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ORIGINAL ARTICLE

Stem subsidence after total hip revision: 183 cases at 5.9 years follow-up

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KEYWORDS
Revision total hip arthroplasty;
Stress shielding;
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Summary
Introduction: Secondary subsidence of a revision femoral stem is often a negative predictive sign for successful osseointegration and perfect long-term stability.
Materials and methods: We performed a retrospective study in a series of 183 revision total hip replacements between 1996 and 2000 to evaluate the importance and risk factors of secondary subsidence with a cementless press-fit design femoral stem as well as this subsidence's consequences to osseointegration.
Results: Secondary subsidence did not occur in 80 cases (53%), was between 0 and 4 mm in 41 cases (27%); between 5 and 10 mm in 17 cases (12%) and was greater than 10 mm in 12 cases (8%). Mean subsidence of all patients was 3 mm (0—30). There was a statistically significant negative correlation between subsidence and the quality of osseointegration ($P = 0.03$). There was no significant relationship between component diameter and stem subsidence ($P = 0.9$). The presence of preoperative bone deficiencies did not increase the risk of secondary subsidence ($P = 0.2$).
Conclusion: In the case of revision with press-fit stems, the importance of secondary subsidence should not be overestimated, because it usually does not negatively affect satisfactory osseointegration.
Level of evidence: Level IV. Prospective study.

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Introduction

Radiological evaluation of the femoral component is usually limited to evaluating stability [1,2]. For Khalily and Witeside [3], the identification of a radiolucent line during assessment of osseointegration of a cementless femoral component suggests imminent loosening. Secondary subsidence of the stem should also be taken into account. For many authors [1,2,4,5], more than 5 mm of subsidence is a negative factor suggesting component instability; on the other hand, if there is no subsidence, satisfactory osseointegration and long-term stability should be guaranteed. In fact, interpretation of secondary subsidence of a femoral component depends on the design of the component. Thus, when subsidence occurs in a cemented stem without impaction grafting, there is a risk of failure of primary stabilization and the hip replacement itself. In stems cemented by the Exeter technique, the consequences are less systematic since the surgical technique was improved, [6]. In locking cementless stems, secondary subsidence is the sign of unsuccessful secondary fixation, especially if it is associated with ruptured screws. With so called 'fit and fill' designs, which generally include straight cylindrical femoral components with an extensive porous surface coating, primary stability is obtained in the diaphyseal femoral area by close contact between the host bone and the component. With these components, secondary subsidence of between 4 and 10 mm is not a good sign and usually indicates loosening [5].

''Press-fit'' designs use straight, cone shaped stems [7—9]. After obtaining bone-component surface contact, primary stability is obtained by a wedging effect which is supposed to create greater stress at the bone-component interface than the destabilizing forces on the femoral stem which include rotation and subsidence strains. [10]. In these cases, the consequences of secondary subsidence are usually less serious.

The aim of this study was to evaluate secondary subsidence in a revision straight press-fit stem component to evaluate the risk factors and determine whether this event negatively affected secondary osseointegration.

Patients and methods

Patients

We performed a retrospective study of 183 consecutive revision total hip replacements between April 1996 and December 200 (175 patients). Ten of these initial patients (6%) died for reasons unrelated to revision surgery and were excluded from the study. There were six patients (3%) lost to follow-up. Seventeen (9%) of the 160 remaining patients (167 cases) were only questioned by telephone. None of these patients underwent additional (re-revision) surgery and all of them had satisfactory autonomy with no groin or femoral pain.

A total of 150 hip replacements (82%), which corresponded to 142 patients, were included in this study (eight bilateral revisions) and underwent a complete clinical and radiological assessment by an independent observer (Table 1).

Table 1 Demographic characteristics and preoperative clinical assessment of patients.

Parameters	Number of patients (150)
Mean follow-up	5.9 (3—12)
Mean age	70 (38—93)
M/W	67 H/75 F (47%/53%)
Overweight patients (%)	63%
Harris score (pre and postoperative)	(22—67)/82.5 (44—99)
PMA score (pre and postoperative)	10.7 (4—14)/15.2 (8—17)
Devane classification	
Manual labor, sports	5 (3%)
Light activity	7 (5%)
Occasional activity	76 (51%)
Semi-sedentary	60 (40%)
Sedentary	2 (1%)

There were 75 women and 67 men (59 left hips and 91 right). Mean age was 70 years old (38-93). The level of activity of the patients was evaluated according to the Devane classification [11]: 2 patients grade 1, 60 grade 2, 76 grade 3, 7 grade 4 and 5 grade 5. Mean follow-up was 5.9 years (3-12).

In 79 cases, (53%) the cause of revision was aseptic femoral loosening; in 47 cases (31%) extensive femoral granuloma, in 21 cases (14%) a change in the femoral stem and revision due to a loose cup, allowing placement of new bearings. Finally, two cases were due to a periprosthetic fracture, and in one case rupture of the stem. In 23 patients (12%), loosening had occurred before (second case of loosening; 19 cases, third case of loosening: four cases). The explanted femoral stem was cemented in 140 cases (93%) and 19 cups were not changed.

Surgical technique

All operations were performed by the same surgeon (LBP). The surgical approach was anterolateral in 26 cases and posterolateral in 124 cases. The femoral approach was either entirely endofemoral (38 cases) or by trochanterotomy (8 cases) and in 104 cases a diaphysealtrochanter flap was performed. A flap was performed in the presence of significant femoral curving, difficulties extracting the cement during surgery or significant bone deficiency.

A straight, cone shaped, cementless modular femoral stem composed of a titanium alloy with a rough blasted surface was implanted (Revitan, Zimmer, Warsaw - USA).

Primary stability was obtained by press-fit effect to obtain an area of stability of at least 3 cm high. No bone graft was used. Whatever the surgical approach patients were allowed to partial weight bearing during the post-operative period using two crutches for two weeks.

Methods of assessment

The Harris [12] and Merle d'Aubigné (PMA) [13] scores were used for the clinical evaluation.

Table 2 X-ray assessment of osseointegration of femoral component.

Presence of radiolucent line	Assessment of proximal femur	Assessment of distal femur	Quality of osseointegration
Stage 1: line absent	10 points	10 points	20 points = Very good
Stage 2: line < 50%	7 points	7 points	17 points = Good
Stage 3: line > 50%	4 points	4 points	14 points = Average
			Less than 11 points = Poor

Anteroposterior (AP) X-rays of the pelvis as well as AP and lateral views of the entire femur were used for radiological assessment. Reproducibility of X-rays was confirmed based on criteria by Tannast et al. [14].

Evaluation of bone defects, based on the classification by Della Valle and Paprosky [15] was performed in 148 cases, the two periprosthetic fractures were excluded.

Stem subsidence was evaluated with two AP X-rays: one obtained immediately after revision surgery and the other at the final follow-up visit. The most distal cerclage wire or the middle of the lesser trochanter (if there was no metal wire) was used as the reference point. The reference point for the stem was the rim of the component. Calibration of measurements was standardized based on the fixed diameter of the metaphyseal-diaphyseal assembly area of the component (fixed diameter of 19 mm). Measurement of the distance between the femoral reference point and the rim of the stem was calculated on the two X-rays and the difference between the two represented subsidence in millimeters.

Osseointegration of the stem was evaluated according to the presence or absence of a radiolucent line along the stem. The femoral implant zone was divided into two equal parts: the proximal femur (corresponding basically to Grüen zones 2 and 6) [16]) and the diaphyseal femur (corresponding to Grüen zones 3 and 5). The extent of the radiolucent line was evaluated in each of these two zones and any line located at the rim of the component (Grüen zone 1) was not taken into account. No radiolucent line: 10 points; line present but covering less than 50% of the area being assessed: seven points; line covering more than 50% of the area: four points. Addition of the two values (proximal femur and diaphyseal femur) provided an evaluation of stem osseointegration: very good (20 points), good (17 points), average (14 points), poor (less than 11 points) [17] (Table 2).

Evaluation of the amount of osteoporosis was determined with the Cortical Index (CI) which is obtained by adding the thickness of the medial cortex to that of the lateral cortex divided by the diameter of the diaphysis, which is then multiplied by 100 [32]. CI results were grouped into four stages: very good if the cortical index was above 0.55; good between 0.45 and 0.54; average between 0.35 and 0.44; and poor if it was 0.34 or less [18]. The Cortical Index was evaluated in the middle third of the femur and the femoral neck.

The press-fit contact zone (area of primary stability corresponding to implant-bicortical bone contact surface) was evaluated. It could be proximal (that is metaphyseal or metaphyseal-diaphyseal), global (that is both proximal and diaphyseal) or diaphyseal (in the neck area). The press-fit effect could be absent and in this case, there were three contact points. The height of the diaphyseal press-fit zone was measured and evaluated in centimeters.

All quantitative radiological measurements were obtained with EvalNet software (LeadTools [Matesys]).

Statistical methods

Statistical analysis was performed using the statistical SPSS Version 16.0 software (SPSS Inc, Chicago, IL). The two groups were compared to determine whether variances were equal using the Levène test. Continuous variables were compared with the Student *t* test or analysis of variance (ANOVA test). Categorical variables were compared using the Chi^2 test. When the minimal effect was weak, the non-parametric Kruskal-Wallis test was used.

Results

Functional status was significantly improved in all patients. The mean preoperative clinical rate (PMA) went from 10.7 (4—14) to 15.2 (8—17) at the final follow up ($P < 0.001$). The mean preoperative Harris score was 47.1 (22—67) and 82.5 (44—99) at the final follow-up ($P < 0.001$). The greatest improvement was found in pain data (from 2.8 to 5.6 ($P < 0.001$)). Clinical results were not significantly different between the endofemoral approach group and the femorotomy group (HHS score at final follow-up 84.9 (44—98) in the endofemoral group and 81.4 (50—99) in the femorotomy group $P = 0.7$). Moreover, no significant difference was found in clinical scores (PMA or HHS) between the group with more than 10 mm of subsidence and the rest of the cohort.

Secondary subsidence did not occur in 80 cases (53%), was between 0—4 mm in 41 cases (27%), between 5—10 mm in 17 cases (12%) and was greater than 10 mm in 12 cases (8%). Mean subsidence for the entire cohort was 3 mm (0—30) (Table 3).

Classification of preoperative bone lesions included 62 patients (42%) with severe lesions (Stage 3 A and B and Stage 4 on the Della Valle and Paprosky scale [15]). The presence of significant bone deficiency did not increase the risk of secondary subsidence ($P = 0.2$).

Mean subsidence was markedly different between patients who underwent surgery by the endofemoral approach and those who were operated by femoral flap. Mean subsidence was 2.6 mm (0—20) by endofemoral approach and 3.2 mm (0—30) with a femoral flap. Nevertheless, there was no significant relationship between surgical approach and stem subsidence ($P = 0.7$).

Osseointegration was found to be very good in 94 cases (63%), good in 33 cases (22%), average in 17 cases (11%) and poor in 6 cases (4%). In the latter 6 cases, two were associated with aseptic loosening requiring revision. In the four

Table 3 Results of subsidence and osseointegration.

Parameters	Number of patients (150)
Secondary subsidence	
0 mm	80 (53%)
1—4 mm	41 (27%)
5—10 mm	17 (12%)
> 10 mm	12 (8%)
Mean (mm)	3 (0—30)
Osseointegration	
Very good	94 (63%)
Good	33 (22%)
Average	17 (11%)
Poor	6 (4%)

other cases secondary fixation was limited to the distal end of the component (Table 2).

The relationship between mean subsidence and the quality of osseointegration showed that in the groups with very good, good, average and poor osseointegration, mean subsidence was 2.6 mm, 4.4 mm, 1.6 mm and 7.3 mm respectively (Table 4). The 29 patients with more than 5 mm of secondary implant migration 24 (83%) had very good or good osseointegration. On the other hand, in the 23 patients with average or poor osseointegration — 18 (78%) had no (13 cases) or slight < 4 mm (4 cases) secondary migration. There was a statistically significant negative correlation between subsidence and the quality of osseointegration ($P = 0.03$).

The Cortical Index (CI) was considered very good or good (stages 1 and 2) in 53% of cases (80 patients) and average or poor (stages 3 and 4) in 47% of cases (70 patients). Subsidence was significantly different between patients with a very good or poor CI. Thus the mean risk of secondary subsidence was 4 mm (0—20) in hips with a very good CI and 2.5 mm (0—25) in those with a poor CI ($P < 0,05$). In addition, 28% (or at least 5 mm) of secondary subsidence was found in hips with a very good CI, compared to 10% in the group with a poor CI ($P < 0.05$). On the other hand, there was no significant relationship between subsidence and an average or good CI.

The mean length of the femoral component was 233 mm (195—325 mm). In 92 cases (61%), the length was less than 225 mm (''short'' stems) and in 58 cases (39%) it was more than 250 mm (''long'' stems). The mean diameter of components was 17.5 mm (14—22) and it was between 16 and 20 mm in 89% of the cases. Mean subsidence was the same (3 mm) for both these groups of patients. There was no significant relationship between component diameter and stem subsidence ($P = 0.9$).

The estimated press-fit area was proximal in 13 cases (9%), global in 17 cases (11%), diaphyseal in 89 cases (59%) and in 31 cases (21%) no press fit effect could be obtained (3 fixation points). There were no cases of subsidence greater than 10 mm and only 3 cases (10%) of subsidence between 5 and 10 mm when primary stability was proximal or global (mean subsidence 2.7 mm (0—8) and 1.1 mm (0—4) respectively). On the other hand, in the group with diaphyseal stability mean subsidence was the greatest (3.6 mm) (0—30) and the percentage of cases of subsidence of at least 5 mm was the highest (22%).

The mean height of the diaphyseal press-fit zone was 38 mm (15—75). There was no significant relationship between the height of the press-fit area and stem subsidence ($P = 0.7$).

There were 3 cases of secondary stem revision (1.6%) due to aspectic loosening in two and unsuccessful integration (revision with a longer replacement stem with a larger diameter) and in one case the metaphyseal component was changed due to significant subsidence (30 mm) with osteointegration of the diaphyseal part.

Discussion

Secondary subsidence of a cementless hip replacement is frequent and varies from between 2 and 20 mm depending on the author [19—21]. Böhm and Bischel [20] reported a mean subsidence of 5.9 mm with this type of stem, compared to a meansubsidence of 3 mm in our study. In our series, 29 patients (20%) presented with secondary subsidence of at least 5 mm compared to a rate of 16% reported by Paprosky [5] and Weeden [21] with ''fit and fill'' design stems.

Secondary subsidence is not serious with press-fit stems as long as it is moderate (less than 4 mm) [10]. Indeed there is a negative correlation between the amount of subsidence and the quality of osseointegration. Under these conditions the importance of secondary subsidence in radiological results in the studies by Engh and Massin [1] or Epinette [2], for example, are relative and should be placed in perspective. This subsidence is a result of the contact between the stem and cortical bone. Indeed, because the viscoelastic properties of cortical bone are different from that of the metal alloy of the stem, bone deformation may occur if it is submitted to stress (which always occurs when the press-fit component is wedged in place). [22,23]. This

Table 4 Radiographic results in relation to the quality of osseointegration, and implant subsidence.

Subsidence	Osseointegration			
	Very Good (20 points) $N = 94$	Good (17 points) $N = 33$	Average (14 points) $N = 17$	Poor (less than 11 points) $N = 6$
0 mm ($N = 80$)	49	17	11	3
1—4 mm ($N = 41$)	28	9	3	1
5—10 mm ($N = 17$)	12	2	3	0
> 10 mm ($N = 12$)	5	5	0	2
Mean subsidence (mm)	2.5	4.5	1.6	7.3

deformation can result in a reduction in surface contact pressure at the bone-component interface [23,24] and cause secondary subsidence. However, if the area of fixation is prepared correctly, and if a cone shaped stem is chosen, the risk of significant subsidence and instability is minimal because it can always be rewedged. According to Morscher one of the main advantages of a cone shaped press-fit stem is to provide ''a second line of defence'' [10].

Except for cases of inappropriate indications for press-fit stems (no diaphyseal femoral area) [8] significant secondary subsidence (more than 5 mm) is often due to technical errors during surgical procedure. It should be noted that in our series secondary subsidence usually occurred in femurs with a fairly healthy cortex, with little bone loss that were treated by femorotomy and a short stem stabilized in the diaphyseal region. These results (which may seem somewhat paradoxical because normally these conditions are favorable for revision surgery) do not necessarily mean that a long stem should be chosen to limit secondary subsidence. [25—27]. Indeed, a long stem has other well-known disadvantages (deficient proximal osseointegration, stress shielding, difficult or even impossible extraction) [28] and when a press-fit system is chosen, a flap can be indispensable if the femur is curved. This observation emphasizes the importance of carefully preparing the zone of fixation when primary stability is located in the area of the diaphyseal area, because to obtain a true press-fit effect the bone-implant contact must first be obtained on a surface [10]. This may be difficult to achieve with dense or thick cortexes.

Secondary subsidence can also be due to ineffective wedging of revision components during surgery [29]. This is a difficult point in surgery and it is not always easy to evaluate the quality of results during the procedure. Good wedging of the stem can be obtained by using the distal or intermediate part of the cone shaped area of the component, making it possible to repeat this manoeuvre and preventing the risk of significant subsidence.

In our series, secondary migration was limited in the presence of significant osteoporosis, which did not seem to negatively affect long-term fixation of this type of device. In this case, the design of the implant and the beneficial role of longitudinal sharp edged fins play a role in providing perfect stability by penetrating deeply into the endocortex [30—32]. Nevertheless, an osteoporotic femur is classically considered to be a contraindication to press-fit stems (risk of stress shielding) and a possible indication for locking femoral stems because the diaphysealfemoral area is often absent (cylindrical femur). [32].

In our study, there were no cases of more than 10 mm of subsidence and a relatively moderate percentage of cases between 5 and 10 mm (10%) in stems with primary stability in the proximal region or global stability (proximal and diaphyseal) [33]. These two types of primary fixation should be chosen whenever possible, in particular when the femur is straight and lesions from loosening are minor, or in the presence of significant osteoporosis.

Unlike the Warren [34] series, our study shows that internal fixation of the femorotomy flap does not prevent the risk of secondary subsidence in all cases. On the other hand, obtaining a ''global'' diaphyseal press-fit (by bringing the cortex in contact with the implant) and performing careful internal fixation of the flap, seem to be beneficial by limiting the extent of secondary subsidence (Table 2). Indeed, closing the flap on the component increases metaphyseal fixation. Systematic femorotomy is therefore advised when implanting a press-fit stem to increase primary stability and still have access to a straight femur with a healthy cortex. Finally, it should also be emphasized that three point fixation seems to create a risk of rotational instability especially since secondary subsidence, which would make rewedging of the component possible, is limited by the varus position of the stem.

Conclusion

The importance of secondary subsidence varies depending on the implant design. For ''Fit and Fill'' type components, or for screw system stems, secondary subsidence is often a negative sign. On the other hand, with revision cementless press-fit design cone shaped components, the importance of secondary subsidence should not be overestimated, because it usually does not affect osseointegration. Indeed, there is a negative correlation between the amount of subsidence and the quality of osseointegration.

Disclosure of interest

None.

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