International Orthopaedics (SICOT) (2012) 36:511–518
DOI 10.1007/s00264-011-1289-4

ORIGINAL PAPER

Primary total hip arthroplasty with dual mobility socket to prevent dislocation: a 22-year follow-up of 240 hips

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Received: 1 May 2011 / Accepted: 19 May 2011 / Published online: 23 June 2011

Abstract
Purpose The longest follow-up dual mobility series from inventor Gilles Bousquet focussing on implant survival and the incidence of dislocation.
Methods This was a retrospective study from 1985 to 1990, on 240 hips using a PF® modular femoral stem and a dual mobility Novae® tripodal socket (SERF).
Results The 22-year follow-up global survival rate was 74%. No dislocation occurred, 41 hips were revised, including ten retentive failures (RF), 12 hips were lost to follow-up, 87 patients (99 hips) died without revision, and 90 hips were still in situ.
Conclusion The dual mobility socket global survival rate is comparable to similar series. The 0% dislocation rate demonstrates the success of dual mobility with regard to implant stability. The main issues were cup fixation, which might be improved by the use of macrostructures and HA coating, and osteolytic lesions, caused by polyethylene wear. Traditionally suitable for patients older than 60 years, dual mobility might be extended for use in patients over 50.

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Introduction

Sir John Charnley introduced his total hip arthroplasty (THA) concept in 1962, using a cemented monobloc stainless steel femoral stem combined with an ultra high molecular weight polyethylene (UHMWPE) liner. Low-friction arthroplasty led the THA modern era with regards to its long-term survival rates. Nevertheless, this system highlighted drawbacks, such as a dislocation rate of a mean of 5% when a postero-lateral approach was selected [1], or osteolysis sometimes leading to aseptic loosening, occurring at median or long-term periods. Osteolysis is believed to result from UHMWPE wear [2].

In 1975, Gilles Bousquet proposed a modification in the Charnley concept by making the liner mobile in a metallic shell. This innovation, called dual mobility socket (DM), lowered dislocation rates while increasing range of motion (ROM) [3].

Retentive chamfer wear might cause what was called intraprosthetic dislocation or retentive failure, loss of contact between head and liner. As the liner is no longer retentive, liner and head have to be revised. If there had been no contact between head and metallic shell, replacement of the cup is not necessary. Another cause of concern was UHMWPE wear rate, this system added another articulation between liner and metallic shell.

Was this improvement on hip stability followed by similar to classical THA implant survival rates? A long follow-up study was needed to observe classical THA dislocation rate increasing with time.

This study evaluates DM-THA long-term survival and long-term dislocation rates thanks to a long series.

Materials and methods

Implant types

A total of 240 consecutive THA were performed in 205 patients younger than 75 years of age at the time of operation. Surgery was performed from October 1985 to January 1991. The median duration of follow-up was 22 years (minimum of 19, maximum of 24).

It was a retrospective study on patients undergoing primary THA only. Implants chosen were an association of the cementless screwed PF® stem and the cementless tripodal dual mobility Novae® system.

The PF® (femoral stem, SERF, Décines, France) was composed of a cementless screwed stem made of alumina (Al_2O_3) plasma-coated stainless steel, articulated with a modular monobloc neck-head component. The head diameter was 22 mm (Fig. 1).

The Novae® tripodal metal back (SERF, Décines, France) possessed, in addition to a press-fit fixation, a tripodal fixation, using two plots and a screw orientated in three orthogonal spatial planes [4]. The material used was also an alumina-coated stainless steel.

The Cestilene® UHMWPE liner (SERF, Décines, France) design offered, in addition to its mobility inside the metallic shell, a retentive chamfer. It prevents loss of contact between head and liner, called retentive failure (RF). Its molecular weight was about 4.5 mg/mol.

Preoperative data

The preoperative conditions of this study included: a gender ratio of 1.14 (128 males for 112 females); the average age of the patients, at the time of the surgery, was 55 years and eight months; the standard deviation (SD) was 11 years and ten months; and the body mass index (BMI) was 25.84 (SD 4.57). The diagnosis was primary arthritis for 161 hips (67%), developmental dysplasia of the hip in 29 hips (12%), osteonecrosis in 27 hips (11%), rheumatoid arthritis in six hips (3%), neck pseudarthrosis in nine hips in patients younger than 55 years with femoral neck fracture (4%) and hip arthrodesis in eight hips (3%).

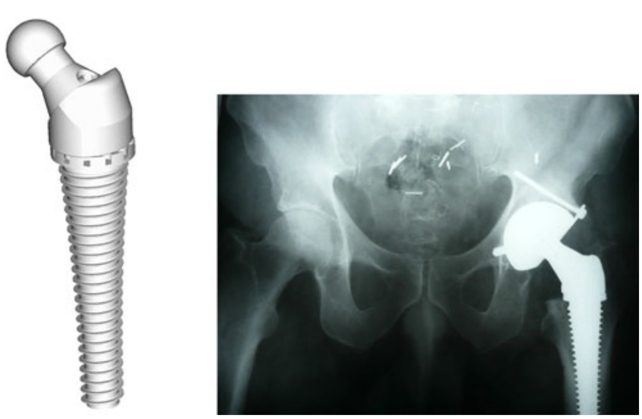

Fig. 1 3D and AP radiograph of PF® modular screwed stem (SERF, Décines, France)

Charnley, Devane, Postel & Merle d'Aubigne, and Harris scores were chosen on preoperative data. The Charnley score allowed ranking the hips in three classes: 154 hips were evaluated as Charnley A (64.2%), 68 as Charnley B (28.3%), and 18 as Charnley C (7.5%). The majority of patients exhibited a score of 3, in relation to usual preoperative data. Moreover, the preoperative Postel-Merle d'Aubigne average score and Harris hip score were 10.9 and 65, respectively (SD 4.72 and 10.3, respectively).

Clinical conditions and follow-up

Procedures were performed by the entire Centre surgical team from October 1985 to December 1990. Two approaches were selected for all patients: 199 hips by Moore approach and 41 by a Hardinge modified approach. It is worth noting that intraoperative complications were exclusively limited to femoral fractures in five hips (2%).

Finally, all patients underwent clinical revision at follow-up with Devane, Charnley, Postel-Merle D'Aubigne, Harris and Sedel [5] scores and, when possible, radiographical analyses of ossification, radiolucent lines, osteolytic zones and implant migration. No radiographical analysis software was used. Patients were not specifically recalled for this study.

Statistical analysis

GPL software R® was chosen for statistical analysis (http://www.R-project.org).

Kaplan-Meier survivorship analyses were performed for several end points as implant revision, aseptic loosening, retentive failure, or excessive liner wear of more than 4 mm. Confidence intervals of 95% (95% CI) were determined by Greenwood's algorithm.

Results

Immediate postoperative data

Concerning the metallic shell, average ideal hip centre offset was 4 mm medial (SD 6.6 mm) and 3.6 mm superior (SD 6.8 mm). The average cup inclination was 45 degrees (SD 8.2 degrees).

The average femoral lengthening was 3.9 mm (SD 8.1 mm), which caused an average leg lengthening of 0.3 mm (SD 8.1 mm). Finally, the average femoral offset was 4.9 mm (SD 9.3 mm).

Implant survival (Fig. 2)

The survival rate is submitted with the patient follow-up. Figure 2 presents the outcome of the 240 hips at 22 years of follow-up. From 240 explants, 128 represent the remaining cohort. An exhaustive analysis is detailed below.

A total of 89 hips, in 73 patients, had not been revised at the last follow-up (38.3%); 87 patients (99 hips) had died without being revised (41%), death occurring at an average time of 13 years and three months (SD 5.3 years) post implant. Twenty hips were revised for cup aseptic loosening (8.3%), occurring after an average of 11 years and five months (SD five years). Two hips in two patients were revised for septic loosening (0.8%), occurring after an average time of ten years and 11 months for one hip and one year and eight months for the other hip. Ten hips in ten patients were revised for retentive failure (RF, 4.1%) after an average time of nine years and 11 months (SD four years and six months).

Five hips in four patients were revised for excessive liner wear (2%) after an average time of 17 years and five months (SD six years and eight months). Five hips in five patients presented a failure of stem fixation (2%) that led to revision at an average time of one year and six months (SD of one year and one month). Twelve hips in ten patients were lost to follow-up (5%) at an average time of 45 days.

Global survival rate (Fig. 3) at an average follow-up of 22 years was 73.9% (95% CI 67.3–80.6%). It was 75.4% at 20 years of follow-up (95% CI 69.2–81.5%) and 81.4% at 15 years of follow-up (95% CI 76.2–86.6%).

Survival rate considering femoral revision as end point (Fig. 4) was 92.5% at 22 years of follow-up (95% CI 89–96%). It was identical at 20 years, and 93.3% at 15 years (95% CI 90.1–96.5%).

Survival rate considering cup or liner revision as end point (Fig. 5) was 80.0% at 22 years of follow-up (95% CI 73.4–86.4%). It was 81.5% at 20 years (95% CI 75.6–87.4%) and 89% at 15 years (95% CI 84.7–93.4%).

Survival rate considering cup aseptic loosening as end point was 88.3% at 22 years of follow-up (95% CI 83.4–93.2%). It was identical at 20 years, and 93.3% at 15 years (95% CI 89.8–96.8%). Survival rate considering retentive failure as end point (Fig. 6) was 94.5% at 22 years of follow-up (95% CI 91.1–97.9%). It was identical at 20 years, and 95.9% at 15 years (95% CI 93.2–98.7%).

No patients radiologically evaluated at final follow-up showed any sign of femoral or acetabular loosening.

The relation between age at the time of the surgery and revision rate was studied (Fig. 7).

The highest revision rate was for the group below 30 years, up to 45% for the cup or liner revision. From 50 to 70 years, the revision rate was almost equal to 10%.

Clinical and radiological evaluation at last follow-up

Clinical evaluation

First of all, it is worth noting that no THA dislocation occurred.

At the last follow-up, 73 living patients (89 hips) had not been revised and were clinically evaluated. None suffered from thigh pain.

The clinical score evolution was investigated from the 73-patient cohort. From the last follow-up, the average Devane score was of 3 (SD 1). PMA score at last follow-up was 16.9 (SD 1.9). Last follow-up Harris Hip Score was 92 (SD 8.4).

Last follow-up radiological analysis

The last follow-up of the radiological analysis was investigated on 62 patients from 89 hips. Twenty-seven hips were lost to radiological follow-up. This kind of investigation needs motivated patients who are willing to respond to the demand from the surgical team. Unfortunately, some patients were not open to follow an additional surgical examination for various reasons, i.e. poor patient health or the lack of health insurance.

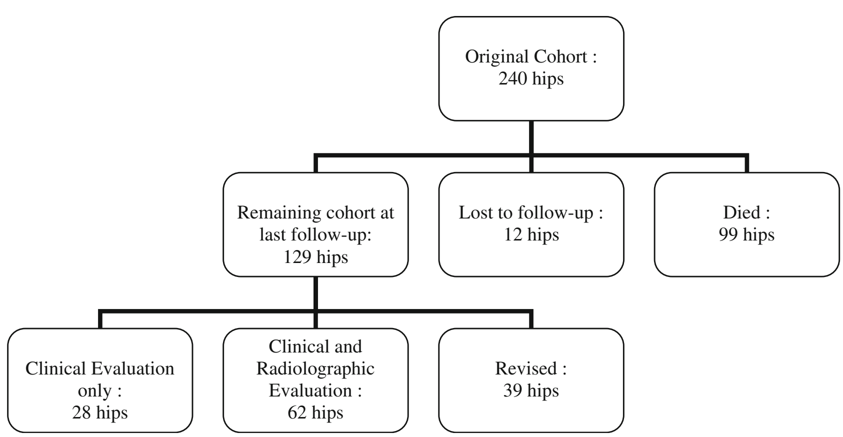

Fig. 2 Outcome of the 373 240 hips at 22 years of follow-up

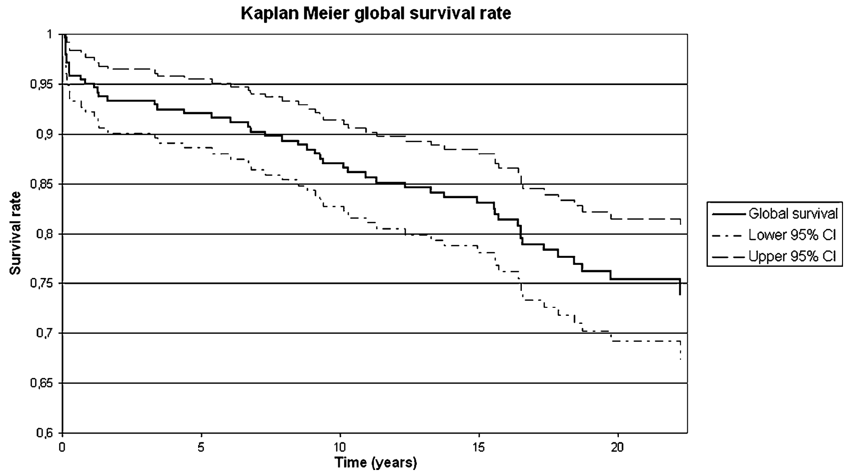

Fig. 3 Kaplan-Meier survivorship curve showing the series global survival rate, with 95% confidence intervals (Greenwood algorithm)

For 56 hips (90.3%), the Sedel score was A, two patients were Sedel B (3.2%), and four patients were Sedel C (6.5%).

Considering femoral osteolysis, in Gruen zone 1 we found osteolytic lesions with a mean of 3.2 mm wide (SD 2.1 mm). In zone 7, mean osteolytic lesions were 0.7 mm wide (SD 1.2 mm). No radiolucent line was found in other Gruen zones. Considering the acetabulum, two osteolytic lesions in zone I of De Lee and Charnley (3%) and six zone III osteolytic lesions (10%) were noticed. No implant loosening was found. A broken screw was found in one of the hips with the zone I osteolytic zone previously mentioned.

The average Brooker score was 1.2 (SD 0.5) for the 62 hips.

Patients younger than 50 years of age at the time of the surgery

This population is the most demanding in terms of implant lifetime. This patient category contained 59 patients (69 hips).

Nine aseptic loosenings were found (13%). There were also eight RFs (11.6%), three revisions for excessive liner wear without implant loosening (4.3%), and one failure of femoral stem fixation (1.4%).

Differences between this category and the rest of the patients were all statistically significant, with $p<0.001$, except for the failed femoral stem fixation, where age did not seem to be a relevant factor.

Discussion

Dislocation rate

In this clinical series, we observed no dislocation on 240 hips (0%).The dislocation rate was similar in our previous studies [4, 6, 7]. This rate did not increase in time, unlike the other THA concepts using polyethylene bearings. On over 450 THA [4], this rate of 0% still stood. No other THA concept has this kind of result on THA stability, not even large head diameter metal-on-metal or ceramic-on-ceramic THA series.

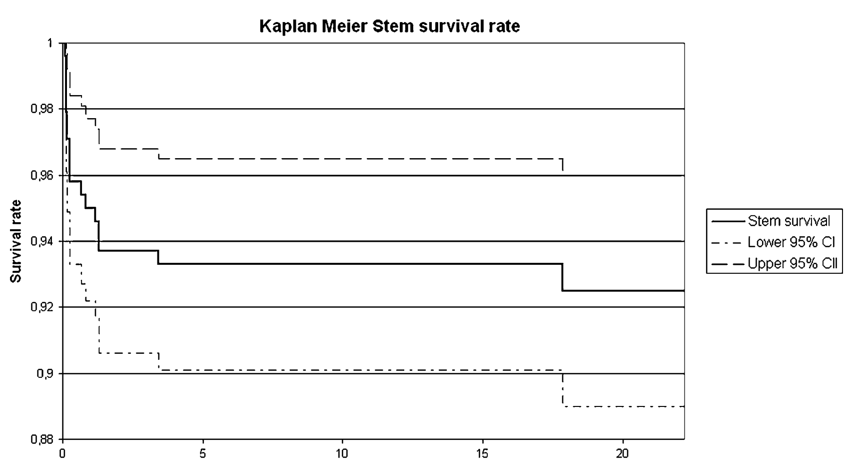

Fig. 4 Kaplan-Meier survivorship curve showing stem revision as the end point, with 95% confidence intervals (Greenwood algorithm)

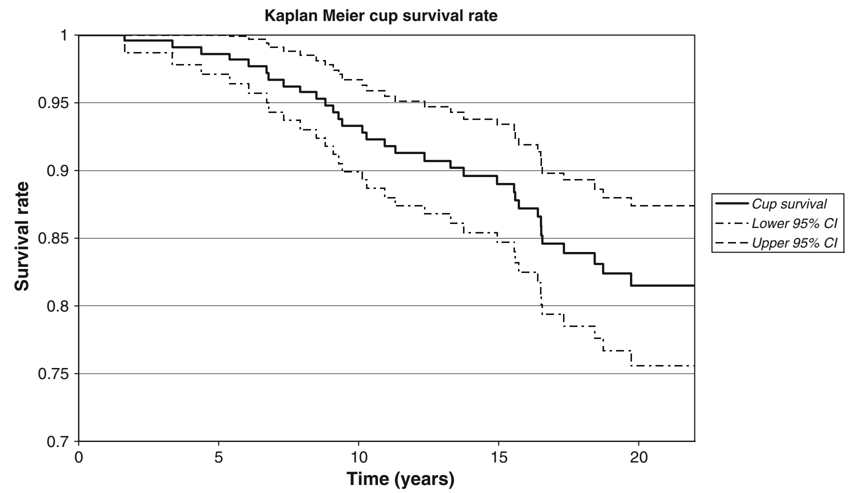

Fig. 5 Kaplan-Meier survivorship curve showing cup survival as the end point, with 95% confidence intervals (Greenwood algorithm)

Implant survival (Tables 1 and 2)

If we compare our series to other cementless THA series [8–17], or cemented THA series [19–22], our series survival rate was similar. Mean global cementless THA survival rate was less than 80% at 15 years (from 76 to 88%). Our series showed 81.4% survival rate at 20 years; 20–25-year survival rate of cemented implants was similar, concerning every cause of revision, or aseptic loosening only. Log-rank comparison was not possible. Global survival rate varied from 66.2% for Nercessian [19] at 19 years to 80% for Callaghan [20] at 25 years.

When fixation failure was not an issue, stem survival was remarkable, which shows the efficiency of the screwing process on long periods of implantation. Screwed stem revision only occurred during the first two years, as a sign of a poor primary fixation.

Cup survival rate is known to be lower than stem survival, with a mean of 85%, and varies from 36 to 95%, which may emphasize the interest of the fixation choice (cement, screwing, macrostructures, coating, etc.).

The Lord screwed metallic shell had a 65% survival rate at 17.5 years for Grant and Nordsletten [14].

For cemented shells, survival rate considering cup or liner revision as end points was 87% for Berry et al. [18] at 25 years.

Our series had a survival rate for cup or liner revision as end points of 80%. Aseptic loosening survival rate was 88.3%. We believe this last survival rate to be more adequate for studying acetabular fixation, revision for liner wear or RF not leading to cup revision, but only to a bearing material change.

These results were obtained with a surface processing, which is now not considered to be optimal. Alumina-only coating has been abandoned, and the Novae® tripodal shell did not possess macrostructures.

We also have a different attitude than many authors concerning radiological loosening. Many Charnley THA patients presented radiological loosening, but were not revised. For example, 19% of the stems and 16% of the

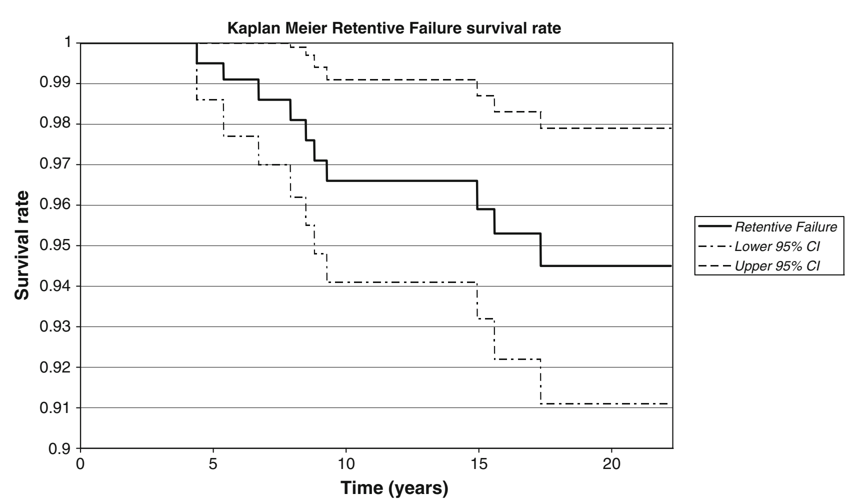

Fig. 6 Kaplan-Meier survivorship curve showing the onset of retentive failure (RF), with 95% confidence intervals (Greenwood algorithm)

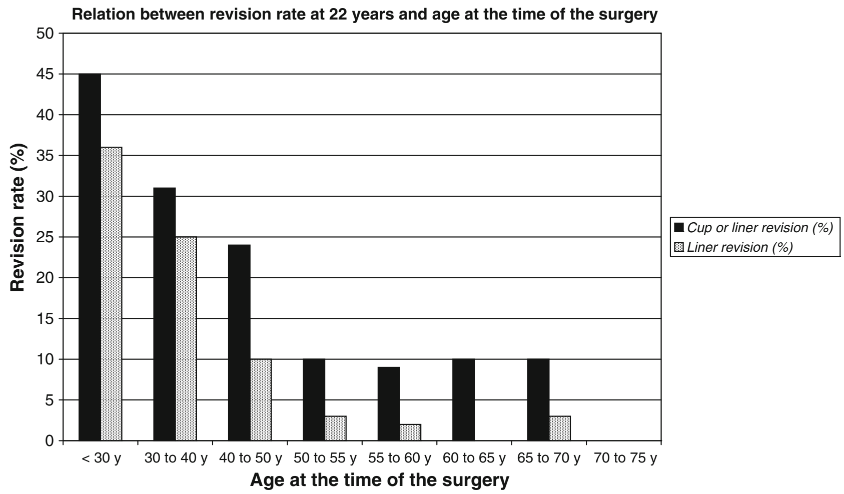

Fig. 7 Relation between revision rate at 22 years and age at the time of the surgery

Table 1 Uncemented long follow-up THA series comparison

Series	Hips	Follow-up (years)	Stem	Cup	Cup survival (95% CI)	Stem survival (95% CI)	Global survival
Aldinger et al. [8]	154	17	CLS	Mecron 67%, Weill 27%, cemented 4%	Mecron 38% (26–50), Weill 68% (54–82)	90% (87–97) AL 95% (91–99)	-
Kim [9]	131	19.4	PCA	PCA	79% (73–100)	91%	80% (−)
Hallan et al. [10]	11516	15	14 stems 47% Corail	-	-	Corail 97% (−)	-
Rajaratnam et al. [11]	331	17.5	Furlong	Cement 217, uncemented 114	-	97.4% (94.1–99.5)	-
Yoon et al. [12]	157	17.2	Autophor	Biolox CoC CST C/PE	81% (77.9–84.1), 74.4% (71.5–77.3)	94.5% (91.9–97.1)	78.7% (75.1–82.3)
Martinez and Keisu [13]	114	21	Lord	Lord	-	83% (69–97)	-
Grant and Nordsletten [14]	116	17.5	Lord	Lord	65% (53–72)	98% (95.3–100)	-
Grübl et al. [15]	208	15	Zweymüller	CSF	85% (79–91)	98% (96–100)	-
Bojescul et al. [16]	100	15.6	PCA	PCA	83% (−)	92% (−)	76% (−)
Della Valle et al. [17]	204	20	151 HG I 39 cemented 14 Gustilo–Kyle	Harris–Galante I	86% (83–89), AL 96% (94–98)	68% (64–72)	-
Vielpeau et al. [18]	437	16.5	Charnley	Novae	84.4% (80–89)	-	-
Farizon et al. [7]	135	11	Screwed PIM/PF	Novae	95.4% (92–98.8)	100%	95.4% (92–98.8)
Philippot	384	17	Screwed Profil/PF	Novae/Novae Ti	93.3% (92.6–100)	-	89.2% (80–98)
Our series	240	22	Screwed PF	Novae	80% (73.4–86.4), AL 88.3% (83.4–93.2)	92.5% (89–96)	74% (67.3–80.6)

AL aseptic loosening, *CoC* ceramic on ceramic, *C/PE* ceramic on polyethylene

Only series with more than 100 hips and at least 15 years of mean follow-up were included, with the exception of the historical dual mobility series from Farizon et al.

Table 2 Cemented long follow-up THA series comparison

Series	Hips	Follow-up (years)	Stem	Cup	Cup survival (95% CI)	Stem survival (95% CI)	Global survival
Nercessian et al. [19]	447	18.9	Charnley	Charnley	-	-	66.2% (60.5–71.9)
Callaghan et al. [20]	330	30	Charnley	Charnley	AL 84% (77–91)	AL 92% (86–98)	77% (69–84)
Sochart and Porter [21]	226	19.7	Charnley	Charnley	68% (61–75)	81% (76–87)	54% (39–69)
Berry et al. [22]	2000	25	Charnley	Charnley	87% (84.6–88.9)	84.6% (82.3–86.7)	77.5% (74.9–80.3)

AL aseptic loosening

Only series with more than 100 hips and at least 15 years of mean follow-up were included.

metallic shells were radiologically loosened for Callaghan et al. at 25 years [20], when only 10% of the stems and 7% of the cups were revised. We consider radiological loosening as an indication for surgical revision, as osteolysis progresses at least linearly, so an early revision on adequate bone stock presents more chances of success and a better functional prognosis for the patient.

These remarks seemed to be confirmed by the Sochart and Porter [21] study on THA on young patients. Global survival rate was 54%.

The dual mobility socket possesses a specific complication, linked to retentive chamfer wear, which is retentive failure.

Vielpeau et al. [18] analysed 435 DM THA hips at a mean 16.5-year follow-up. The main difference between the two series was Caen's team choice of a cemented Charnley stem. Stem survival rate was not mentioned. Cup survival rate was quite similar (84%). There seemed to be fewer RFs for Vielpeau et al. (0.9% versus 4%), although the high incidence of 21% of patients lost to follow-up in this series prevented comparison of the two rates. A plausible hypothesis for this lower RF rate might be the thinner Charnley neck, versus the massive PF® neck, the latter causing more chamfer demands in every day range of motion.

RF seemed to occur later in our study than in the study from Philippot et al. [4], which studied the Profil® titanium screwed stem. There is no statistical difference concerning RF between the two groups.

In the previous series of 384 cases from Philippot et al. [1], with a shorter follow-up and 160 PF® stems, we noticed 14 RFs (or IPDs). Two screwed stems (PF®, 316 L stainless steel large neck, and Profil®, Ti6Al6V slender non polished neck) were used, and two materials for the metallic shell. No significant difference was found between the groups: PF-Novae 316 L, Profil-Novae Ti, and Profil-Novae 316 L. The two series were too different in size and population to be compared directly, but it might be interesting to increase the follow-up of the Profil stem sub-group in the series from Philippot et al., to compare both screwed stems, PF and Profil. Neck wideness, roughness and materials could be important factors in the occurrence of RF.

Analysis of patients of less than 50 years of age at the time of the surgery showed a higher complication rate. This significant difference could be linked to a more intense bearing solicitation, leading to polyethylene wear. The cup or liner revision rate, higher for patients of less than 50 years of age at the time of the surgery, dropped drastically between 50 and 55 years, then stagnated. The liner change rate also decreased more abruptly from this age. Standard common practice considers dual mobility socket to be only an option for patients older than 60 years, since the Societe Française of Chirurgie Orthopedique & Traumatologique (SOFCOT) 2006 symposium [4]. This concept might be extended to patients from 50 to 60 years.

There was no revision on patients older than 70 years at the time of the surgery, which could predict dual mobility socket success in this population, which is also the population liable to implant dislocation.

Conclusion

This study of the dual mobility socket concept confirmed the ability of this system to prevent THA dislocation, whether over the short- or long-term. No other hip implant, even the use of large head diameter implants, can boast of such a low dislocation rate. The absence of dislocation on more than 450 operations performed confirmed Gilles Bousquet's intuition.

Survival analysis did not show higher cup revision rates than more classical THAs. Metal shell survival is influenced by the bone–implant primary fixation. The Novae® design used for the study did not possess macrostructures; also, stainless steel was only coated with Al_2O_3. Macrostructures, titanium-coating and HA might improve implant long-term survival.

The other aspect of implant survival concerns periprosthetic osteolysis and its relation to wear debris [2]. As osteolysis is known to be linked to annual wear volume, improvements have been necessary concerning the liner material. Cestilene® polyethylene was replaced by a UHMWPE with a higher density. Liner design was also modified. The dual mobility socket is our choice for patients older than 60 years of age at the time of the surgery, or at risk of dislocation. Long-term survival for young patients without a high risk for dislocation, though comparable to other similar series, was low.

Nowadays, some manufacturers are working out new liner designs to improve the survival rate, and to extend dual mobility socket indication to younger patients. Before manufacturing new DM implants, additional investigations seem necessary. A multi-scale dual mobility explant retrieval analysis, focussing on the understanding of the system wear mechanisms, will be conducted.

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