2	3
Müller	1	2
Stanmore	–	2
McKee-Farrar	3	1
McKee-Arden	1	–

clinical and radiographic follow-ups. 42 hips in 42 patients had a clinically and radiographically successful outcome and comprised the control group in this study. There were 8 men and 34 women. Average age at the time of the primary surgery was 63 (39–77) years, with a mean follow-up period of 14 (12–16) years.

Radiographic analysis

The radiographs in the revision series fulfilled our requirements for this analysis, if films of good quality following the primary THA were available postoperatively, after 1 year and at follow-up (prior to revision in the revision series). The same film standards were required for the control series.

The postoperative films were compared with those taken at 1 year and at the time of follow-up. An anteroposterior and true lateral radiograph were available for each assessment and, in most cases, also a pelvic anteroposterior radiograph. The degrees of rotation of the femur and the pelvis were taken into account. Correction was made and only comparable radiographs were evaluated. Vertical migration of the cup was estimated by measuring the vertical distance from the center of the cup to a line drawn through the bottom of each teardrop contour. Horizontal migration of the cup was estimated by measuring the horizontal distance along this line, from the base of the teardrop to the perpendicular line dropped from the center of the cup (Massin et al. 1989). When pelvic anteroposterior radiographs were missing, we used instead a line perpendicular to Kohler's line and passing through the tip of the teardrop as reference. (Strömberg et al. 1988). The lines were drawn with a lead pencil, the measurements were made with a ruler and correction was made for magnification. Rotation of the cup ≥ 10 degrees on the pelvic AP films was also regarded as migration.

Readily identifiable points such as the tip of the trochanter, the lesser trochanter and trochanteric wires were used as references for measuring migration of the stem (Loudon and Charnley 1980).

Cups and stems were considered loose if signs of migration were found or if they were surrounded by a continuous, progressive radiolucent line ≥ 1 mm. These criteria for loosening are in accordance with the definition of loosening proposed by Harris and Hodgkinson (Harris et al. 1982, Hodgkinson et al. 1988). We had margins for what we classified as component migration (Sutherland et al. 1982, Nunn et al. 1989); only migration greater than 5 mm was considered (Sutherland et al. 1982).

We measured the location and extent of radiolucencies, using the 7 femoral zones of Gruen et al. (1979) and the 3 acetabular zones of DeLee and Charnley (1976).

The 1-year radiographs were compared with the postoperative films and examined for further changes such as 1) separation of the lateral side of the stem from the cement, 2) radiolucent zones at the bone-cement interface, 3) fracture of the cement, 4) endosteal cavitation (Carlsson 1980) and 5) migration.

Intra- and interobserver measurements

In order to elucidate the intra- and interobserver errors in early radiographic changes (1–4), the 1-year radiographs in 15 patients were evaluated. The radiographs were analyzed with an interval of 1 week by two experienced observers. For these discrete variables—i.e., variables assuming a few values only—the proportion of cases with coinciding results from the two observers was determined.

There was no difference between the two observers with respect to the evaluation of 1) separation of the lateral side of the stem from the cement, 2) radiolucent zones at the bone-cement interface, 3) fracture of the cement and 4) endosteal cavitation. The proportion of cases with coinciding results was 93–100% for one observer and 73–100% for two observers.

Statistics

Comparisons of proportions were performed by Fischers's exact test. Two-tailed tests were used. The test for trend in the contingency table was used to take advantage of the order structure of the variables studied.

Results

An unchanged radiographic appearance after 1 year, was commoner on the femoral and acetabular sides among the successful hips with a long follow-up

Table 2. The radiographic appearance at one year of 61 stems subsequently revised for stem loosening compared with 42 clinically and radiographically successful stems with 12–16 years follow-up

Radiographic appearances at 1 year	61 stems revised for loosening	42 successful stems	P-value
Unchanged	13	40	<0.001
Separation of stem from cement	30	2	<0.001
Demarcation bone-cement, zone			
I	21	1	<0.001
II	8	0	0.03
III	9	0	0.01
IV	13	1	0.009
V	12	0	0.002
VI	9	0	0.01
VII	10	0	0.008
Tip of the cement (III, IV, V)	34	0	<0.001
Progressive demarcation in percent of the cement-bone interface			
≤ 25	16	1	
26–50	5	0	
51–100	6	0	<0.001[a]
Fracture of cement, zone			
I	0	0	...
II	4	0	0.3
III	3	0	0.4
IV	0	0	...
V	5	0	0.1
VI	1	0	0.8
VII	1	0	0.8
Endosteal cavitation	6	0	0.08
Migration	0	0	...

[a] Test for trend in contingency table, all other comparisons made with Fischer's exact test.

Table 3. The radiographic appearance at one year of 23 sockets subsequently revised for loosening, compared with 42 clinically and radiographically successful sockets with 12–16 years follow-up

Radiographic appearances at 1 year	23 sockets revised for loosening	42 successful sockets	P-value
Unchanged	7	33	<0.001
Demarcation bone-cement, zone			
I	7	5	0.2
II	13	4	<0.001
III	9	6	0.05
Progressive demarcation in percent of the cement-bone interface			
≤ 25	1	2	
26–50	8	5	
51–100	9	2	<0.001[a]
Migration	0	0	...

[a] Test for trend in contingency table, all other comparisons made with Fischer's exact test.

compared to the failure group (Tables 2 and 3).

Radiographic risk factors for femoral loosening were separation of the proximal lateral side of the stem from the cement, any progressive cement-bone radiolucency, most evident in zone I and at the tip of the cement (Table 2).

Risk factors for loosening of the socket were any progressive cement-bone radiolucencies located in zone II and zone III (Table 3).

According to our definition, there was no implant migration on these early radiographs.

Discussion

Cemented total hip arthroplasties have been used for almost 30 years. In spite of this, we know little about the predictive value of early radiographic changes for future mechanical loosening.

In recent years, radiostereometry (RSA) has become a useful method for the evaluation of prosthetic component fixation (Mjöberg et al. 1986, Ryd 1986, Kärrholm 1989, Snorrason and Kärrholm 1990, Kärrholm and Snorrason 1993). RSA studies have indicated that early and continuous prosthetic migration, will eventually result in an increased rate of loosening of the prosthetic components (Ryd et al. 1993, Kärrholm et al. 1994). However, RSA is time-consuming, costly and specific equipment is needed.

Radiographic analysis using computers and digitizing systems have been reported to measure migration with high accuracy (Ilchmann et al. 1992). Still this is a time-consuming method, restricted for clinical research.

Traditional pencil and ruler estimates have been reported to be accurate within 5 mm (Sutherland et al. 1982). With standardized high quality radiographs expected limits for measurement of socket migration is ± 3 mm, according to Nunn et al. (1989), implying that plain radiography is an inferior method for detecting early migration. This is supported by the findings in our study. However, conventional radiography is an accepted and sensitive method for finding other indications of mechanical loosening (Gruen et al. 1979, Miniaci et al. 1990). Pacheco et al. (1988) in a retrospective review of 72 cases of Charnley low-friction arthroplasty revised for stem-loosening, identified early radiographic risk factors such as demarcation of the distal cement and fracture of the cement near the tip of the stem.

We found in our study that an unchanged radiographic appearance 1 year postoperatively meant that there was little risk of stem loosening in the future. However, in agreement with Pacheco et al. (1988) demarcation at the tip of the cement was recognized as an early risk sign of future mechanical failure. This is probably attributable to difficulties centralizing the distal stem and causing a thin cement mantle, with an obvious risk for cement fractures. Analogous to the findings of Carlsson and Gentz (1980), separation of the stem from cement proximally implied a risk of later loosening. These findings are further supported by the observations made by Jasty et al. (1990) and Schmalzried et al. (1992a). According to their theory, debonding of the cement-implant interface precedes clinical loosening of the femoral prosthesis and initiates the process of mechanical loosening.

The radiographic analysis of the socket similarly showed that an unchanged radiographic appearance 1 year after the primary arthroplasty implied little risk for later loosening. Important risk factors for loosening of the socket were any new cement-bone radiolucency located in Gruen zone II or III. Our results are in accordance with those of Hodgkinson et al. (1988), who pointed out that any radiolucent line that is new, progressive or not apparent on the initial radiographs should be regarded as important and assessed accordingly. In their study they found the 1-year radiograph to be useful in predicting the long-term result for the socket. 50% of sockets with complete demarcation on the 1-year radiograph had migrated by the time revision was undertaken.

Our findings indicate that conventional radiographic evaluation can be used to predict outcome after cemented total hip arthroplasty. Intra- and inter-observer errors for early radiographic changes were small. We consider new demarcations and separation of the stem from the cement proximally to be useful risk signs for mechanical failure. An unchanged radiographic appearance of stem-cement and bone-cement interfaces at 1 year, strongly indicates that the risk of later loosening is small and we regard that as the most important finding in this study. Our interpretation of that observation is that in these cases there is a stable metal-cement interface and a seal-off between bone and cement, with no access for wear particles that could initiate an inflammatory reaction, bone loss and loosening. The hip arthroplasties in this study, as well as those reported by Pacheco et al. (1988), were performed using first-generation cementing techniques. However, with the use of modern cementing techniques, improved prosthetic designs and materials, it might turn out, at least regarding the stem, that risk signs will appear on the radiographs more than 1 year postoperatively (Thanner et al. 1995). This reasoning is further supported by current knowledge of the process of loosening (Jasty et al. 1990, Schmalzried et al. 1992a, 1992b).

We suggest that an unchanged radiographic appearance after 1 year and a limited life expectancy of the patient indicate that there is no need for further radiographic follow-up, except in cases with clinical symptoms. However, a patient at risk should be followed indefinitely, to detect progressive loosening and/or concomitant bone resorption in time.

Such a policy would reduce the number of radiographic follow-ups of a steadily increasing number of total hip arthroplasties and make it possible to concentrate our resources on patients with a high risk of loosening and associated bone deficiencies, such as

revisions and young and more active patients (Chandler et al. 1981, White 1988, Dorr et al. 1994). These patients must be followed indefinitely on a time schedule that is partly based on the radiographic findings. Revision is a challenge, but the best chance to achieve a long lasting fixation is to detect mechanical loosening in good time and to perform a revision while the bonestock is still good (Herberts 1992, Strömberg et al. 1992).

Acknowledgements

This study was supported by 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 J. Prognosis of total hip replacement. A Swedish multicenter study of 4,664 revisions. Acta Orthop Scand (Suppl 238) 1990; 61.

Carlsson Å S. Mechanical failure of total hip replacement. Thesis. Malmö, Sweden 1980.

Carlsson Å S, Gentz C-F. Mechanical loosening of the femoral head prosthesis in the Charnley total hip arthroplasty. Clin Orthop 1980; 147: 262-70.

Chandler P H, Reineck F T, Wixson R L, McCarthy J C. Total hip replacement in patients younger than thirty years old. J Bone Joint Surg (Am) 1981; 63: 1426-34.

Charnley J. Low friction arthroplasty of the hip: Theory and practice. Springer-Verlag, Berlin 1979.

DeLee J G, Charnley J. Radiological demarcation of cemented sockets in total hip replacement. Clin Orthop 1976; 121: 20-32.

Dorr L D, Kane T J 3rd, Conaty J P. Long-term results of cemented total hip arthroplasty in patients 45 years old or younger. A 16-year follow-up study. J Arthroplasty 1994; 9: 453-6

Gruen T A, McNiece G M, Amstutz H C. "Modes of failure" of cemented stem-type femoral components. A radiographic analysis of loosening. Clin Orthop 1979; 141: 17-27.

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, Penenburg B L. Further follow-up on socket fixation with a metal-backed acetabular component for total hip replacement. A minimum ten-year follow-up study. J Bone Joint Surg (Am) 1987; 69: 1140-3.

Harris W H, McCarthy J C, O'Neill D A. Femoral component loosening using contemporary techniques of femoral cement fixation. J Bone Joint Surg (Am) 1982; 64: 1163-7.

Herberts P. Hip arthroplasty revision. Guest editorial. Acta Orthop Scand 1992; 63 (2): 109-10.

Hodgkinson J P, Shelley P, Wroblewski B M. The correlation between the roentgenographic appearance and operative findings at the bone-cement junction of the socket in Charnley low friction arthroplasties. Clin Orthop 1988; 228: 105-9.

Ilchmann T, Franzén H, Mjöberg B, Wingstrand H. Measurement accuracy in acetabular cup migration. A comparison of four radiological methods versus stereophotogrammetric analysis. J Arthroplasty 1992; 7: 121-7.

Jasty M, Maloney W J, Bragdon C R, Haire T, Harris W H. Histomorphological studies of the long-term skeletal responses to well fixed cemented femoral components. J Bone Joint Surg (Am) 1990; 72: 1220-9.

Kärrholm J. Roentgen stereophotogrammetry. Review of orthopedic applications. Acta Orthop Scand 1989; 60: 491-503.

Kärrholm J, Snorrason F. Subsidence, hump and tip micromovements of non-coated ribbed femoral prostheses. Clin Orthop 1993; 273: 50-60.

Kärrholm J, Borssén B, Löwenhielm G, Snorrason F. Does early micromotion of femoral stem prostheses matter? 4–7 year stereoradiographic follow-up of 84 cemented prostheses. J Bone Joint Surg (Br) 1994; 76: 912-7.

Loudon J R, Charnley J. Subsidence of the femoral prosthesis in total hip replacement in relation to the design of the stem. J Bone Joint Surg (Br) 1980; 62 (4): 450-3.

Malchau H, Herberts P, Ahnfelt L. Prognosis of total hip replacement in Sweden. Follow-up of 92,675 operations performed 1978–1990. Acta Orthop Scand 1993; 64: 497-506.

Massin P, Schmidt L, Engh C. Evaluation of cementless acetabular component migration. An experimental study. J Arthroplasty 1989; 4: 245-51.

Miniaci A, Bailey W H, Bourne R B, McLaren A C, Rorabeck C H. Analysis of radionuclide arthrograms, radiographic arthrograms and sequential plain radiographs in the assessment of painful hip arthroplasty. J Arthroplasty 1990; 5: 143-9.

Mjöberg B, Selvik G, Hansson L I, Rosenquist R, Önnerfelt R. Mechanical loosening of total hip prostheses: a radiographic and roentgen stereophotogrammetric study. J Bone Joint Surg (Br) 1986; 68: 770-4.

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

Pacheco V, Shelley P, Wroblewski B M. Mechanical loosening of the stem in Charnley arthroplasties. Identification of the "at risk" factors. J Bone Joint Surg (Br) 1988; 70: 596-9.

Ryd L. Micromotion in knee arthroplasty: a roentgen stereophotogrammetric analysis of tibial component fixation. Acta Orthop Scand (Suppl 220) 1986.

Ryd L, Albrektsson B E J, Carlsson L, Toksvig-Larsen S, Herberts P, Lindstrand A. On the clinical significance of micromotion of joint implants. 39th Annual Meeting, Orthopedic Research Society, San Francisco 1993.

Schmalzried T, Jasty M, Harris W H. Periprosthetic bone loss in total hip arthroplasty. Polyethylene wear debris and the concept of the effective joint space. J Bone Joint Surg (Am) 1992a; 74: 849-63.

Schmalzried T P, Kwong L M, Jasty M, Sedlacek R C, Haire T C, O'Conner D O, Bragdon C R, Kabo J M, Malcolm A J, Harris W H. The mechanism of loosening of cemented acetabular components in total hip arthroplasty. Analysis of specimens retrieved at autopsy. Clin Orthop 1992b; 274: 60-78.

Snorrason F, Kärrholm J. Early loosening of revision hip arthroplasty. A roentgen stereophotogrammetric analysis. J Arthroplasty 1990; 5: 217-29.

Strömberg C N, Herberts P, Ahnfelt L. Revision total hip arthroplasty in patients younger than 55 years old. J Arthroplasty 1988; 3: 47-59.

Strömberg C N, Herberts P, Palmertz B. Cemented revision hip arthroplasty. A multi-center 5–9 year study of 204 first revisions for loosening. Acta Orthop Scand 1992; 63: 111-9.

Stauffer R N. Ten-year follow-up study of total hip replacement, with particular reference to roentgenographic loosening of the components. J Bone Joint Surg (Am) 1982; 64: 983-90.

Sutherland C J, Wilde A H, Borden L S, Marks K E. A ten-year follow-up of one hundred consecutive Müller curved stem total hip replacement arthroplasties. J Bone Joint Surg (Am) 1982; 64: 970-82.

Thanner J, Freij-Larsson C, Kärrholm J, Malchau H, Wesslén B. Evaluation of Boneloc®. Chemical and mechanical properties, and a randomized clinical study of 30 total hip arthroplasties. Acta Orthop Scand 1995; 66: 207-14.

White S H. The fate of cemented total hip arthroplasty in young patients. Clin Orthop 1988; 231: 29-34.