Acta orthop. scand. 52, 531–542, 1981

CLINICAL AND RADIOLOGICAL LONG-TERM RESULTS AFTER CHARNLEY-MÜLLER TOTAL HIP REPLACEMENT

A 5 to 10 Year Follow-up Study with Special Reference to Aseptic Loosening

SVEN S. OLSSON, ACKE JERNBERGER & DAGNY TRYGGÖ

Department of Orthopaedic Surgery, Central Hospital, Norrköping, Sweden

Ninety-nine per cent of the arthroplasties available for follow-up after a minimum of 5 years were assessed clinically and radiologically. Of the original 151 hips, 14 had been reoperated on with exchange of the femoral components because of aseptic loosening. Thirty-one of the 115 re-examined hips showed radiological evidence of femoral component loosening and in 15 hips loosening was suspected. One acetabular component was loose. No deep infection was detected. In 10 of the 31 hips with femoral stem loosening, no complication was suspected after clinical examination only. Varus position of the prosthesis and insufficient cement support at the proximal and distal parts of the stem were associated with increased loosening rates. In patients with a body-weight over 80 kg and in patients younger than 60 years at the operation, loosening had occurred in over 50 per cent of the hips. The clinical overall results were satisfactory, with 79 per cent of the hips being free from significant pain.

Key words: hip joint, surgery; joint prosthesis; osteoarthritis, surgery; postoperative complications

Accepted 12.ii.81

Follow-up studies with long observation periods (Beckenbaugh & Ilstrup 1978, Blacker & Charnley 1978) have shown that artificial hip joints can function for long periods of time with preservation of good mobility and freedom from pain. Wear of the implants does not seem to be a significant cause of clinical failure (Griffith et al. 1978) and the rate of delayed septic complications can be reduced to about 1 per cent (Carlsson et al. 1977). On the other hand, aseptic loosening of the implants is reported with increasing frequency as the follow-up times become longer. Thus, radiographic evidence of non-infected loosening has been reported in 17.8 per cent after 3 to 6 years' observation time by Hackenbroch et al. (1976), in 19.6 per cent by Maier et al. (1977), and 24 per cent by Beckenbaugh & Ilstrup (1978) after 4 to 7 years' observation. In a radiographic analysis of 389 total hip replacements, Gruen et al. (1979) found evidence of mechanical loosening in 19.5 per cent of the hips and Buchhorn et al. (1979) reported femoral component migration in 30 per cent of 285 Müller prostheses after 2 to 7 years. In a previous study of Charnley-Müller hip replacements with 2 to 7 years' observation time (Olsson et al. 1979) we found radiographic signs of implant loosening in a number of hips without significant clinical symptoms. In that study, radiographs were not made of all asymptomatic hips. To analyse the problem further, we have made a new assessment of all those arthroplasties that have reached a minimum of 5 years' observation time.

At the follow-up examinations, special attention has been paid to radiographic and clinical signs of implant loosening. We have searched for

0001-6470/81/050531-12 $02.50/0

Table 1. Sex distribution and age at operation

Age (years)	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	Total
Women	0	3	8	11	18	25	15	10	2	92
Men	1	0	5	9	10	18	10	6	0	59
Total	1	3	13	20	28	43	25	16	2	151

Numbers include data for both operations in patients operated bilaterally.

factors which can be responsible for the occurrence of loosening and also analysed the clinical findings associated with implant loosening in order to ascertain the reliability of clinical methods of examination for disclosing this complication.

PATIENTS AND METHODS

The operations were performed from August 1969 through March 1974. The observation period varied from 5 to 9.5 years with a mean of 5.9 years. There were 151 operated hips in 128 patients; 92 were women and 59 men. The youngest patient was 40 and the oldest 81 years old at the time of operation. The mean age was 65 years (Table 1). Fourteen hips had been reoperated on because of implant loosening less than 5 years after the original operation. One of these patients had a contralateral arthroplasty which is included in the study. Nineteen patients had died. Three of them were operated bilaterally; in one of these patients, one hip had been reviewed. Only one patient, severely disabled by rheumatoid arthritis, declined to appear for the follow-up examination. Thus, 115 hips in 96 patients were available for the study. In the sections that deal with preoperative data and early postoperative X-ray appearance, the 14 reoperated hips are included in the material. The preoperative diagnoses were primary osteoarthritis in 98 hips, rheumatoid arthritis in 12 hips and osteoarthritis secondary to fracture, CDH, slipped capital epiphysis or osteomyelitis in 19 hips. In 24 hips various operations had been performed prior to the replacement (Table 2).

Operative technique, postoperative regime, antibiotic prophylaxis and the methods of clinical assessment were the same as in the earlier report (Olsson et al. 1979). In the present study the pre- and postoperative radiograms of all hips were examined together with current radiograms, which included a–p and lateral views of the hip and a frontal projection of the pelvis with proximal parts of both femora. All measurements on the radiograms were corrected with regard to the magnification factors, determined on each film with the aid of the diameter of the head of the femoral prosthesis. Radiopaque cement had been used in all operations. All the clinical follow-up examinations were made by the same observer, who had not been personally involved in any of the operations, and they took place before the radiographic examinations.

Table 2. Previous operations

Osteosynthesis of hip fracture	7
Intertrochanteric osteotomy	5
Adductor tenotomy	4
Femoral head replacement	3
Arthrodesis	1
Epiphyseodesis	1
Acetabuloplasty	1
McKee-Farrar arthroplasty	1
Drainage of osteomyelitis	1
Total	24

The erythrocyte sedimentation rate was determined in all patients.

RESULTS

Complications

In the total number of 151 replacements the following complications have occurred:

One patient died of myocardial infarction on the twelfth day after the operation. Seven patients had thromboembolic complications, all treated successfully by anticoagulants. One hip dislocated postoperatively; it was treated by closed reduction and no recurrence of the dislocation has occurred. There was one peroperative femoral shaft fracture which was treated with a wire-loop and subsequently healed uneventfully. One patient, in whom an osteotomy of the greater trochanter was performed, developed an infection associated with the trochanteric cerclage 2 years later, and simultaneously had septic arthritis of the contralateral knee. The infection

healed after drainage and extraction of the cerclage.

We have not encountered any deep infection and in none of the hips has an excision arthroplasty been necessary.

Reoperations

At the time of the follow-up study, 14 hips had been reoperated on with exchange of the femoral component because of aseptic loosening. The time intervals from the original replacement operations varied from 7 months to 6 years and 8 months. The mean interval was 3 years and 6 months. The interval of 7 months was in a hip where the stem had penetrated the femoral cortex and loosened rapidly. None of the hips had been operated on prior to the original replacement operation. In none of the exchange procedures have we obtained bacterial growth from the joint or from the tissue samples taken from the immediate surroundings of the implant after its removal and before intravenous antibiotics were administered. The cultures were made on both aerobic and anaerobic media. The implants were all loose within their cement encasements, which were widened proximally, where longitudinal cracking and sometimes fragmentation had occurred on the medial aspect.

One of the loose femoral stems had fractured.

No acetabular component has been exchanged.

Radiographic signs of implant loosening

The material was divided into groups according to the findings recorded from the X-ray films taken at the 5-year follow-up.

Group I: Sixty-nine hips without any signs of loosening or change of position of the implants. Changes in the proximal femur without established relation to loosening will be described separately.

Group II: Fifteen hips with minor signs of deteriorated fixation or change of position of the femoral stem which we have treated separately as an "undecided" group as the significance of these signs has been considered uncertain. Proximal lateral separation between the metal stem and cement amounting to 2 mm was found in 6 hips and less than 2 mm in 5 hips. Distal migration of the femoral stem measuring 2 to 8 mm (mean 4 mm) was noted in 13 hips and 2 degrees or less of varus shift in 6 hips. Cystic resorptions of the medial cortex at the level of the lesser trochanter or calcar were present in 3 hips and in one the distal tip of the stem had eroded one-third of the posterolateral cortex.

Group III: Thirty-one hips with radiological evidence of femoral component loosening. The minimum requirements for a radiological diagnosis of loosening were selected to correspond to the minimum radiological signs of loosening noted in those hips in which the loosening had been verified at reoperation. In the 31 hips the following was noted:

Proximal lateral separation between the metal stem and the cement amounting to at least 3 mm (maximum 9, mean 4.5 mm) was present in 27 hips. In 3 of the remaining hips the separation measured only 1–2 mm but in addition distal migration of 13 and 19 mm, respectively, was present in two hips and a lateral cortical resorption and 11 mm of distal migration in one. In one hip the cement was completely surrounded by a radiolucent zone measuring 5 mm and the distal end had gradually penetrated the femoral cortex. This was the only hip in which the radiologically detectable loosening had taken place only between cement and bone.

In 9 hips the distal end of the stem had penetrated partially into the femoral cortex, creating cavities that were not present on the early postoperative radiograms. Distal displacement of the stem exceeding 2 mm (3 to 17 mm; mean 8 mm) had occurred in 28 of the 31 hips. In the remaining three the femoral components had shifted into accentuated varus positions without measurable subsidence. Varus shift measuring 2 to 6 degrees (mean 2.9 degrees) had also taken place in 18 of the 28 hips with distal displacement. Transverse fractures of the cement were detected in 7 hips and areas of circumscript resorption of the femoral cortex from its inner as-

pect in 8 hips, in addition to the 10 with partial or total distal tip penetration. These areas were located medially in the region of the lesser trochanter and the neck rest or laterally along the middle and distal parts of the stem.

Only one acetabular component showed evidence of loosening. The femoral component of that prosthesis was also loose.

Radiolucent zones exceeding 2 mm in width or surrounding the entire periphery of the acetabular cement, migration or altered orientation of the socket were not detected in any further arthroplasties. In two hips, rounded cyst-like lesions with a 10–15 mm diameter were observed adjacent to the cement in the former acetabular roof. They could be identified as subchondral degenerative cysts, which had been left intact at the operations and after that had increased in size.

Group IV is added in the study of factors, which may contribute to increased risk of loosening. It contains the 14 hips reoperated for aseptic femoral stem loosening before the follow-up examination.

To summarize, out of the total of 129 operated hips in patients still alive and available for follow-up, no less than 45 hips (35 per cent) showed radiographic evidence of implant loosening or had already been reoperated on for aseptic loosening, and in an additional 15 hips (12 per cent) loosening is suspected.

Clinical results

The clinical results with reference to pain, range of motion and ability to walk are shown for the whole series of 115 re-examined hips in Figures 1 to 3 and the results for the 69 radiologically normal hips in comparison with the 31 hips with evidence of loosening are shown separately in Figures 4 to 6. The numerical rating system advocated by Charnley (1972) was used.

Before operation, 76 per cent of the hips were in the lower three grades for pain. At the follow-up, 79 per cent of the hips were free from significant pain (grades 5–6). The average grade for pain was 2.7 before and 5.3 after the operation. As seen in Figure 1, seven hips were

PAIN

PREOP. \ FOLLOW UP	1	2	3	4	5	6	
1				1		10	11
2			5	6	6	20	37
3			5	4	15	25	49
4				2	3	12	17
5				1			1
6							
Grade	-	-	10	14	24	67	Sum

Figure 1. Numerical grading for pre- and postoperative pain in 115 total hip replacements. Grading system according to Charnley (1972).

RANGE OF MOTION

PREOP. \ FOLLOW UP	1	2	3	4	5	6	
1		1	2	10	4	2	19
2			1	7	8	3	19
3			1	10	13	11	35
4				6	18	11	35
5				1	4	2	7
6							-
Grade	-	1	4	34	47	29	Sum

Figure 2. Numerical grading for pre- and postoperative total range of motion in 115 total hip replacements. Grading system according to Charnley (1972).

unchanged and one worse with regard to pain at the follow-up. Four of these eight hips showed radiographic signs of implant loosening. However, the majority of hips with loosening were rated in grades 5 and 6, and one-third was completely pain-free (Figure 4).

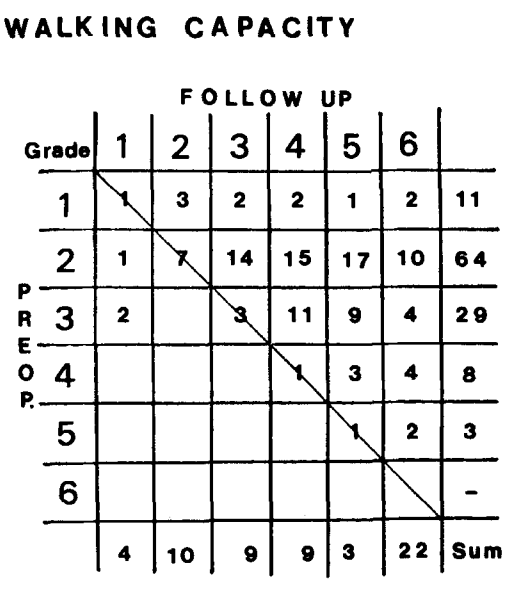

Figure 3. Numerical grading for pre- and postoperative walking ability in 115 total hip replacements. Grading system according to Charnley (1972).

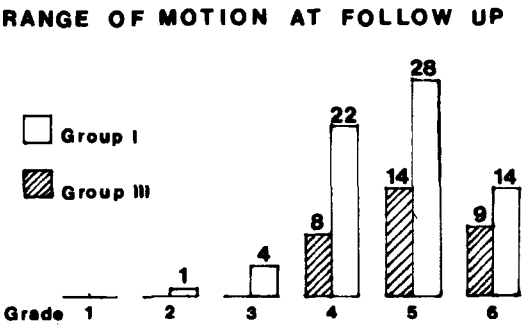

Figure 5. Numerical grading for total range of motion at follow-up in 69 total hip replacements with normal X-ray = Group I and 31 with implant loosening = Group III. Grading system according to Charnley (1972).

The range of motion is expressed as the sum of degrees of movement in all three standard directions (Figures 2 and 5). The range of motion had improved by at least two grades in 71 hips (62 per cent). In 11 hips motion had not changed beyond the limits of the grade and in one it had deteriorated. As seen in Figure 5, the pattern is quite uniform regardless of the presence of radiological evidence of loosening. A reference value for normal range of motion in patients with the same age distribution is provided by 43 contralateral asymptomatic hips in the re-examined patients. The mean range of motion was 220 degrees, which is just over the limit between grades 5 and 6. At the follow-up, 76 of the operated hips (66 per cent) were in grades 5 and 6.

For walking capacity, the preoperative ratings were in the upper three grades in only 11 hips (9.6 per cent), as compared to 82 hips (71 per cent) at the follow-up (Figure 3). As shown in Figure 6, assessment of walking capacity is of limited value for disclosing implant loosening. When the 115 re-examined hips are classified into categories A, B and C according to Charnley

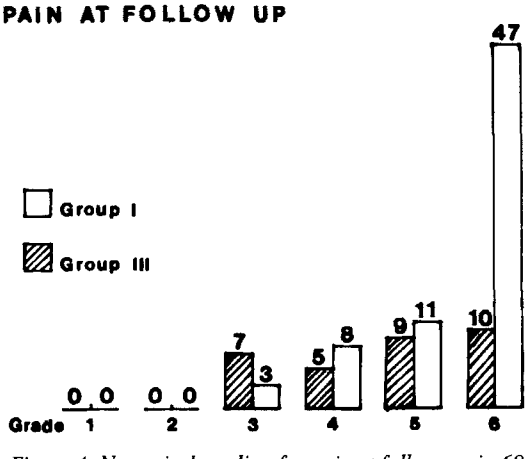

Figure 4. Numerical grading for pain at follow-up in 69 total hip replacements with normal X-ray = Group I and 31 with implant loosening = Group III. Grading system according to Charnley (1972).

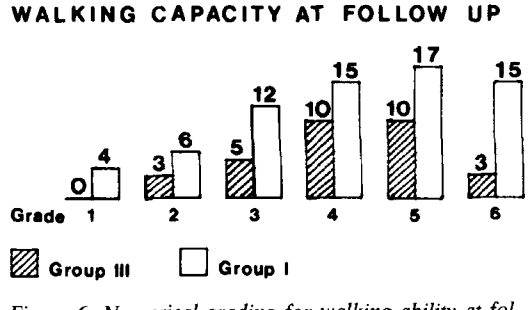

Figure 6. Numerical grading for walking ability at follow-up in 69 total hip replacements with normal X-ray = Group I and 31 with implant loosening = Group III. Grading system according to Charnley (1972).

(1972), where A and B denote unilateral and bilateral hip involvement, respectively, in otherwise healthy individuals and C the presence of an additional factor impairing walking, it is found that in only 13 hips was the operated joint the single restricting factor, whereas 34 hips belonged to category B and 68 to category C.

Trendelenburg's test had been carried out in 111 hips both pre- and postoperatively. In the whole series it was positive or questionable in 66 per cent of the hips before operation and in 27 per cent at the follow-up. Of the hips with normal radiograms 19 per cent (11/59) had a positive Trendelenburg's test and in those with loosening, it was positive in no less than 47 per cent (14/30). The difference is statistically significant ($P<0.01$). Active straight leg raising in the supine position was painful or impossible in 5 of the hips with a normal X-ray (7 per cent) and in 5 of the hips (16 per cent) with loosening.

Ten of the 31 hips with stem loosening could be classified as clinically normal with the following criteria: No pain (grade 6), range of movement more than 160 degrees (grade 5–6), walking capacity corresponding to grade 4 or better, painless active straight leg raising and a negative Trendelenburg's test.

Elevation of the erythrocyte sedimentation rate to more than 30 mm was found in 7 patients with a normal preoperative ESR. Four of these had rheumatoid arthritis and 3 had developed other diseases which could explain the raised ESR.

Risk factors with respect to loosening

Clinical and radiological features with known or suspected influence on loosening rate were studied, comparing group I (69 hips with normal X-ray at the 5-year follow-up) with group III and group IV (containing 31 hips with radiologic evidence of loosening and 14 hips reoperated for aseptic loosening prior to the follow-up). In Table 3, group II (15 hips with suspected loosening) is also included.

Age. The average age at the operation was 65.6 years in group I and 62.5 years in group III + IV. In 19 of the 37 hips (51 per cent), which had been operated on before 60 years of age, loosening had occurred.

Sex. In group I, 32 per cent were men and in group III + IV 49 per cent. Loosening had taken place in 48 per cent of the male and 28 per cent of the female hips.

Body weight. The average weight was 69 kg in group I and 74 kg in group III + IV. Patients heavier than 80 kg made up 16 per cent of group

Table 3. Incidence of implant loosening under various conditions

	Number	Distribution in groups (per cent)		
		I	II	III+IV
Prosthetic position: Valgus or neutral	17	77	5	18
1–5 degrees varus	58	64	12	24
≥6 degrees varus	53	36	13	51
Medial cement packing: Cancellous bone remaining, less than 3 mm of cement	104	50	12	38
Cancellous bone removed and/or ≥3 mm of cement	24	71	8	21
Lateral metal-to-bone contact	23	43	18	39
Distal metal-to-bone contact	48	35	11	54
No cement past distal tip	19	47	16	37
Lack of collar-calcar contact	68	51	12	37
Wide marrow canal	43	51	9	40
Total	128	54	12	34

Group I = normal X-ray. Group II = suspected loosening. Group III = femoral stem loosening established at 5-year follow-up. Group IV = femoral stem loosening reoperated before follow-up.

I and 32 per cent of group III + IV. Twenty-seven patients weighed over 80 kg at the time of operation and loosening had occurred in 14 (52 per cent) of these.

An analysis of the combined effects of age and body-weight shows that in patients older than the median age of 65 years at the operation and weighing less than the median weight of 70 kg the rate of loosening was only 1/25 (4 per cent), and in the rest of the material 44/89 (49 per cent). The difference is statistically significant ($P<0.001$).

Physical activity. The categories A, B and C for walking capacity (Charnley 1972) reflect the physical activity levels and thereby to some extent give an indication of the strain to which the prosthesis is subjected. Category A hips made up 8.7 per cent of group I and 22 per cent of group III + IV. In category A, 10 hips (59 per cent), in category B, 17 hips (42 per cent) and in category C, 18 hips (25 per cent) showed evidence of implant loosening or had been reoperated.

Bilateral operations. We found a decreased incidence of loosening in the 19 patients who had been bilaterally operated during the period under study. Of these 38 hips, 26 (68 per cent) belong to group I and 8 (21 per cent) to group III + IV.

Previous operations. In group I 13 hips (19 per cent) and in group III + IV 7 hips (16 per cent) had been operated on prior to the replacement (Table 2).

Radiographic features. In one of the reoperated hips a technical fault with penetration of the stem through the femoral cortex had led to loosening, necessitating reoperation after 7 months. This hip is excluded from this section, leaving 44 hips in group III + IV. The observations are summarized in Table 3. As the curved Charnley-Müller stem has no true longitudinal axis, its orientation in the frontal plane was defined as the angle between the longitudinal axis of the femur and a line passing through the most distal point of the stem and the most proximal point of the prosthesis collar. According to this definition, the average angle was 3 degrees of varus in group I and 6 degrees of varus in group III + IV.

This difference is statistically significant ($P<0.001$).

A varus angle of 6 degrees or more was associated with loosening in 51 per cent of the hips. The thickness of the cement layer medially was measured at the level of the remaining part of the femoral neck and the presence of cancellous bone was noted. In 104 operations, the cement layer was less than 3 mm thick and cancellous bone had been preserved. In only 5 hips was the cement layer more than 5 mm thick. Among the 24 replacements with a cement thickness of more than 3 mm and/or all cancellous bone removed, 17 (71 per cent) belong to group I and only 5 (21 per cent) to group III + IV. No significant correlation could be established between medial cement thickness and varus-valgus orientation within the narrow range of variations in this series. The average angle was 4.4 degrees of varus for the whole material and 4.0 degrees of varus for the 24 hips with thicker medial cement.

Along the convex lateral aspect of the stem it was observed whether or not the cement layer was continuous. In 23 replacements it was interrupted, with direct contact between metal and cortical bone. No significant effect on the rate of loosening was seen.

It was further noted whether the cement surrounded the distal tip of the prosthesis or whether the tip was in direct contact with the bone. Whether or not the cement extended distally past the prosthesis was also noted. Metal-to-bone contact at the distal end was seen in 37.5 per cent of the total number, in 25 per cent of the radiologically normal hips and in 59 per cent of the loosened implants. In 19 hips the cement did not extend past the tip of the femoral stem. This had no demonstrable effect on the rate of loosening. Direct contact between the collar of the femoral prosthesis and the cut end of the medial femoral neck had not been achieved in 68 replacements. No effect on the rate of loosening was noted.

In 43 femora the marrow canal was more than twice as wide as the prosthesis stem, measured at its mid-point. The loosening rate in these hips did

not deviate significantly from that of the whole material.

Changes in the upper femur

The resorptive bone changes noted in connection with implant loosening have been described in the presentation of the radiological signs of loosening. In addition, resorption of the cortical bone on the medial side of the remaining part of the femoral neck and hypertrophy of the femoral diaphysis at the level of the distal part of the stem have been observed. The reoperated hips are not included in these observations in the 115 hips with a minimum of 5 years' follow-up time.

Femoral neck resorption. In 57 hips (49.5 per cent) resorption of 2 mm or more of the cut end of the femoral calcar had occurred. In group I resorption was present in 24 hips (35 per cent) but only in 6 did it exceed 5 mm. The average resorption was 4.6 mm. In group II resorption was noted in 10 out of 15 hips with a mean value of 4.5 mm and in group III resorption had occurred in 23 hips (74 per cent), on average 8.7 mm. In addition to resorption of the outer end, cystic resorption from the inner surface of the calcar was observed in 3 hips in group II and in 7 hips in group III.

Cortical hypertrophy. At the 5-year follow-up the outer diameter of the femur at the level of the distal part of the stem showed an increase by 3 mm or more in 44 hips (38 per cent). In group I the increase was 3 mm in 13 hips (19 per cent) and 4 mm or more in 7 hips (10 per cent) with a maximum value of 6 mm. In group III the increase was 3 mm in one hip and 4 mm or more in 16 hips (52 per cent) with a maximum value of 10 mm.

COMMENTS

The clinical results are still satisfactory after more than 5 years' follow-up even though the proportion of totally or almost pain-free hips (79 per cent) is slightly smaller than in series with shorter observation times (Hellinger et al. 1978, Olsson et al. 1979). The absence of deep infections is particularly gratifying. However, the large number of hips with loosening of the femoral component is alarming. In 14 of the original 151 hips, recurrence of pain and radiological evidence of loosening had led to reoperation before the follow-up. This incidence (9.3 per cent) is not remarkably high in relation to comparable reports (Witt & Hackenbroch 1976, Tönnis & Asai 1976, McBeath & Foltz 1979) and so our findings concerning radiologically detectable implant loosening may well be generally applicable.

A radiographic diagnosis of implant loosening does not necessarily have clinical consequences, if there are no symptoms and the condition is radiologically stable at subsequent examinations. Weber & Charnley (1975) described "subsidence" of the femoral stem and stated that it did not constitute an indication for revision of the prosthesis. On the other hand, Beckenbaugh & Ilstrup (1978) found that 2 mm of drift was associated with increased pain and predicted that ultimately the loosening will cause trouble and Gruen et al. (1979) demonstrated that radiological signs of loosening progressed with time in 56 out of 76 hips. Markolf & Amstutz (1976) from an experimental study of prosthesis orientation and fixation concluded that even the slightest amount of loosening can be of critical importance in producing high stress levels. In many instances, the loosening is associated with bone resorption in connection with the implant, often appearing as cyst-like cortical defects medially at the level of the calcar and lesser trochanter and laterally at the level of the distal part of the stem. These are the two regions where the bending moment of the loose implant exerts maximum pressure on the bone and the absorption may be the result of excessive load (Brockhurst & Svensson 1977), although a foreign body reaction caused by particles of fragmented bone cement may also be involved (Harris et al. 1976). Progressive bone resorption will ultimately ruin the bone stock available for the fixation of a new implant and a revision of the prosthesis must take place without delay (Buchhorn et al. 1979, Hupfauer & Seifert 1976, Maier et al 1977). According to Mach (1976) and Witt & Hackenbroch (1976) an absolute indication for revision exists in every case of proven implant loosening.

The strict criteria for a diagnosis of loosening in this series resulted in the formation of an "uncertain" group of 15 hips with minor loosening signs, which may represent subsidence into a new, stable position. Support for this assumption can be found in the statement by Blacker & Charnley (1978), that a cemented femoral prosthesis, which has been successful for about 4 years, is very unlikely to loosen subsequently. It can not be excluded, however, that at least some of these hips may be in the early stages of progressive loosening. The difficulties in establishing an absolute definition for implant loosening are illustrated by the observations by Fornasier & Cameron (1976) that a thin layer of organized fibrous tissue was consistently present between metal and cement in post-mortem specimens. The pattern of loosening may at least to some extent be specific for each type of prosthesis and also influenced by variations in operative technique. The pattern observed in the majority of our cases corresponds to mode II of Gruen et al. (1979), which represented only 3 per cent of their material of loosened Charnley and Trapezoidal-28 stems. The Charnley-Müller stem is curved and diamond-shaped in cross-section, and in the present series no consistent attempts had been made to avoid varus insertion or to remove all cancellous bone. Generally, the cement encasement was thinnest on the medial aspect of the proximal part and on the dorso-lateral aspect of the distal tip. In the distal part, the cement filling was often irregular and incomplete. The cement had been inserted into the medullary canal from above without the use of a cement syringe or plugging of the canal. On the basis of theoretical calculations and experimental and clinical studies, aseptic failure of femoral stem fixation has been attributed to a number of factors, such as varus position of the stem, inadequate cementing technique, lack of collar-calcar contact, wide femoral marrow canal, cracking of the cement caused by shrinkage during its polymerization and various details of the stem design (Andriacchi et al. 1976, Beckenbaugh & Ilstrup 1978, Bocco et al. 1977, Grünert & Ritter 1973, Hackenbroch et al. 1976, Heipertz 1974, Hinterberger & Ungethüm 1977, Holz & Ungethüm 1975, Markolf & Amstutz 1976, McBeath & Foltz 1979, Müller 1974, Oh & Harris 1978, Pellicci et al. 1979, Ritter et al. 1973, Savino 1978). In our series, increased varus orientation of the femoral component was associated with a significantly higher incidence of loosening. It is not possible from this material to determine whether a different reaming and cementing technique may reduce or eliminate the importance of varus-valgus orientation for the long-term stability. Our findings indicate that distal lateral cement support of the stem may be as important as the support of the proximal medial part. It has been pointed out that there is an increased risk of implant loosening in patients who are relatively young, heavy or physically active (McBeath & Foltz 1979, Pellicci et al. 1979, Weber & Charnley 1975). In the present series, age, sex and body-weight significantly influenced the rate of loosening, and unilateral arthroplasties in otherwise healthy persons were subjected to an increased risk of loosening. For patients in the risk groups, alternative methods of treatment should always be considered, and excessive weight should be reduced preoperatively. We agree with the opinion, expressed by several authors, that proximal femoral osteotomy should be considered as a first choice of treatment in younger patients with hip osteoarthritis (Brinkmann & Heilmann 1974, Collert & Gillström 1979, Gierse 1979, Maier et al. 1977, Mogensen et al. 1980, Müller 1974, Morscher 1979, Olsson 1974). Resorption of the medial femoral neck was found in more than half of the arthroplasties with suspected or confirmed loosening but in only 24 out of 69 with normal X-rays. The nature of such resorption is still not fully understood. According to Griss et al. (1978) a cortical atrophy measuring 1–4 mm is a consequence of the disturbance of vascularisation at the operation and the same opinion is expressed by Cupic (1979), who states that up to 4 mm of resorption can be considered normal. Maier et al. (1977) noted 53.2 per cent calcar resorption and Blacker & Charnley (1978) noted "significant" resorption (greater than 3 mm) in 117 out of 167 hips, whereas Beckenbaugh & Ilstrup (1978) found resorption in only 16.1 per cent of 255 hips after an average of 69 months. Bocco et al. (1977) and Griss et al. (1978) describe and clas-

sify different patterns of resorptive changes in the calcar and conclude that a foreign body reaction against fragmented PMMA as well as femoral stem loosening are responsible for the development of extensive erosion including cavitation of the inner surface of the calcar. In a stress analysis of the femoral stem, Andriacchi et al. (1976) demonstrated that the mechanical consequences of calcar resorption are increased tensile stresses in the stem, which may lead to failure. Oh & Harris (1978) regard calcar resorption as a manifestation of disuse atrophy and suggest that such atrophy may be prevented if the femoral component has a sufficiently wide collar which by direct contact transfers load to the cut femoral neck. Other authors, however, have come to the conclusion that no significant load is transmitted to the cut neck (Brockhurst & Svensson 1977, Griss et al. 1978, Huggler et al. 1978). Probably this question is of limited practical consequence, since even a small amount of stump atrophy induced by the surgical trauma may reduce or eliminate any collar-calcar load transfer which may have existed initially. Hypertrophy of the femoral cortex was found by Blacker & Charnley (1978) in 48 out of 167 hips studied an average of 9.9 years after operation whereas Beckenbaugh & Ilstrup (1978) found cortical thickening in only 3 out of 237 hips followed for more than 5 years. In our series, the diameter of the femur had increased by 4 mm or more at the level of the distal part of the stem in more than half of the hips with implant loosening but in only 10 per cent of the radiologically normal hips. It is reasonable to assume that femoral cortex hypertrophy may be induced by the altered stress distribution at the end of the rigid implant but that the still higher stress concentrations resulting from loosening of the implant may give rise to a more vigorous regenerative bone reaction. Another sign of this process is the increased radionuclide uptake in the region of the distal stem in bone scintigraphy of hips with femoral component loosening (Hupfauer & Seifert 1976, Häckel et al. 1978).

CONCLUSIONS

1. Although the clinical results after more than 5 years' follow-up time are satisfactory, the high incidence of radiologically detectable implant loosening is disquieting. The indications for conventional total hip replacement should not be broadened until better long-term results with improved technique have been documented. Such improvements should include both implant design and operative technique.

2. Symptoms and clinically detectable signs are not necessarily present in spite of radiological evidence of implant loosening. Even in asymptomatic hips, X-ray may show bone resorption around the implant, indicating progressive loosening and destruction of the bone available for the fixation of a new implant. We suggest that all total hip replacements are checked by X-ray examination after 5 years. New symptoms from an operated hip should always give rise to a suspicion of loosening.

3. Individual risk factors with regard to prosthesis loosening must be taken into account before a total hip replacement is decided upon. Excessive weight should be reduced preoperatively. In young patients with osteoarthritis, osteotomy should be considered as an alternative treatment.

REFERENCES

Andriacchi, T. P., Galante, J. O., Belytschko, T. B. & Hampton, S. (1976) A stress analysis of the femoral stem in total hip prostheses. *J. Bone Joint Surg.* **58**-A, 618–624.

Beckenbaugh, R. D. & Ilstrup, D. M. (1978) Total hip arthroplasty. A review of three hundred and thirty-three cases with long follow-up. *J. Bone Joint Surg.* **60**-A, 306–313.

Blacker, G. J. & Charnley, J. (1978) Changes in the upper femur after low friction arthroplasty. *Clin. Orthop.* **137**, 15–23.

Bocco, F., Langan, P. & Charnley, J. (1977) Changes in the calcar femoris in relation to cement technology in total hip replacement. *Clin Orthop.* **128**, 287-295.

Brinkmann, K. E. & Heilmann, K. (1974) Klinische, röntgenologische und feingewebliche Untersuchungen an ausgelockerten Hüftgelenksprothesen. *Arch. Orthop. Unfallchir.* **80**, 333–342.

Brockhurst, P. J. & Svensson, N. L. (1977) Design of total hip prosthesis. The femoral stem. *Med. Prog. Technol.* **5**, 73–102.

Buchhorn, U., Griss, P., Niederer, P. G. & Willert, H.-G. (1979) Klinische Relevanz von Lockerungszeichen bei Hüftendoprothesen. *Z. Orthop.* **117**, 685–690.

Carlsson, Å. S., Lidgren, L. & Lindberg, L. (1977) Prophylactic antibiotics against early and late deep infections after total hip replacements. *Acta Orthop. Scand.* **48**, 405–410.

Charnley, J. (1972) The long-term results of low-friction arthroplasty of the hip performed as a primary intervention. *J. Bone Joint Surg.* **54**-B, 61–76.

Charnley, J. & Halley, D. K. (1975) Rate of wear in total hip replacement. *Clin. Orthop.* **112**, 170–179.

Collert, S. & Gillström, P. (1979) Osteotomy in osteoarthritis of the hip. A prospective study. *Acta Orthop. Scand.* **50**, 555–561.

Cupic, Z. (1979) Long-term follow-up of Charnley arthroplasty of the hip. *Clin. Orthop.* **141**, 28–43.

Fornasier, V. L. & Cameron, H. U. (1976) The femoral stem/cement interface in total hip replacement. *Clin. Orthop.* **116**, 248–252.

Gierse, H. (1979) Endoprothese oder Osteotomie? Zwei Möglichkeiten der operativen Therapie der Koxarthrose. *Ther. Ggw.* **118**, 19–29.

Griffith, M. J., Seidenstein, M. K., Williams, D. & Charnley, J. (1978) Socket wear in Charnley low friction arthroplasty of the hip. *Clin. Orthop.* **137**, 37–47.

Griss, P., Heimke, G., Werner, E., Bleicher, J. & Jentschura, G. (1978) Was bedeutet die Resorption des Calcar femoris nach der Totalendoprothesenoperation der Hüfte? *Arch. Orthop. Traumat. Surg.* **92**, 225–232.

Gruen, T. A., McNeice, G. M. & Amstutz, H. C. (1979) "Modes of failure" of cemented stem-type femoral components. *Clin. Orthop.* **141**, 17–27.

Grünert, A. & Ritter, G. (1973) Experimentelle Untersuchungen zum Problem der Verankerung von Hüftendoprothesen. *Arch. Orthrop. Unfallchir.* **77**, 149–153.

Hackenbroch, M. H., Bruns, H., Holbe, R. & Lechleutner, H. (1976) Weitere Erfahrungen mit der Totalendoprothese des Hüftgelenks. Klinische und radiologische Nachuntersuchungsergebnisse nach 3- bis 6-jähriger Implantationszeit. *Arch. Orthop. Unfallchir.* **84**, 149–168.

Harris, W. H., Schiller, A. L., Scholler, J.-M., Freiberg, R. A. & Scott, R. (1976) Extensive localized bone resorption in the femur following total hip replacement. *J. Bone Joint Surg.* **58**-A, 612–618.

Heipertz, W. (1974) Lockerung und Infektion der Hüftgelenk-Totalendoprothese. *Z. Orthop.* **112**, 938–940

Hellinger, J., Purath, W. & Kleditzsch, J. (1978) Ergebnisse der Müller-Totalendoprothesen-Implantation nach standardisierter Technik. *Beitr. Orthop. Traumatol.* **25**, 667–678.

Hinterberger, J. & Ungethüm, M. (1977) Biomechanische Betrachtungen zur Beanspruchung der Verankerung von Femurschaftprothesen. *Z. Orthop.* **115**, 936–941.

Holz, U. & Ungethüm, M. (1975) Klinische und experimentelle Untersuchungen wesentlicher Faktoren bei der dauerhaften Verankerung von Hüfttotalendoprothesen. *Arch. Orthop. Unfallchir.* **82**, 195–204.

Huggler, A. H., Jacob, H. A. C. & Schreiber, A. (1978) Biomechanische Analyse der Lockerung von Femurprothesen. *Arch. Orthop. Traumat. Surg.* **92**, 261–272.

Hupfauer, W. & Seifert, J. (1976) Diagnostik der Implantatlockerung. *Orthop. Prax.* **12**, 1099–1103.

Häckel, H., König, B., Mostbeck, A. & Pflüger, W. (1978) Zur Wertigkeit der Knochenszintigraphie bei Kunstgelenklockerungen. *Z. Orthop.* **116**, 727–731.

Mach, J. (1976) Zur Problematik der Endoprothesenlockerung und -auswechslung am Hüftgelenk. *Beitr. Orthop. Traumatol.* **23**, 622–630.

Maier, S., Griss, P., Rahmfeld, T. & Dinkelacker, T. (1977) Nachuntersuchungsergebnisse der totalen Alloarthroplastik der Hüfte unter besonderer Berücksichtigung der Spätkomplikationen 4 bis 7 Jahre post operationem. *Z. Orthop.* **115**, 274–283.

Markolf, K. L. & Amstutz, H. C. (1976) A comparative experimental study of stresses in femoral hip replacement components: The effects of prostheses orientation and acrylic fixation. *J. Biomech.* **9**, 73–79.

McBeath, A. A. & Foltz, R. N. (1979) Femoral component loosening after total hip arthroplasty. *Clin. Orthop.* **141**, 66–70.

Mogensen, B. A., Zoëga, H. & Marinko, P. (1980) Late results of intertrochanteric osteotomy for advanced osteoarthritis of the hip. *Acta Orthop. Scand.* **51**, 85–90.

Morscher, E. (1979) Die intertrochantere Osteotomie bei Koxarthrose als Alternativlösung zur Endoprothese. *Z. Orthop.* **117**, 427–432.

Müller, M. E. (1974) Der derzeitige Stand der Totalendoprothese des Hüftgelenkes. *Z. Orthop.* **112**, 933–938.

Oh, I. & Harris, W. H. (1978) Proximal strain distribution in the loaded femur. An in vitro comparison of the distribution in the intact femur and after insertion of different hip-replacement femoral components. *J. Bone Joint Surg.* **60**-A, 75–85.

Olsson, S. S. (1974) Intertrochanteric osteotomy of the femur for osteoarthritis of the hip joint. Thesis. Göteborg.

Olsson, S. S., Jernberger, A. & Tryggö, D. (1979) Total hip replacement by the Müller-Charnley prosthesis. A follow-up study of 238 operations after 2 to 7 years. *Acta Orthop. Scand.* **50**, 457–463.

Pellicci, P. M., Salvati, E. A. & Robinson, H. J. (1979) Mechanical failures in total hip replacement requiring reoperation. *J. Bone Joint Surg.* **61**-A, 28–36.

Ritter, G., Grünert, A. & Schweikert, C.-H. (1973) Biomechanische Ursachen von Lockerung und Bruch der Hüftendoprothese. *Arch. Orthop. Unfallchir.* **77**, 154–164.

Savino, A. W. (1978) Experimental study in femoral component total hip replacement: Mechanical failures of cement-bone interface with comparison of prosthesis, cement thickness, orientation and plug insertion. *Proc. Inst. Med. Chic.* **32**, 13–14.

Tönnis, D. & Asai, H. (1976) Untersuchungen über die Lockerungsraten verschiedener Hüftgelenksprothesen und unterschiedlicher Halslängen. *Arch. Orthop. Unfallchir.* **86**, 317–332.

Weber, F. A. & Charnley, J. (1975) A radiological study of fractures of acrylic cement in relation to the stem of a femoral head prosthesis. *J. Bone Joint Surg.* **57**-B, 297–301.

Witt, A. N. & Hackenbroch, M. H. (1976) Therapeutische Möglichkeiten bei gelockerten Hüfttotalprothesen. *Z. Orthop.* **114**, 330–341.

Correspondence to: Sven S. Olsson, M.D., Department of Orthopaedic Surgery, Central Hospital, S-601 82 Norrköping, Sweden.