LONG-TERM CLINICAL AND RADIOLOGICAL RESULTS OF THE LORD TOTAL HIP PROSTHESIS

A PROSPECTIVE STUDY

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We enrolled 98 patients (107 hips) with a mean age of 47 years (SD 8.6) into a prospective study of the Madreporic Lord THR; 34 hips had primary and 73 secondary osteoarthritis.

After ten years, the survival rate using revision as the endpoint for failure was 70% (± 9) for the cup and 98% (± 0.3) for the stem. The combined clinical and radiological survival rates were 46% (± 11) and 81% (± 10), respectively. Osteoporosis due to stress-shielding was observed in the proximal femur. Hips with radiologically dense bone postoperatively showed the most pronounced bone loss.

We recommend continued radiological follow-up of patients with this type of implant to allow revision to be performed before there is severe bony destruction of the pelvis.

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In the 1970s Lord developed an uncemented cobalt-chromium implant with a fully porous (Madreporic) coated stem and a threaded cup. Initial stem fixation depended on a fit in the tight trochanteric and diaphyseal area. The preliminary results were promising (Lord 1978), but we are not aware of prospective reports of long-term series. Our aim was to assess the efficacy of this implant in a series of young and active patients over a ten-year period.

PATIENTS AND METHODS

Between September 1979 and November 1986 we enrolled 98 patients in the study, all of whom gave their informed consent. Nine had bilateral operations, giving a total of 107 arthroplasties. Patients were excluded if they had active inflammatory disease, severe osteoporosis, corticosteroid treatment for more than three months, a previous replacement of the same hip, or grossly deficient femoral or acetabular bone stock.

Of the 107 hips, 34 showed primary osteoarthritis, and 33 had arthritis secondary to childhood diseases. Thirteen had old fractures of the acetabulum or femoral neck, 13 had idiopathic avascular necrosis, 7 showed inflammatory arthritis, and 7 miscellaneous disorders. Fifty-nine patients (60%) had unilateral hip disease only (Charnley group A), 28 had bilateral hip disease (group B) and 11 had multiple joint involvement (group C) (Charnley 1979).

There were 40 men and 58 women with a mean age of 47 years (SD 8.6; 25 to 67) and a mean weight of 70 kg (SD 12). All the patients were operated on at the two University hospitals in Gothenburg, most of them by one of the two senior authors (PH, BR). After 1984, other uncemented implants were also used and therefore the series is not consecutive for the last two years.

Clinical data and follow-up. For clinical evaluation we used a standard proforma recording age, gender, weight, diagnosis, social and working status, previous operation(s), Charnley class, subsets of the Harris hip score, implant size, peroperative assessment of bone quality and peroperative fracture. The Harris hip score and subsets of this score were used for outcome measurement (Harris 1969).

We performed clinical and radiological examinations before and after the operation and at 1, 3, 5, 7, 10 and 13 years. For up-to-date information about revisions, especially for patients who had only one component revised or had been revised after the latest follow-up, we used the National Register of THA in Sweden (Malchau, Herberts and Ahnfelt 1993).

Patients were withdrawn from the study (Table I) when the cup ($n = 39$), the stem ($n = 1$) or both components ($n = 1$) were revised or extracted. Seven patients (7 hips) died 3 to 14 years after the operation and one patient emigrated and could not be contacted. The postoperative

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Table I. Number of hips evaluated at different follow-up intervals. Hips revised and patients deceased or lost to follow-up are listed at their last follow-up before being withdrawn

Follow-up (yr)	Clinical examination		Radiological examination		Withdrawn hips		
	Yes	No	Yes	No	Revision or extraction	Deceased	Lost to follow-up
1	101	5	86	21		1	
3	91	12	86	17	2		1
5	87	5	77	12	9	2	
7	63	7	70	15	18	4	
10	43	6	41	8	12		

Table II. Details recorded from the digitised radiographs

	View	Definition, grading and reference line or point
Preoperative		
Acetabular cysts	AP and lateral	Yes/No
Femoral head cysts	AP and lateral	Yes/No
Immediate postoperative		
Cup		
Inclination	AP	Teardrop line (degrees)
Stem		
Varus/valgus position	AP	Femoral v prosthetic longitudinal axis*
Fill-fit ratio	AP	Area prosthesis/femoral canal distal to tip of lesser trochanter*
Cortical contact ratio	AP	Length of prosthetic contact/length of prosthesis $\times 2$ *
Follow-up v Postop		
Cup		
Vertical and horizontal cup migration	AP	Teardrop line and teardrop†
Sclerotic and lucent lines	AP and lateral	Length in 3 + 3 regions‡
Osteolytic area	AP	Yes/No
Stem		
Vertical subsidence		Tip lesser trochanter - stem shoulder†
Sclerotic and lucent lines	AP and lateral§	Length of sclerotic lines/length of prosthesis $\times 2$ *
Pedestal formation	AP	Length of line in Gruen zone 4
Osteolytic area	AP	Yes/No
Change in cortical density	AP	Difference of bone area in 6 regions¶

* Kärrholm and Snorrason (1993)

† Malchau et al (1995)

‡ DeLee and Charnley (1979)

§ Excluded from statistical analysis due to few observations

¶ 3 medial and 3 lateral (Gruen et al 1979)

clinical examinations were done by an unbiased observer in more than 75% of the cases and the remainder by the surgeon. The participating surgeons agreed an overall assessment of the clinical status and the radiological appearance of each case.

Operative procedure. Antibiotic cover and thromboembolic prophylaxis were used in all patients. In 100 hips we used the posterior (Moore 1952) approach and in seven the transgluteal route (Hardinge 1982). Five sizes of cup and eight sizes of stem were available. The two smallest cup sizes were used with a 22 mm cobalt-chromium femoral head and the larger sizes with a 32 mm head.

In 15 of the 107 hips (12%) peroperative complications were recorded. Eight patients had undisplaced spiral femoral fractures due to mismatch between the femoral canal and the design of the stem. Six had undisplaced fractures of the greater trochanter and in one an early reoperation was required to reattach a loose trochanter by cerclage wiring.

Radiological analysis. At each review an AP-pelvic view was taken, centred on the symphysis, with AP and lateral

femoral views centred on the proximal part of the stem. A total of 2302 radiographs was recorded by video and digitised with a resolution of 1024×1024 pixels and 256 greyscales, using a frame-grabber card in a personal computer. We developed software for the correction of the planar distortion, and used image analysis software (Research Metrics; OrthoGraphics Inc, Salt Lake City, Utah) to compute distances from landmarks defined by the examiner (Nunn et al 1989; Malchau et al 1995). Only digitally evaluated radiographs were included in the analysis shown in Table II. Previous determinations of the accuracy of our radiological measurements of cup migration and stem subsidence (Malchau et al 1995) enabled us to regard the implant as having migrated if the distance exceeded 5 mm.

We used a new method for the semiquantitative evaluation of change in mineral content of the proximal femoral bone. We traced the outline of visible cortical bone in the seven regions of Gruen, McNeice and Amstutz (1979) on to the digitised radiograph. The areas were measured on the

Table III. Mean (SD, range) Harris hip score for pain and *percentage* at score levels of 0 to 20, 30, 40 and 44

Follow-up (yr)	Number	Score	Score			
			0 to 20	30	40	44
Preoperatively	107	5.2 + 7.2 (0 to 30)	99.0	1.0		
1	101	40 + 6.2 (10 to 44)	2.2	6.9	16.8	74.3
3	91	42 + 4.9 (29 to 44)	2.4	5.9	17.6	74.1
5	87	42 + 5.1 (20 to 44)	2.1	8.5	20.2	69.1
7	63	41 + 5.5 (20 to 44)	3.5	7.1	31.8	57.6
10	43	41 + 6.7 (10 to 44)	3.8	3.8	30.2	62.3

postoperative and the follow-up AP radiographs, compensating for different exposures by adjustment of the brightness on the monitor to the level at which the bone trabeculae in the centre of the tuber ischii precisely faded away. The intra- and interobserver errors for the method were assessed on 15 radiographs analysed twice with an interval of one month by three observers (HM, YXW and JK).

We defined focal or linear osteolytic areas as rounded or longitudinal areas showing decreased bone density, localising them by the regions of DeLee and Charnley (1976) on the acetabular side and Gruen et al (1979) on the femoral side.

Definition of failure. We defined clinical failure as revision with exchange or extraction of one or both prosthetic components or exchange of a polyethylene liner. Radiological failure of the cup was defined as migration exceeding 5 mm in any direction, and radiological failure of the stem as subsidence of over 5 mm. Focal osteolyses were not classified as radiological failures because of their small size and location.

Statistical methods. We used survivorship analysis according to Kaplan and Meier (1958). The proportion of surviving hips (± 1.96 SEM) was calculated and indicated on the survival curves. The statistical methods used are indicated in the text.

RESULTS

Clinical results. These are given in Tables III to V and did not change significantly between the first and subsequent follow-ups. Three patients had a transient peroneal nerve palsy, and there were no early deep infections.

The overall assessment of the radiological appearance by the surgeons agreed approximately with the evaluation of the independent observer as regards the stem (Table VI). A time-dependent increase in cup migration was noted by the surgeons, but the proportion of this was smaller than that found by the independent observer.

Revisions. Survival analysis using clinical failure with revision of the cup or stem as the endpoint gave ten-year survival rates of 70% (± 9) (Fig. 1) and 98% (± 0.3) for the two components, respectively. We found no obvious association between any of the parameters which we evaluated

Table IV. Mean $\pm$ SD (range) Harris hip score for limp and *percentage* at score levels of 0 to 5 and 8 to 11

Follow-up (yr)	Number	Score	Score	
			0 to 5	8 to 11
Preoperatively	107	1.6 $\pm$ 2.6 (0 to 8)	95.0	5.0
1	101	9 $\pm$ 2.9 (0 to 11)	20.2	79.8
3	91	10 $\pm$ 2.7 (0 to 11)	12.9	87.1
5	87	10 $\pm$ 2.6 (0 to 11)	11.7	88.3
7	63	9 $\pm$ 2.6 (0 to 11)	11.7	88.3
10	43	9 $\pm$ 2.9 (0 to 11)	11.4	88.6

Fig. 1

Survival rate using failure with cup revision as the endpoint. The 95% confidence limits are shown.

and revision of the cup (Cox proportional hazard regression analysis). Forty cups and two stems (40 hips) were exchanged or revised, but there were too few stem revisions for statistical analysis. The main reasons for revision were aseptic loosening (36 hips), and localised acetabular or femoral osteolysis (3 hips). One patient required a two-stage revision after ten years for late deep infection with cup loosening. None of the stems in hips with revised cups has so far been revised.

Radiological results. At one year 7 of 86 cups (8%) had migrated more than 5 mm in the vertical or horizontal direction (Fig. 2). After ten years, 23 of the 41 remaining cups (56%) had migrated (Table VII). During the first

Fig. 2a

Fig. 2b

Postoperative (a) and ten-year radiographs (b) showing migration into the pelvis in a 48-year-old woman with primary osteoarthritis.

postoperative year 6 of 80 stems (7.5%) had subsided 5 mm or more and at the ten-year examination 5 of 32 stems (16%) had subsided (Table VII, Fig. 3).

A total of 17 stems migrated more than 5 mm. In six this migration was first noted at the one-year follow-up, in eight at three years, in two at five years and in one patient the migration was diagnosed as late as ten years after the operation.

On the femoral side six osteolytic granulomas were seen, all in Gruen zones 1 or 7. Minor areas of acetabular osteolysis were seen in three hips, all in zone 3.

Sclerotic lines were frequently seen around the cup, but very few hips developed sclerotic lines or lucencies around the stem (Figs 4 and 5).

In regard to the relative change in area of cortical bone there was no significant difference between the three observers. The intraobserver error (2 SD from zero) was 16% and the interobserver error (2 pooled SD) was 28%. The cortical bone area surrounding the femoral stem decreased between

Fig. 3a

Fig. 3b

Postoperative (a) and ten-year follow-up (b) radiographs in a 45-year-old man with primary arthritis. The stem has subsided and the medial cortex has disappeared.

Table V. Sum of hip movement in degrees; mean $\pm$ SD (range)

Follow-up (yr)	Number	Movement
Preoperatively	107	97 $\pm$ 43 (0 to 220)
1	100	192 $\pm$ 39 (50 to 285)
3	91	201 $\pm$ 45 (50 to 325)
5	87	200 $\pm$ 50 (50 to 330)
7	63	191 $\pm$ 46 (50 to 280)
10	43	182 $\pm$ 61 (50 to 310)

Fig. 4
The percentage of sclerotic lines around the cup in zones 1 to 3 (DeLee and Charnley 1982) at the different follow-up times.

Fig. 5
The percentage of sclerotic lines around the stem in zones 1 to 7 (Gruen et al 1979) at the different follow-up times.

the postoperative and the seven-year follow-up examinations in zones 1 ($p < 0.0001$), 2 ($p = 0.002$) and 7 ($p < 0.0001$) (Wilcoxon matched-pair signed-rank test, Fig. 6). In all six regions which we evaluated (1 to 3, 5 to 7) the bone area on the immediate postoperative radiograph was the most important variable for predicting changes in bone density up to seven years after the operation ($p = 0.0005$ to 0.005 , stepwise linear regression). A large postoperative area of dense bone was associated with an increased loss of bone. Other factors such as stem length, age, weight, diagnosis, bone quality, stem length and occurrence of preoperative fracture had an inconsistent and usually small

effect which varied according to the Gruen zone analysed.

Clinical and radiological survival. Analysis of failures of the cup (revision or migration) showed a ten-year survival rate of $46\% (\pm 11)$ (Fig. 7). None of the variables which we considered in relation to the patient, the operation or the findings on the preoperative or immediate postoperative radiographs could predict this very high failure rate.

The survival rate for the stem was $81\% (\pm 10)$ at the ten-year follow-up (Fig. 8). Stem failure was associated with a varus position of the stem on the early postoperative radiograph. The increase in relative risk per degree of varus

Fig. 6
The mean percentage ($\pm$ SEM) relative change in the cortical bone area surrounding the stem in zones 1 to 7 (Gruen et al 1979).

Fig. 7

Survival rate of the cup using revision or migration of more than 5 mm as the endpoint. The 95% confidence limits are shown.

Fig. 8

Survival rate of the stem using revision or subsidence of more than 5 mm as the endpoint. The 95% confidence limits are shown.

angulation was 3.5 (1.5 to 8.3, $p = 0.003$, Cox regression).

DISCUSSION

The early to intermediate results for the first generation of threaded cups have already been reported (Engh, Griffin and Marx 1990; Lautiainen, Joukainen and Mäkelä 1994), but we are not aware of any reports of the long-term results. Sweetnam et al (1995) reported a high revision rate for threaded cups at six years, when used with a ribbed femoral prosthesis. Huiskes (1987) pointed out that stress concentration at the edge or tip of the threads imposes a focal overload on bone, which leads to bone necrosis and subsequent migration. In a radiostereometric study of 20 threaded cups, Snorrason and Kärrholm (1990) found a mean

proximal migration of 0.6 to 0.7 mm in the first six post-operative months, which was more than three times higher than that observed for cemented cups and cementless press-fit cups (Snorrason 1990). They were concerned about the early and high migration rate and recommended that threaded cups should not be used until long-term clinical results were available. Other threaded cup designs coated with hydroxyapatite are now in use, but whether these new cups have better fixation and long-term performance is not yet known.

The Harris hip subscores for pain or limp did not deteriorate with time despite the high failure rate of the cup, possibly because cup migration does not always cause pain (Carlsson and Gentz 1984). When present, the pain or discomfort was different from that experienced before the operation. Moreover, before the symptoms became severe,

Table VI. Assessment by the surgeon of the stem and cup stability, by *percentage*

Follow-up (yr)	Number	Stem stability			Cup stability		
		Stable	Possibly unstable	Definitely unstable	Stable	Possibly unstable	Definitely unstable
1	101	94	5	1	99	1	
3	91	95	4	1	93	5	2
5	87	98	2		92	3	5
7	63	96	4		78	10	12
10	43	98	2		70	13	17

Table VII. Number and *percentage* of implants showing subsidence exceeding 5 mm (stem) and vertical or horizontal migration (cup) exceeding 5 mm. The number evaluated decreased mainly because of the comparatively high revision rate of the cup

Follow-up (yr)	Stem		Cup	
	Number evaluated	Subsidence	Number evaluated	Migration
1	80	6 8	86	7 8
3	73	10 14	86	22 26
5	67	8 12	77	26 34
7	66	6 9	70	32 46
10	32	5 16	41	23 56

the cup was often revised because of the radiological findings. The comparatively long intervals between reviews and the tendency for the cup sometimes to fail rapidly when it penetrated the medial wall of the pelvis have contributed to inadequate documentation of cup failure in the scoring system. Furthermore, the high revision rate may have contributed to the selective survival of comparatively well-fixed cups and patients with a high threshold to pain. Once cup migration was diagnosed, it was usually progressive and resulted in clinical failure.

In contrast to the high and early migration rate of the threaded cup, the fully-porous-coated Lord stem was comparatively stable. Several reports (Engh, Bobyn and Glassman 1987; Engh and Bobyn 1988; Engh, Glassman and Suthers 1990; Engh et al 1992, 1994) have presented a high clinical success rate with this stem in both primary and revision cases. In our series subsidence greater than 5 mm was observed in 17 hips. Most of these patients were identified at the three-year follow-up or earlier, but so far these implants have not been revised. This suggests that subsidence of a fully porous-coated cobalt-chromium stem may result in a more durable fibrous fixation and is better tolerated by the patient (Engh et al 1992) than subsidence of a cemented stem (Kärrholm et al 1994a).

The next generation of uncemented stems had porous coating of only a short proximal area to minimise stress-shielding. These designs are sometimes associated with early migration (Kärrholm et al 1994b) and have also a higher revision rate (Maric and Karpman 1992; Owen et al 1994).

Proximal stress protection due to distal fixation has been regarded as a major problem with fully-coated stems (Engh et al 1987, 1990, 1992, 1994; Huiskes et al 1987; Huiskes,

Weinans and Dalstra 1989; Huiskes 1990). Although there are no reports of the size of this problem in clinical series, these considerations have resulted in the rapid clinical use of the second generation of partially-coated stems.

Changed load distribution on the femoral bone surrounding the stem results in bone resorption in zones 1, 2 and 7 which, in our study, was particularly evident if a large proximal cortical bone area was recorded on the post-operative view; in cases with a small area there was almost no change. This agrees with previous findings (Engh et al 1992, 1994). In contrast to the finite-element models that predict a distal hypertrophy (Huiskes et al 1989; Skinner et al 1994), we did not find any increase in the cortical bone area in the distal Gruen zones at the seven-year follow-up. Skinner et al (1994) presented a finite-element analysis based on one retrieved AML stem of 15 mm diameter and suggested that a stress increase of 200% to 800% at the tip of a 5/8 coated prosthesis was responsible for distal cortical hypertrophy. They predict a near normal stress situation at the tip of a fully-coated stem. This is in agreement with our findings that the bone area in zones 3 and 5 did not change. We could not show any significant relationship between stem diameter and changes in the bone area. If present, this effect may have been masked by other variables which had the same but stronger influence. Insensitivity of our semi-quantitative method and the lack of sequential bilateral measurements may also have had an effect. Future long-term studies using DEXA analysis may clarify this.

Conclusions. We cannot recommend the use of an uncoated threaded cup of the Lord design. The clinical impact of the bone remodelling observed after the insertion of a fully-porous coated stem is still unclear, but is a cause for concern, especially in relation to future revisions.

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