

Loosening of the Charnley hip

Radiographic analysis of 102 revisions

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This retrospective study was based on 102 Charnley hip arthroplasties that underwent a revision operation. Radiographs of hips with loose prosthetic components were compared with those with firm components. Migration and tilting of the socket and subsidence and varus shift of the stem were associated with loosening.

Radiographic signs which have been considered to indicate loosening of total hip prostheses are frequently seen in patients without any clinical discomfort. Little is known about the long-term outcome of their hips. We have compared radiographic signs of prosthetic loosening with the findings at revision in 102 total hip prostheses.

Patients and methods

Patients

During the period 1970-1980, 107 Charnley hips were subjected to 120 revision operations at the orthopedic department in Falun. Of the 120 cases, 6 were excluded because the primary radiographs were not available and 2 because grouping according to our criteria for infection was not possible. The operative reports did not state whether 14 of the stems and 16 of the sockets were loose or firm. Thus, 98 stems and 96 sockets in 102 prosthetic hips remained for the investigation (Table 1). Sixty-five stems and 46 cups were found to be loose during the operation. The remaining firmly seated components, 33 stems and 50 sockets, served as controls in the radiographic evaluation. The mean age of the patients at the revision operation was 69 (43-86)

years, and 35 (3-126) months had elapsed since the insertion of the prosthesis. Fifty-six of the patients were men and 46 were women. The underlying diseases are summarized in Table 2. In 10 hips a prosthetic exchange operation had been performed once before and in one hip twice before.

Infection

Five aerobic and anaerobic swab cultures (Kamme and Lindberg 1981) were taken during the revision operations in 29 of the patients. The prosthesis was considered to be infected if three of the five cultures showed growth of the same bacteria with an identical pattern of resistance against antibiotics. Sinus formation in combination with pain on weight bearing was another criterion of infection. Forty-seven prostheses fulfilled these criteria of infection. Eight prostheses were considered to be noninfected, as all of the five cultures were negative. A further 19 were considered to be infected, since the erythrocyte sedimentation rate (ESR) exceeded 35 mm/h (Carlsson 1978) without any other plausible explanation. In the remaining 28 cases, the ESR did not exceed 35 mm/h, and these hips were thus considered to be noninfected. Altogether, 66 hips were found to be infected and 36 noninfected.

Operation

Information on whether the stems and sockets were loose or firmly attached was searched for retrospectively in the records from the revision operations. Only components that were clearly stated to be firm or loose were included in the study.

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Table 2. Primary hip disease. The sockets (A) and the stems (B) have been divided into four subgroups, which were compared with one another

Subgroup	Total		Primary arthrosis		Rheumatoid arthritis		Femoral neck fracture		Dysplasia		
	A	B	A	B	A	B	A	B	A	B	
Loose	not infected	6	26	5	23	1	3	0	0	0	0
	infected	40	39	33	33	1	0	4	4	2	2
Firm	not infected	26	8	24	7	2	1	0	0	0	0
	infected	24	25	17	18	1	2	5	4	1	1
All		96	98	79	81	5	6	9	8	3	3

Radiographic methods

As part of a prospective study of all of our arthroplasties, routine hip radiographs were obtained preoperatively, immediately after operation, and 1 year postoperatively. Frontal views of the pelvis, centered on the symphysis, were taken together with frontal views centered on the hip joint. The film-focus distance was 1 meter. The measurements were made directly on the films. When old films were compared with more recent ones, correction was made for variation of the magnification factor by comparing the stem length of the prosthesis. Radiopaque cement was not used routinely until 1975. The 56 stems and 54 sockets inserted with radiopaque cement did not differ from the entire material regarding the age or sex of the patients, the primary disease, or the frequency of prosthetic infection. In the whole material the revision was undertaken, on an average, 35 months after the primary total hip replacement. In the stems (with radiopaque cement), which were both loose and infected, the corresponding period was 16 months. The following radiographic signs associated with prosthetic loosening were recorded:

1. *Radiolucent zone at the stem.* The area around the stem was divided into seven sectors as described by Gruen et al. (1979). The width of the zone at the bone-cement interface was recorded at the widest site within each sector.

2. *Scalloping.* When irregularities or rounded bone defects appeared in connection with the cement-bone interface, the part exceeding the zone width was measured. These phenomena were regarded as scalloping if the width of this excess part exceeded 2 mm.

3. *Sclerosis.* Any sclerosis of the bone bordering the stem cement was recorded. It was often seen as just a hair-thin white line. Attention was paid to the fact that Mach effects might be mistaken for sclerosis (Lane et al. 1976).

4. *Periosteal reaction.* Lamellated bone formation outside the cortical bone was recorded as a periosteal reaction. The margin of the original cortex could usually be identified without difficulty.

5. *Thickening of the cortical bone.* The criteria for thickening were that the bone was not lamellated and that the original contour was undetectable. The femoral diameter had to be increased by at least 2 mm for such thickening to be considered present.

6. *Ectopic ossification* was recorded only if it was so profuse that it gave the impression of bony ankylosis on the AP films. This corresponds to Brooker's class 4 (Brooker et al. 1973).

7. *Subsidence* was defined as sinking of the stem down into the femoral canal observed on comparison of radiographs from the primary operation with the most recent ones before the revision operation. The distance of subsidence was measured from the tip of the stem to a reference point in the femur; the lesser trochanter or the cerclage wires were often selected for this purpose. The edge of the femoral neck stump was avoided, as it could become resorbed with time.

8. *Varus shift* was defined as an alteration of the stem alignment with the longitudinal axis of the femur between two different examinations.

9. *Cup zone.* A radiolucent zone that had appeared after the primary radiographs was measured at its widest spot at the cement-bone border (54 hips).

10. *Cup migration* (Figure 1) was defined as an increase in the perpendicular distance from a line drawn between the ischial tuberosity and the anterior inferior spine of the ilium to the cup (67 hips). In cases where the inferior spine was not prominent enough to serve as a reference point, the superior spine was chosen instead.

11. *Cup tilting* (Figure 1) was measured as a change in the projected angle between the opening of the cup and the line connecting the two ischial tuberosities (67 hips).

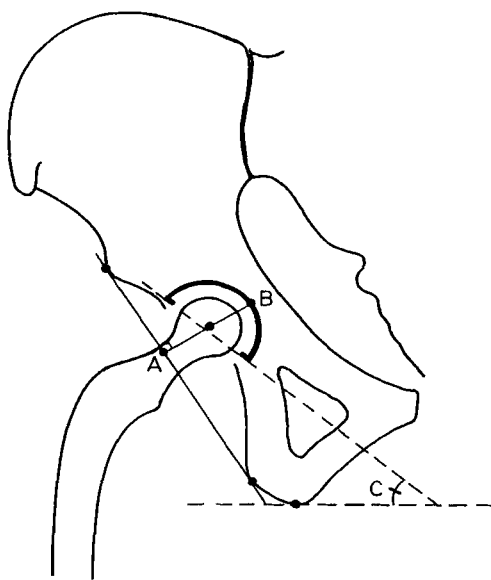


Figure 1. Cup migration is a change in the distance A-B between two examinations. Cup tilting is a change in the projected angle C between the socket opening and the ischial tuberosity line (dashed lines).

Methods of evaluation

On the basis of the clinical diagnosis of loosening and infection, the stems and the cups were divided into subgroups: namely, noninfected and infected loose prosthetic components and noninfected and infected firm components (Table 2). These subgroups were compared with one another in the statistical analysis. The infected hips were compared with noninfected ones to rule out infection as the cause of radiographic changes. Ten fractured stems were not included in the measurements of subsidence and varus shift. Measurement of changes in the position of the components demands standardized projections with adequate reference points on the films. Sixty-seven cups met these requirements for the investigation of tilting and migration, 78 stems for the investigation of varus shift, and 81 stems for the investigation of subsidence. The excluded hips had the same distribution among the primary diseases and among the above-mentioned subgroups as the entire material.

Our intention was to identify those radiographic signs that indicated that the prosthesis was physically loose, irrespective of whether it was infected or not. Chi-square analysis with Yates' correction and two-tailed *t*-tests were used for the statistical calculations. For the numerical variables an attempt was made to

find the division line between firm and loose stems that would fit this material optimally. This was done by chi-square analyses and estimation of the sensitivity and specificity. The sensitivity was expressed as true-positive/(true-positive + false-negative) observations. The specificity was expressed as true-negative/(true-negative + false-positive).

Results

1. *Radiolucent zone at the stem.* Twenty-six of the 35 loose stems and 12 of the 21 firmly attached ones had a radiolucent zone of at least 3 mm (NS). The sensitivity was 0.74 and the specificity 0.43. Four out of 35 loose prostheses did not have any radiolucent zone, and three loose prostheses had a zone that did not exceed 1 mm in width. No relationship was found between loosening and the width or site of the zone. There were only five noninfected firm stems in this material, and three of these had a zone of at least 3 mm.

2. *Scalloping* was seen in 34/65 loose stems and in 19/33 firm ones (NS). The sensitivity was 0.52 and the specificity 0.42.

3. *Sclerosis* was seen in 24/65 loose stems and in 3/33 firm ones ($P < 0.01$). The sensitivity was 0.37 and the specificity 0.91. Among the 24 loose stems with sclerosis, 18 were infected. Six of the 26 uninfected loose stems displayed sclerosis.

4. *A periosteal reaction* was seen in 22/65 loose stems and in 15/33 firm ones (NS). The sensitivity was 0.34 and the specificity 0.55.

5. *Thickening of the cortical bone* was seen in 35/65 loose stems and in 21/33 firm ones (NS). The sensitivity was 0.54 and the specificity 0.36.

6. *Ectopic ossification* was seen in 5/65 loose stems and in 2/33 firm ones (NS). The sensitivity was 0.08 and the specificity 0.94.

7. *Subsidence* of at least 2 mm was seen in 27/53 loose stems and in 4/28 firm ones ($P < 0.01$). The sensitivity was 0.51 and the specificity 0.86.

8. *Varus shift* of at least 2° was seen in 24/51 loose stems and in 4/27 firm ones ($P < 0.01$). The sensitivity was 0.47 and the specificity 0.85.

9. *Cup zone.* A radiolucent zone at the cup with a width of 2 mm or more was seen in 12/30 loose cups and in 4/24 firm ones (NS). The sensitivity was 0.40 and the specificity 0.83. None of the nine noninfected firm cups had a radiolucent zone reaching 2 mm. There were only three noninfected loose cups with radiopaque cement. A zone of at least 2 mm was seen in 12/27 infected loose cups and in 4/15 infected firm ones (NS).

10. Migration of the cup of 6 mm or more was seen in 12/34 loose cups and in 3/33 firm ones ($P < 0.05$). The sensitivity was 0.35 and the specificity 0.91.

11. Cup tilting of 2° or more was seen in 31/34 loose cups and in 14/33 firm ones ($P < 0.001$). The sensitivity was 0.91 and the specificity 0.58. Tilting of 4° or more was noted in 24 of the loose cups and in five of the firm ones ($P < 0.001$). The sensitivity was 0.71 and the specificity 0.85.

Discussion

The fact that there is often a considerable discrepancy between the reported frequency of loosening and the frequency of actually performed revisions in follow-up studies of total hip replacements (Stauffer 1982, Johnston and Crowningshield 1983, Paterson 1986) indicates that the criteria used to describe the materials have not been found appropriate as a basis for the decision as to whether a reoperation should be performed or not. During its lifetime a failed prosthetic component may undergo a continuous transition from being relatively firm, but still separated from the surrounding bone by a biological membrane (Fornazier and Cameron 1976, Linder and Hansson 1983, Jones and Hungerford 1987), to a state of micromotion and finally to macroscopic looseness. The aim of the present investigation was to study the radiographic appearance of prosthetic components that were judged to be firm or loose by the surgeon at a revision operation. The criteria arrived at for radiographic loosening do not necessarily give information on the optimal timing for any revision.

It is not easy to confirm the clinical impression of loosening of a component. Micromotion cannot be identified by the surgeon. Migration determined by roentgen stereophotogrammetry does not inevitably correspond to any detectable component instability (Mjöberg et al. 1985) nor to symptoms experienced by the patient (Chafetz et al. 1985). The approach in the present investigation puts one question into focus: How reliable are the observations made at surgery in a retrospective study? Loosening with only slight instability might have been overlooked. There is a possibility that firm components were described as loose in order to subconsciously justify the decision to reoperate. When one component was found to be loose, the second one might have been less carefully examined. If firm prosthetic components were erroneously judged to be loose and vice versa, there would be a risk that certain radiographic signs of loosening with a low sensitivity and specificity would escape detection. On the

other hand, such relatively nonspecific signs would probably not be the ones that are sought for. If the clinical diagnosis of loosening was incorrect in some cases, the values for sensitivity and specificity presented here will be too low.

There were only five noninfected, firmly seated stems, and we were not able to verify or rule out any relationship between loosening and a radiolucent zone at the stem by statistical analysis. Follow-up studies on consecutive series of primary total hip replacements have revealed such radiolucent zones in 10-60 percent within 11 years (Amstutz et al. 1976, Salvati et al. 1976, Cotterill et al. 1982, Johnston and Crowningshield 1983).

Some authors have suggested that *scalloping* might be a sign of loosening (Tehransadeh et al. 1981, Cotterill et al. 1982, Carlsson et al. 1983). Scalloping was often seen with firm prostheses, and it would be difficult to identify scalloping as a sign of loosening with the present design of the study.

Sclerosis was mainly observed around loose infected stems, and was less frequently encountered in stems that had become loose without infection. Cotterill et al. (1982) found sclerosis to be a sign of loosening, but Tapadiya et al. (1984) reported that sclerosis was equally common among loose and firm stems.

A periosteal reaction, thickening of the cortical bone, and ectopic ossification were not associated with loosening, confirming previous reports (Salvati et al. 1976, Schneider et al. 1982, Hierton et al. 1983, Gristina and Kolkin 1983, Lindberg and Carlsson 1983, Weissman 1983).

Subsidence has become one of the most important signs of loosening (Almby and Hierton 1982, Amstutz et al. 1982, Reikerås 1982, Salvati et al. 1982, Stauffer 1982, Carlsson et al. 1983, Johnston and Crowningshield 1983, Lindberg and Carlsson 1983, Alho et al. 1984). Loudon and Chamley (1980) estimated the mean error of the method in measuring subsidence to be 1.6 mm. Sutherland et al. (1982) consider more than 5 mm to be pathologic. In our material a subsidence of at least 2 mm showed a high specificity for loosening.

Varus shift, defined as a change in the stem alignment with the femur of at least 2° , was a reliable sign of loosening in our material. Other authors have recorded it as a zone between the metal and cement over the prosthetic shoulder (Carlsson et al. 1983, Lindberg and Carlsson 1983, Alho et al. 1984, Lyons et al. 1985). A varus shift of the stem together with the cement will not be detected in that way, however.

Cup zone. A radiolucent zone around the cup was not found to be related to loosening in our material. Zones of at least 1 mm have been found in 50-100 percent at follow-up studies 1-10 years after primary ar-

throplasties (Amstutz et al. 1976, DeLee and Charnley 1976, Salvati et al. 1976, Reckling et al. 1977, Salvati et al. 1981, Cotterill et al. 1982, Johnston and Crowninshield 1983, Alho et al. 1984). Expansion of the radiolucent zone has often been considered to indicate loosening, especially if it increases beyond 2 mm or is still progressive 6-12 months postoperatively (Lindberg 1978, Moreland et al. 1980, Harris 1982, Hierton et al. 1983, Lyons et al. 1985).

Migration. Cup migration of 6 mm or more was associated with loosening in this study. The incidence of migration at 10-year follow-up studies seems to be 2-23 percent (DeLee and Charnley 1976, Salvati et al. 1981, Almby and Hierton 1982, Sutherland et al. 1982, Johnston and Crowninshield 1983). Migration has often been used as a criterion of loosening (Reikerås 1982, Schneider et al. 1982, Stauffer 1982, Johnston and Crowninshield 1983, Lindberg and Carlsson 1983, Weissman 1983, Kavanagh and Fitzgerald 1985, Lyons et al. 1985). Reikerås (1982) and Sutherland et al. (1982) considered migration of 3 mm and 5 mm, re-

spectively, to indicate loosening.

Tilting of the cup was found to be a sensitive and easily measured variable. Some other authors have also mentioned tilting as a sign of loosening (Beabout 1975, Almby and Hierton 1982, Schneider et al. 1982, Stauffer 1982, Carlsson and Gentz 1984, Lyons et al. 1985). We concluded that to achieve an acceptable specificity only tilting of at least 4° should be considered pathologic. Lesser degrees of migration and tilting probably also indicate loosening, provided that the radiography projections can be strictly standardized.

Conclusions

Subsidence of at least 2 mm and varus shift of at least 2° were associated with stem loosening, and tilting of at least 4° and migration of at least 6 mm were associated with socket loosening in this study.

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