

# Increased migration of the SHP prosthesis

## Radiostereometric comparison with the Lubinus SP2 design in 40 cases

Bo Nivbrant<sup>1</sup>, Johan Kärrholm<sup>2</sup> and Per Söderlund<sup>1</sup>

40 patients with primary arthrosis were randomized to receive either a cemented SHP (Scientific Hip Prosthesis) or Lubinus SP2 prosthesis. At 2 years radiostereometric measurements showed increased proximal migration (0.4/0.2 mm;  $p = 0.02$ ) and more proximal wear (0.3/0.1 mm,  $p = 0.01$ ) of the SHP socket. The SHP stem also subsided ( $-0.6/-0.1$  mm,  $p < 0.001$ ) and rotated more into retroversion (2.6/0.3°) than did the SP2 design. This subsidence mainly occurred inside the cement mantle in 17 of 18 cases

(13 SHP, 4 SP2), where this type of motion could be measured. The changes in bone mineral density evaluated with DEXA and the clinical results did not differ between the 2 groups.

The subsidence of the SHP stem is the most pronounced so far recorded with radiostereometry in stems without a completely polished surface. This subsidence and the rotational instability imply a substantial risk of abrasive wear and increased stresses in the cement mantle.

Departments of Orthopedics, <sup>1</sup>Northern University Hospital, SE-901 85 Umeå, Sweden. Tel +46 90-785 2556. Fax -90137455. E-mail: Bo.Nivbrant@Orthop.umu.se, <sup>2</sup>Sahlgren University Hospital, Göteborg, Sweden. Submitted 99-03-27. Accepted 99-09-30

Several designs of cemented hip prostheses have shown 10-year survival rates of about 95% when evaluated in large series (Espehaug et al. 1995, Herberts and Malchau 1997). These implants have evolved mainly on an empirical basis, which may partly explain the wide variety of combinations of shapes, surface finishes and other design characteristics. Occasionally minor design changes in prostheses have given unexpected results (Dall et al. 1993, Malchau and Herberts 1998, Rockborn and Olsson 1993). The exact reason why a specific combination of stem properties provides good results, whereas others do not is still poorly understood. Huiskes and Boeklagen (1989) tried to calculate the optimal shape of cemented stems using finite element analysis (FEA) and mathematical shape optimization. The rationale for these calculations was to reduce stresses at the stem-cement-bone interfaces to a minimum and hence increase the longevity of the implant. On the basis of their findings, the Scientific Hip Prosthesis (SHP) was developed.

This new prosthetic concept has been clinically tested in a consecutive and prospective series since 1992. A report after a maximum of 4 years' follow-up showed good to excellent clinical and radiographic results (Ypma et al. 1997). As another

part of the early clinical trials, we started a prospective randomized study in 1995, using radiostereometry (RSA) to measure implant migration and wear. Measurements of stem motions in the cement mantle were thought to be of particular interest, not least because of the design rationale of this implant. Our hypothesis was that the migration of this stem should be the same or less than one of the best performing cemented hip implants in Sweden (Malchau and Herberts 1998). Since our standard implant (Lubinus SP2, Waldemar Link) belonged to this group, it was chosen as the control. We used radiostereometric analysis to measure migration of the stem and cup and the penetration of the femoral head. We also studied bone remodeling, changes on conventional radiographs and clinical parameters.

### Patients and methods

40 patients planned for a THA were preoperatively randomized by chance to receive either a SHP (Promotion/Biomet) or Lubinus SP2 prosthesis (Waldemar Link). Inclusion criteria were non-inflammatory arthrosis of the hip, 50–80 years of

**Table 1.** Patient data and Harris hip and pain scores, median (range)

	Lubinus SP 2	SHP
Male/female	8/12	8/12
Age	67 (52-78)	67 (55-78)
Primary/secondary		
arthrosis	19/1	18/2
Charnley group (1/2/3)	13/4/3	14/5/1
Weight, kg	71 (53-92)	70 (48-100)
Harris hip score		
Total		
Preop.	42 (23-61)	39 (15-57)
2 years	96 (65-100)	99 (78-100)
Difference	48 (29-77)	58 (32-76)
Pain		
Preop.	15 (10-20)	15 (10-20)
2 years	44 (20-44)	44 (40-44)
Difference	24 (10-34)	27 (20-34)

There were no significant differences between the groups ( $p > 0.12$ , Mann Whitney U-test)

age and informed consent. Patients with a body weight more than 100 kg, skeletal disease or grossly altered hip anatomy were excluded. Stratification was done based on gender. The two groups did not differ preoperatively as regards clinical parameters (Table 1). The local ethics committee approved the study.

The Lubinus cup had wide grooves, plastic spacers and was gamma-sterilized in air. We used a version with a 3 mm peripheral rim. The SP2 stems were made of cobalt-chromium alloy with a surface roughness of 1.5  $\mu\text{m}$ . The stem is anatomic, double-curved with anterior and posterior ridges and has a comparatively wide collar. All stems were 150 mm long with a CCD angle of 135° (Figure 1).

The SHP cup has a smooth backside supplied with PMMA spacers (height 3 mm), an asymmetrical opening and a 3 mm flange to prevent dislocation. The length of the SHP stem increases with increasing sizes (110-140 mm in this study). It has no collar and a teardrop-like appearance proximally but becomes more cylindrical and tapered distally. The tip is comparatively sharp. When viewed from the side, it is flatter than the SP2 stem and especially in the proximal-medial belly-shaped region. It is made of cobalt-chromium alloy. The entire surface of the version used in our study was matte with a proximal roughness of 3.8



Figure 1. The SHP (to the left) and SP2 prostheses.

$\mu\text{m}$  and a distal one of 2  $\mu\text{m}$ . The stem has 4 proximal PMMA spacers and a PMMA centralizer. All had a CCD angle of 120°. (In later designs, the SHP stem has a polished distal part and a circular groove has been added on the backside of the cup. Biomet manufactures this design.)

One of the authors (BN) did all the operations. Before initiation of the study, this surgeon assisted one of the inventors of the SHP implant on 2 occasions and operated on 2 SHP hips himself to become used to the instrumentation. All hips in the study were operated on via a posterior approach, with instruments delivered by the manufacturers and third-generation cementing technique (distal plug, brush, high pressure lavage, tamponade, retrograde filling of cement and pressurization). Reaming of the canal was done with a power tool in the SHP design, as recommended by the manufacturer. The corresponding preparation for the Lubinus stem was done using traditional reamers. In all stems, 28 mm heads were used. 38 patients received a head made of cobalt-chromium and 2 of aluminum oxide (both SP2). In one SHP stem, an original head could not be used due to misfit between the head and taper. These 3 implants

were excluded from the analysis of wear as well as one SP2, where interposition or lack of muscular tension distorted the measurements between the postoperative and first follow-up examination. The patients were mobilized on the day after surgery and received similar postoperative treatment.

The SP2 stems were prepared for radiostereometric evaluation by preoperative marking of the tip, the shoulder and the medial collar with titanium pegs, each with a 0.8 mm tantalum sphere countersunk into its tip. The SHP tip was marked as in the SP2 design, but no corresponding proximal marking was done, due to concern about weakening the material. Instead, 4 markers were placed in a small piece of cement, which was attached around the collar. In addition, the femoral head center was used as a prosthesis landmark (Baldursson et al. 1979, Kärrholm et al. 1997). Subsidence of the midpoint of the stem, the translations of the cup center and the rotations of the 2 components were calculated. In 7 SHP hips, micromotions of the cement with markers attached to the collar developed during the study; they were revealed by the analysis. In these cases, rotations could not be accurately measured during the entire period of observation. Therefore, the anterior (+) - posterior (-) translations of the femoral head center are also presented as an effect of these rotations. Finally, we evaluated the translations of the femoral head center, using the cup markers as a fixed reference segment to measure the femoral head penetration (here called wear).

We inserted 3–9 tantalum markers in the periacetabular bone, the cup, the femur and the cement. The cement markers could be visualized in 18 hips (4 SP2, 14 SHP), which permitted measurements of the stem migration in the cement mantle.

The postoperative RSA examination was done after 4–8 days (40 patients). Further follow-ups were done at 6 months (39 hips evaluated), 1 year (34 hips) and 2 years (39 hips) after the operation. The precision of the measurements was determined as the 99% confidence limits for significant translations and rotations, based on double examinations (Mjöberg 1986, Kärrholm et al. 1997; Table 2).

Conventional radiographs were obtained pre- and postoperatively and at 2 years. We assessed

**Table 2. Precision based on double examinations (99% confidence limits for significant motions)**

Type of motion	Cup migration n 37	Wear n 62	Stem migration n 35
<b>Translations mm</b>			
Transverse axis	0.13	0.20	–
Longitudinal axis	0.11	0.19	0.11
Sagittal axis	0.17	0.47	–
<b>Rotations degrees</b>			
Transverse axis	0.75	–	0.42
Longitudinal axis	0.62	–	0.76
Sagittal axis	0.21	–	0.30

the proximal distal positioning of the cup and its inclination (Nivbrant et al. 1996). On the femoral side, we evaluated the varus/valgus position of the stem, femoral offset, flair index, relative fill of the femoral stem, cement mantle quality, cement thickness at the tip and relative length of radiolucent lines (Noble et al. 1988, Barrack et al. 1992, Kärrholm and Snorrason 1993). The length and localization of radiolucent lines were related to the Dee Lee-Charnley and Gruen regions. All measurements were done on a digitizing table (Digi Pad, Orthographics, Salt Lake City, UT). The change in bone mineral density between the postoperative and the 2-year follow-up examination was measured in the 7 Gruen regions, using a Lunar DPX-L (Lunar Corporation, Madison, Wisconsin). The clinical results were evaluated, using the Harris hip score. One patient with SHP prosthesis refused to participate in the 2-year follow-up, but reported no symptoms from his hip at that time.

### Statistics

The study was designed to detect a difference in stem subsidence after 2 years of 0.2 mm based on the assumption of a SD of 0.2 mm in the 2 groups (> 80% probability). To reduce the effect of missing observations, the migration of the components and wear were statistically evaluated at 2 years only. We used the Mann-Whitney U-test in the comparison between the 2 groups and the Wilcoxon signed rank test to evaluate changes in radiolucent lines. To reduce the risk of spuriously occurring differences between the 2 groups, p-values less than 0.025 were regarded as representing a

Table 3. Cup migration at the 2-year follow-up

	n	Mean <sup>a</sup> (95%CL) <sup>b</sup>	Median <sup>a</sup>	Range	P-value <sup>c</sup>
<i>Cup translations, mm</i>					
<i>Medial (+)/lateral (-)</i>					
SP 2	20	-0.0 (0.1)	-0.0	-0.7-0.4	0.5
SHP	19	-0.1 (0.2)	-0.1	-0.9-0.6	
<i>Proximal (+)/distal (-)</i>					
SP 2	20	0.2 (0.1)	0.2	-0.3-0.8	0.02
SHP	19	0.4 (0.2)	0.3	-0.1-1.3	
<i>Anterior (+)/posterior (-)</i>					
SP 2	20	0.0 (0.1)	0.0	-0.5 - 0.4	0.08
SHP	19	-0.1 (0.1)	-0.1	-0.4-0.3	
<i>Cup rotations, degrees</i>					
<i>Anterior (+)/posterior (-) tilt</i>					
SP 2	20	-0.0 (0.2)	-0.1	-1.2-0.8	0.9
SHP	19	-0.0 (0.2)	0.0	-1.0-0.8	
<i>Ante- (+)/retroversion (-)</i>					
SP 2	20	-0.1 (0.3)	-0.1	-1.2-1.3	0.7
SHP	19	-0.1 (0.2)	-0.1	-0.9-1.1	
<i>Increased (+)/decreased (-) inclination</i>					
SP 2	20	-0.2 (0.2)	-0.2	-1.3-1.0	0.06
SHP	19	-0.7 (0.4)	-0.5	-2.5-0.5	

<sup>a</sup> Signed.<sup>b</sup> 95% confidence limits of the mean = standard error of the mean times 2.1-2.2, depending on the number of observations.<sup>c</sup> Mann-Whitney U-test.

Table 4. Stem migration at the 2-year follow-up

	n	Mean <sup>a</sup> (95%CL) <sup>b</sup>	Median <sup>a</sup>	Range	P-value <sup>c</sup>
<i>Stem translations, mm</i>					
<i>Proximal (+)/distal (-)</i>					
SP 2	20	-0.1 (0.1)	-0.1	-0.2-0.2	<0.0005
SHP	19	-0.6 (0.2)	-0.7	-1.7-0.5	
<i>Femoral head translations, mm</i>					
<i>Anterior (+)/posterior (-)</i>					
SP 2	20	-0.19 (0.2)	-0.1	-0.9-0.3	<0.0005
SHP	18	-2.5 (1.0)	-2.6	-7.4-1.7	
<i>Stem rotations, degrees</i>					
<i>Anterior (+)-posterior (-) tilt</i>					
SP 2	18	-0.1 (0.1)	-0.1	-0.5-0.5	0.2
SHP	13	-0.7 (0.8)	-0.2	-4.9-0.4	
<i>Ante- (-)/retroversion (+)</i>					
SP 2	18	0.3 (0.3)	0.2	-0.7-1.3	0.007
SHP	13	2.6 (1.4)	2.5	-0.6-2.4	
<i>Valgus (+)/varus (-) tilt</i>					
SP 2	18	0.0 (0.1)	0.0	-0.2-0.4	0.03
SHP	13	-0.0 (0.5)	-0.2	-1.1-2.4	

<sup>a</sup> Signed.<sup>b</sup> 95% confidence limits of the mean = standard error of the mean times 2.1-2.2, depending on the number of observations.<sup>c</sup> Mann-Whitney U-test.

significant difference. Stepwise linear regression was used to evaluate factors with a possible effect on the proximal-distal cup and stem migration.

## Results

### Radiostereometry

The SHP cups migrated more than the Lubinus cups in the proximal direction ( $p = 0.02$ ). The other parameters did not differ (Table 3).

The SHP stem subsided more than the control group ( $p < 0.0005$ ). At the 2-year follow-up, the mean and median values were 6-7 times higher in the SHP group (Table 4, Figure 2). Stem subsidence in relation to the cement mantle was evaluated in 18 patients. In 15 of these cases, all of this subsidence occurred in the mantle (11 SHP: -1.10 to -0.17; 4 SP2: -0.20 to -0.12 mm). In 3 SHP stems with distal migration of the stem relative to the bone between -1.18 and -0.36 mm, the cement mantle displaced distally -0.42 and -0.32 mm. In the third case (SHP), the subsidence of the mantle was smaller than the 99% confidence limit (-0.06 mm).

At the 2-year follow-up, the SHP stems had rotated more into retroversion than the SP 2 stems (median: 2.5° and 0.2°,  $p = 0.007$ ), corresponding to

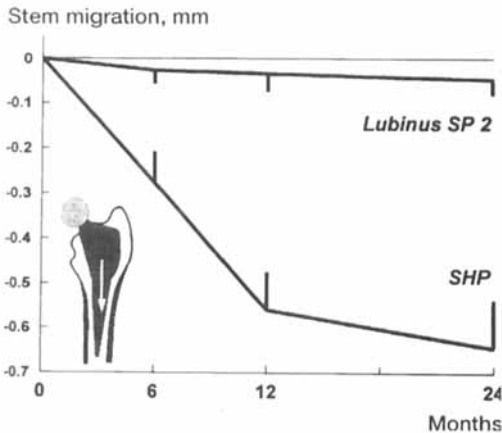


Figure 2. Proximal-distal stem migration (Mean, SE).

an increased posterior displacement of the femoral head ( $p < 0.0005$ ).

At 2 years, the mean and median values of proximal wear were about twice as high in the SHP as in the control group ( $p = 0.01$ , Table 5).

#### Bone mineral density

Between the postoperative and the 2-year follow-up, there was a tendency to a decrease in bone mineral density in most of the Gruen regions and especially medially (Gruen regions 6 and 7). No differences were detected between the 2 groups ( $p > 0.4$ , Figure 3).

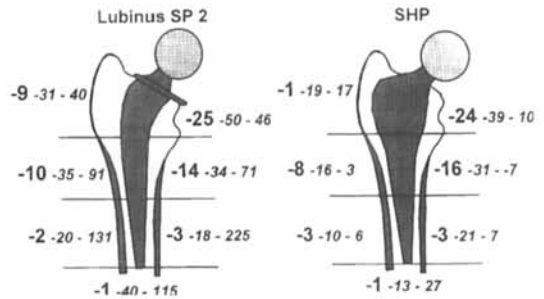


Figure 3. Change in bone density between the postoperative examination and the 2-year follow-up. Median percentages, range.

#### Conventional radiography

We observed postoperative radiolucent lines around the socket in both groups with no significant difference (Table 6). Between the postoperative and the follow-up examinations, the relative length of these lines increased in the SHP group ( $p = 0.003$ ), but not in the SP2 group ( $p = 0.2$ ).

The flare index, stem position, offset and proximal fill of the stem were the same in the 2 groups. As an effect of the shape of the SHP stem, the cement mantle became thicker in these cases. The SHP design was also associated with more radiolucent lines between the cement and the bone on the postoperative radiographs ( $p = 0.02$ ). These

Table 5. Wear at the 2-year follow-up

	n	Mean <sup>a</sup> (95%CL) <sup>b</sup>	Median <sup>a</sup>	Range	P-value <sup>c</sup>
<b>Wear, mm</b>					
<b>Medial (+)/lateral (-)</b>					
SP 2	17	0.0 (0.1)	0.0	0.1-0.3	0.1
SHP	19	0.0 (0.1)	0.0	-0.3-0.3	
<b>Proximal (+)/distal (-)</b>					
SP 2	17	0.1 (0.1)	0.1	-0.1-0.5	0.01
SHP	19	0.3 (0.1)	0.3	0.1-0.7	
<b>Anterior (+)/posterior (-)</b>					
SP 2	17	0.1 (0.1)	-0.1	-0.3-0.4	0.5
SHP	19	-0.1 (0.1)	0.0	-0.6-0.3	
<b>Three-dimensional</b>					
SP 2	17	0.3 (0.1)	0.3	0.1-0.6	0.05
SHP	19	0.4 (0.1)	0.4	0.1-0.7	

<sup>a</sup> Signed.

<sup>b</sup> 95% confidence limits of the mean = standard error of the mean times 2.1-2.2, depending on the number of observations.

<sup>c</sup> Mann-Whitney U-test.

Table 6. Results of the radiographic evaluation, median (range)

	SP2	SHP	P-value <sup>a</sup>
<i>Cup</i>			
Position of hip center, cm <sup>b</sup>	1.2 (0.9-2.5)	1.7 (0.8-2.4)	0.002
Inclination, degrees <sup>c</sup>	53 (44-65)	57 (44-67)	0.4
Radiolucent lines <sup>d</sup>			
Cup postop	5 (0-59)	2 (0-19)	0.8
Cup at 2 years	8 (0-26)	12 (0-30)	0.2
<i>Stem</i>			
Flare index	2.3 (1.2-2.9)	2.4 (1.4-3.3)	0.4
Varus angle of stem, degrees	2.0 (-0.2-4.0)	0.5 (-1.5-6.0)	0.2
Offset, mm	37 (22-48)	41 (34-54)	0.09
Canal fill %, proximal <sup>e</sup>	69 (39-74)	69 (59-76)	0.8
Canal fill %, distal <sup>e</sup>	58 (36-71)	39 (29-59)	<0.0005
Cement quality stem (A/B/C) <sup>f</sup>	11/9/0	11/7/1	1
Width of cement mantle, mm			
Calcar region	4 (0-6)	7 (2-12)	<0.0005
Distally-medially	3 (1-6)	4 (1-13)	0.002
Distally-laterally	3 (0-4)	5 (2-11)	<0.0005
Radiolucent lines <sup>d</sup>			
Stem postop	5 (0-16)	6 (0-27)	0.02
Stem at 2 years	4 (0-15)	5 (0-51)	0.2

<sup>a</sup> Mann-Whitney U-test.

<sup>b</sup> Proximal (+)/distal (-) position in relation to teardrop line

<sup>c</sup> Inclination for indicator wire. SHP has a 15° asymmetry to the real opening.

<sup>d</sup> > 1 mm wide in % of the interface

<sup>e</sup> Proximal or distal to medial tip of the lesser trochanter

<sup>f</sup> Barrack et al. 1992

lines were in most cases localized in regions 3, 4 and 5 and did not progress significantly.

### Regression analysis

The choice of a SHP cup was the only factor that had an influence on the proximal cup migration ( $r^2 = 0.1$ ,  $p = 0.03$ ). Factors related to the patient (age, gender, weight), the surgeon (learning curve) or the cup positioning on the postoperative radiographs did not reach statistical significance.

In the entire material, the choice of a SHP stem (adjusted  $r^2 = 0.44$ ,  $p < 0.0005$ ) and valgus position of the stem (increase of adjusted  $r^2$  to 0.52,  $p = 0.01$ ) were associated with subsidence. A separate analysis of the SHP group revealed that the subsidence increased as one proceeded in grades into poorer quality of the cement mantle, according to Barrack (adjusted  $r^2 = 0.3$ ,  $p = 0.01$ ).

Other factors related to the patient (age, gender, weight), the surgeon (learning curve) or the appearance on the postoperative radiographs (width of the femur or the cement mantle, canal fill, offset, postoperative radiolucencies) had no effect.

### Clinical results

The total hip and pain scores and the gain values did not differ (Table 1).

### Discussion

According to the regression analysis, the slightly increased migration of the SHP cup could only be explained by its design characteristics. Debonding of the cement from the polyethylene is probably extremely uncommon for most acetabular designs, but this type of event cannot be completely excluded because of the smooth backside of the SHP cup. However, it is more likely that this design will become surrounded by a cement mantle with a different thickness and penetration of the cement into the acetabular bone.

This view is compatible with the tendency to increasing radiolucencies between the postoperative examination and the 2-year follow-up. The manufacturer has added a circular groove in later designs, probably to address these problems and improve fixation.

In most previous RSA studies, the mean proximal wear of gamma-sterilized polyethylene articulating against 28 or 32 mm heads has amounted to about 0.1 mm/year during the 2 years after surgery (Kärrholm et al. 1997, Thanner et al. 1998, 1999). Polyethylene sterilized with ethylene dioxide seems to have a higher wear rate (Kärrholm et al. 1998). Thus, the proximal wear rate in our control group was very low, the lowest we know of from RSA studies so far. Lubinus SP2 prostheses with heads made of aluminum oxide have shown an almost equal rate of wear (Nivbrant and Kärrholm 1997).

Nonetheless, we documented an increased wear of the SHP cup. The randomized design of our study should reduce the risk of bias caused by different levels of activity in the two groups. Factors

such as different surface finish of the femoral heads or possibly a difference in quality of the raw polyethylene material might explain this observation. The increased migration of the SHP stem in the cement mantle indicates a risk of stem-cement abrasion and third body wear, which might be a reason as well. Different loading patterns of the cup is another but less probable explanation.

Stem subsidence in the cement mantle has been documented in retrieval studies, with variable frequencies of several prosthetic designs (Schmalzried et al. 1993). RSA studies also have shown early migration as an effect of motions in this interface (Thanner et al. 1995, Nivbrant and Kärrholm 1997, Alfaro-Adrian et al. 1999). The SHP stem represents a new concept, developed to optimize the distribution of stresses in the interfaces. Although tapered and without a collar, it was meant to maintain a stable fixation in the cement mantle. Nevertheless, the subsidence was higher than previously reported for any of the cemented designs studied with RSA, excluding the polished Exeter stem (Nivbrant and Kärrholm 1998, Alfaro-Adrian et al. 1999). This subsidence occurred mainly in the cement mantle.

The reason for this discrepancy between theory and practice is unclear. As regards the tapered Exeter stem, secondary stability after a small subsidence is believed to occur by closing forces from the cement mantle. The SHP is not entirely tapered and was supposed to stay fixed by its shape only. It is not meant to subside into a new stable position (Huiskes et al. 1998). A close to perfect cementing is anticipated in the finite element analysis, which constitutes a basis for the SHP design. Probably this is not often achieved and in such a situation debonding might obviously occur, which will create a new situation so far as load transfer is concerned.

Cement mantle shrinkage of about 5% during curing is one factor that can disturb early stabilization of the stem (Haas et al. 1975). Due to the thin distal part and the slightly smaller AP diameter of the SHP stem, the cement mantle will be thicker, eventually leading to more shrinkage. Since curing starts in the warmer bone-cement interface and continues towards the colder stem, a thicker mantle might imply increased porosity and susceptibility to microfractures in the stem-

cement interface (Bishop et al. 1996). Small air inclusions in the stem-cement interface at insertion also leads to a porous suboptimal interface (James et al. 1993, O'Connor et al. 1996).

A thicker stem with a wide collar might increase the pressure of the cement during its insertion and provide a better cement mantle. This theory, however, is inconsistent with our radiographic findings of the same quality of the cement mantle in the 2 groups. According to O'Connor et al. (1996), removal of the prosthetic collar increases the strains in the proximal part of the cement mantle. This might be one reason why the SHP design proved to be more sensitive to suboptimal cementing.

Failure of cemented stems is thought to start at the cement-stem interface (Jasty et al. 1991). Retrieval studies have also revealed debonding of femoral stems, which have functioned for several years without signs of progressive loosening (Schmalzried et al. 1993). This phenomenon has been explained as a partial and stable debonding of a stem, which probably occurs frequently (Verdonschot and Huiskes 1997b). In our study, subsidence may have been an effect of plastic deformation of the cement but, because the cement markers remained stable, it seems probable that the stem debonded from the cement and slipped in the mantle.

The magnitude of tolerable migration before clinical failure varies depending on the design. Clinical fixation failure and loosening of cemented and cementless stems followed with RSA have not only been associated with increased subsidence but also with rotation into retroversion (Nistor et al. 1991, Kärrholm et al. 1994). The estimated risk of loosening, based on measurements of implant migration, is based on calculations of the probability for a certain event. Thus, a subsiding implant will not necessarily become clinically loose. Nonetheless, we think that little, if any, subsidence during the postoperative 2 years is the best result in most cemented designs. The consistent RSA data on the Exeter stem indicate that some designs can function clinically well, despite a certain subsidence (Nivbrant and Kärrholm 1998, Alfaro-Adrián et al. 1999). The rather pronounced retroversion of the SHP stem is, however, an ominous sign, not least because we have re-

corded 50% smaller retroversion of the polished Exeter stem 1 year after the operation. According to the basic idea with the SHP stem, it should not migrate at all. Even if it probably will tolerate a certain amount of migration, there is a risk that motions of this stem in the mantle will induce osteolysis, as previously has been observed when using matte Exeter stems (Rockborn and Olsson 1993).

The amount of deformation of the cement before breakage in vivo is controversial. According to the calculations of Verdonshot and Huiskes (1997a), creep will only result in a subsidence of 50 µm, whereas subsidence might be considerably higher when allowed to occur for longer periods in vivo (Fowler et al. 1988). Thus, even if we noted subsidence of 1 mm or more in 4 SHP stems this does not necessarily mean that there are fracture lines extending to the cement-bone interface, even if this type of failure cannot be excluded.

We could not verify our hypothesis that the SHP implant was at least as stable as the SP 2 hip. The clinical effects of stem subsidence inside the mantle are difficult to predict and have so far been associated with inferior results in matte designs. In the choice between the SHP stem and other more well-documented designs, we think that the later alternative should be preferred, at least so long as our concerns are not contradicted by successful long-term results.

Financial support was obtained from the Swedish Medical Research Council MFR K98-17x-07941-12c and Anatomica Sweden and Biomet.

- Alfaro-Adrián J, Gill H S, Murray D W. Cement migration after THR. *J Bone Joint Surg (Br)* 1999; 81: 130-4.
- Baldursson H, Egund N, Hansson L I, Selvik G. Instability and wear of total hip prostheses determined with roentgen stereophotogrammetry. *Arch Orthop Trauma Surg* 1979; 95 (4): 257-63.
- Barrack R L, Mulroy R D Jr, Harris W H. Improved cementing techniques and femoral component loosening in young patients with hip arthroplasty. A 12-year radiographic review. *J Bone Joint Surg (Br)* 1992; 74 (3): 385-9.
- Bishop N E, Ferguson S, Tepic S. Porosity reduction in bone cement at the cement-stem interface. *J Bone Joint Surg (Br)* 1996; 78 (3): 349-56.
- Dall D M, Learmonth I D, Solomon M I, Miles A W, Davenport J M. Fracture and loosening of Charnley femoral stems. Comparison between first-generation and subsequent designs. *J Bone Joint Surg (Br)* 1993; 75 (2): 259-65.
- Espehaug B, Havelin L I, Engesaeter L B, Vollset S E, Langeland N. Early revision among 12,179 hip prostheses. A comparison of 10 different brands reported to the Norwegian Arthroplasty Register, 1987-1993. *Acta Orthop Scand* 1995; 66 (6): 487-93.
- Fowler J L, Gie G A, Lee A J, Ling R S. Experience with the Exeter total hip replacement since 1970. *Orthop Clin North (Am)* 1988; 19 (3): 477-89.
- Haas S S, Brauer G M, Dickson G. A characterization of polymethylmethacrylate bone cement. *J Bone Joint Surg (Am)* 1975; 57: 380-91.
- Herberts P, Malchau H. How outcome studies have changed total hip arthroplasty practices in Sweden. *Clin Orthop* 1997; 344: 44-60.
- Huiskes R, Boeklagen R. Mathematical shape optimization of hip prosthesis design. *J Biomech* 1989; 22 (8-9): 793-804.
- Huiskes R, Verdonshot N, Nivbrant B. Migration, stem shape and surface finish in cemented total hip arthroplasty. *Clin Orthop* 1998; 355: 103-12.
- James S P, Schmalzried T P, McGarry F J, Harris W H. Extensive porosity at the cement-femoral prosthesis interface: a preliminary study. *J Biomed Mater Res* 1993; 27 (1): 71-8.
- Jasty M, Maloney W J, Bragdon C R, O'Connor D O, Haire T, Harris W H. The initiation of failure in cemented femoral components of hip arthroplasties. *J Bone Joint Surg (Br)* 1991; 73 (4): 551-8.
- Kärrholm J, Snorrason F. Subsidence, tip and hump micro-movements of noncoated ribbed femoral stems. *Clin Orthop* 1993; 287: 50-60.
- Kärrholm J, Malchau H, Snorrason F, Herberts P. Micro-motion of femoral stems in total hip arthroplasty. A randomized study of cemented, hydroxyapatite-coated, and porous-coated stems with roentgen stereophotogrammetric analysis. *J Bone Joint Surg (Am)* 1994; 76 (11): 1692-705.
- Kärrholm J, Herberts P, Hultmark P, Malchau H, Nivbrant B, Thanner J. Radiostereometry of hip prostheses. Review of methodology and clinical results. *Clin Orthop* 1997; 344: 94-110.
- Kärrholm J, Nivbrant B, Thanner J, Malchau H. In vivo penetration rate of acetabular cups sterilized with ethylene dioxide or gamma radiation. *Trans Orthop Res, New Orleans* 1998: 783.
- Malchau H, Herberts P. Prognosis of total hip replacement. Revision and re-revision rate in THR: A revision risk study of 148,359 primary operations. Scientific Exhibition at the 65th AAOS meeting, New Orleans 1998.
- Mjöberg B. Loosening of the cemented hip prosthesis. The importance of heat injury. *Acta Orthop Scand (Suppl 221)* 1986: 1-40.

- Nistor L, Blaha J D, Kjellstrom U, Selvik G. In vivo measurements of relative motion between an uncemented femoral total hip component and the femur by roentgen stereophotogrammetric analysis. *Clin Orthop* 1991; 269: 220-7.
- Nivbrant B, Kärrholm J. Migration of hip prostheses fixed with a standard or a cold curing cement. *Trans Orthop Res*, San Francisco 1997: 309.
- Nivbrant B, Kärrholm J. Migration and inducible displacements of tapered stems with polished or rough surface. *Trans Orthop Res Combined*, Hamamatsu 1998: 209.
- Nivbrant B, Kärrholm J, Östen I, Carlsson Å, Snorrason F. Migration of porous press-fit cups in hip revision arthroplasty. A radiostereometric 2-year follow-up study of 60 hips. *J Arthroplasty* 1996;11 (4): 390-6.
- Noble P C, Alexander J W, Lindahl L J, Yew D T, Granberry W M, Tullos H S. The anatomic basis of femoral component design. *Clin Orthop* 1988; 235: 148-65
- O'Connor D O, Burke D W, Jasty M, Sedlacek R C, Harris W H. In vitro measurement of strain in the bone cement surrounding the femoral component of total hip replacement during simulated gait and stair-climbing. *J Orthop Res* 1996; 14 (5):769-77.
- Rockborn P, Olsson S S. Loosening and bone resorption in Exeter hip arthroplasties. Review at a minimum of five years. *J Bone Joint Surg (Br)* 1993; 75 (6): 865-8.
- Schmalzried T P, Maloney W J, Jasty M, Kwong L M, Harris W H. Autopsy studies of the bone-cement interface in well-fixed cemented total hip arthroplasties. *J Arthroplasty* 1993; 8 (2): 179-88.
- Thanner J, Freij-Larsson C, Kärrholm J, Malchau H, Wesslén B. Evaluation of Boneloc®. Clinical and mechanical properties, and a randomized clinical study of 30 total hip arthroplasties. *Acta Orthop Scand* 1995; 66 (3):207-14.
- Thanner J, Kärrholm J, Malchau H, Herberts P. Migration and wear in hydroxyapatite-coated porous cups with and without screw fixation. Combined Orthopaedic Research Societies Meeting, September 28-30, 1998, Hamamatsu, Japan.
- Thanner J, Kärrholm J, Malchau H, Herberts P. Migration of porous-coated press-fit cups with and without ceramic coating. Matched pairs evaluated with radiostereometry. *J Arthroplasty*. In press.
- Verdonschot N, Huiskes R. Acrylic cement creeps but does not allow much subsidence of femoral stems. *J Bone Joint Surg (Br)* 1997a ; 79 (4): 665-9.
- Verdonschot N, Huiskes R. Cement debonding process of total hip arthroplasty stems. *Clin Orthop* 1997b; 336: 297-307.
- Ypma J, Jaspers P, Huiskes R. New concepts in cemented hip arthroplasty, the SHP design, clinical and X-ray results. *EFORT* 1997: 617.