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ORIGINAL PAPER

Short-stem total hip arthroplasty is equivalent to a standard-length stem procedure in an unselected population at mid-term follow-up

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Abstract

Purpose Limitations of standard-length femoral stems persist, including proximal-distal mismatch, non-ideal load transfer, loss of bone tissue, and perioperative fracture. Symbol® (Dedienne Santé, France) is a metaphyseal-engaging short-stem implant designed to address these issues in total hip arthroplasty (THA). While short stems have been well studied in selected and younger patients, it is unclear whether they offer advantages in an unselected population. We hypothesized that short femoral stems offer similar mid-term survivorship at five year minimum follow-up and function score to standard-length femoral stems, in an unselected patient population.

Methods We retrospectively reviewed a continuous unselected cohort of patients who undergone THA by one surgeon with a standard-length stem between November 2013 and October 2015, and a short stem between November 2015 and March 2017. We compared modified Harris Hip Score and Oxford Scores with a minimum follow-up of five years and procedural factors that could be associated with worse results with a short stem design.

Results There was no difference in survival rate between the two groups. Average Harris Hip Score and Oxford Scores at the last follow-up were comparable. A multivariate linear regression was performed to assess the relationship between modified Harrys Hip Score at five years post-operatively and the explanatory variables: age, body mass index, physical status score ASA (American Society of Anesthesiologists), and HHS pre-op. None was associated with the standard-length stem but for the short stem.

Conclusion Short-stem implants provide good survival rate at mid-term; nevertheless, a steep learning curve is necessary to optimize the metaphyseal filling of the implant, especially for osteoporotic bone.

Keywords Hip arthroplasty · Short stem · Survival rate · Learning curve

Introduction

Total hip arthroplasty (THA) is one of the most successful and established procedures performed by orthopaedic surgeons worldwide for end-stage arthritis of the hip, available for all patients, both old and sedentary, and young and active. Nevertheless, current research and development of the biological and mechanical design of modern total hip prostheses continue to strive, to improve results and survival rates.

For years, a multitude of published studies report overall survivorship of several standard-length tapered femoral components ranging from 94 to 100%, at up to 20-year follow-up. Over the past decades, femoral fixation with tapered-geometry designs has evolved and shorter stem protheses have been implemented and are nowadays increasingly used in clinical practice. There are several advantages of shorts stems allowing for rapid-recovery protocols including smaller incisions, simpler femoral preparation, and less invasive surgery. Biologically, they facilitate a better bone-conserving procedure, allowing for more favorable conditions in the potential revision setting. Numerous variations of short-stem devices have been

Level of Evidence Level III, therapeutic study.

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designed. Earlier studies have shown that short stems have similar risks of revision, as well as comparable fixation and clinical outcomes at short term to conventional length stems, mostly in a young patient population [1].

Despite increased use of short femoral stems, it remains unclear whether short femoral stem designs can achieve comparable mid-term clinical results to traditional stems for all patients. Some authors observed an increase thigh pain in some patients, as well as radiographic concerns regarding bone fixation of the short stem [2]. Symbol® stem is a short stem with a design specifically studied to be adapted to the tri-dimensional geometry of the proximal femur [3].

The purpose of this study is to analyze survival rate at mid-term of the Symbol® short stem in an unselected patient population, and to identify patients' characteristics and/or procedural factors that are associated with worse outcomes with a short-stem design. Our hypothesis is that a proportion of patients treated with a metaphyseal anatomical short-stem THA femoral component have similar functional results and functional score to patient who undergone THA with a standard-length femoral component, irrelevant to the patient status and background.

Method

We performed a single-centre (one senior surgeon) retrospective analysis of consecutive patients who have undergone a primary THA between November 2013 and March 2017 in order to have a minimum follow-up of five years, representing 301 consecutive THA. All patients were managed with a rapid recovery protocol and THA was performed in all cases by a minimal invasive postero-lateral approach. Post-operatively, all patients were allowed full weightbearing as tolerated with a walker or crutches immediately after the operation and were advised to progress to a cane and eventually without any ambulatory assistance once they were pain-free and limp-free.

Between November 2013 and October 2015, 150 patients have undergone primary THA using a standard-length tapered, titanium femoral component Libra (Serf®, France). Between November 2015 and March 2017, a short-stem femoral component Symbol® (Dedienne Santé®, France) was used in 151 patients (Fig. 1).

Libra® stems are usual Corail® — like stems. These are straight femoral stems, either cementless in titanium alloy and coated with hydroxyapatite or cemented with a highly polished high-nitrogen stainless surface, with or without support. The design relies on a well-known and proven concept of conical shape and quadrangular section with a view to enhancing the primary and secondary distal and proximal femoral fixation. A progressive increase in

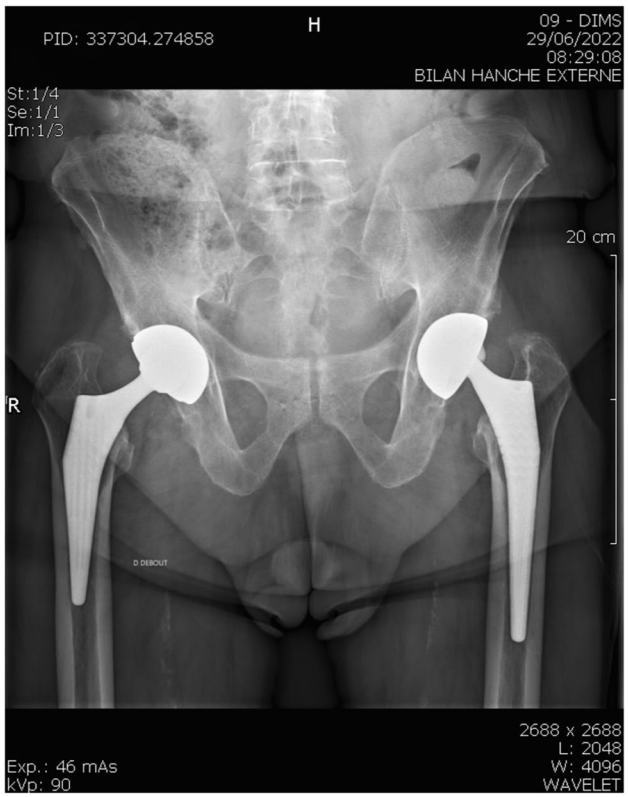

Fig. 1 X-ray with a Libra stem on the left side and a Symbol stem on the right side

neck length to fit the needs of a large population, with standard or lateralized, collared or collarless, version with a cervical angle of 130° is available.

Symbol® (Dedienne Santé, France) stem is a straight shortened titanium collar or collarless stem with several options, uncemented (in TA6V titanium alloy (ISO 5832-3 Standard) with hydroxyapatite circumferentially totally coating) or cemented (stainless stem with nitrogen M30 (ISO 5832-9 standard)) with for each a standard (130°) or lateralized (120°) option. The Symbol® stem was developed after the study of more than 200 scans. The objective was to define the intra- and extra-medullary characteristics of the implants in order to reproduce the femoral anatomy. This three-dimensional anatomical analysis of the femur bones and the synthesis established from the simulation of implantation allowed approval of a family of neutral, straight, and shortened femoral stems with a proximal metaphyseal anchor to respond as simply as possible to all existing morphotypes. The offset and the length of the collar, meanwhile, progress homothetically from size to size. The length of the collar increases with the size of the stem and is suitable for Vara stem.

The femoral component was implanted with a 32- or 36-mm modular head impacted acetabular component and a Delta ceramic insert or with 28- or 32-mm modular

cobalt-chrome head and a double-mobility acetabular component with a highly cross-linked polyethylene.

All the procedures used the design reviewed here and no patient undergoing primary THA was selectively treated with another prosthetic design.

At more than 5 years of follow-up, 51 patients had died, and 28 patients were lost to follow-up. Thirteen have undergone another hip intervention and were excluded. A total of 209 living patients not lost to-follow-up were included in the analysis (Fig. 2).

Follow-up clinical evaluation of the patients included the modified Harris Hip Score (HHS) and Oxford Score. Scores were obtained pre-operatively and at the last clinic visit with a minimum of five years of follow-up. Patients were offered the surveys over the phone or answered them alone (on paper or through Internet). For the HHS and the Oxford Score, a higher score reflects higher function.

We were interested to see if the HHS and Oxford Scores were correlated with any of the patient demographics specifications. Pearson correlation coefficients were calculated for continuous categories: age, body mass index (BMI), physical status score ASA (American Society of Anesthesiologists), and Oxford Score.

The normality was not verified with the Shapiro-Wilk test. The difference between pre-operatively HHS and Oxford Score and HHS and Oxford Scores at five year follow-up was assessed with the Wilcoxon signed-rank test. A multivariate linear regression was performed to assess the relationship between HHS at five years post-operatively and the explanatory variables: age, BMI, ASA, and pre-operatively HHS. Data were checked for multicollinearity with the Belsley-Kuh-Welsch technique. Heteroskedasticity and normality of residuals were assessed respectively by the Breusch-Pagan test and the Shapiro-Wilk test. A p-value < 0.05 was considered statistically significant. Patients with missing data were excluded from the analysis.

Results

Population (Table 1)

The two groups were similar in age, body mass index, sex, ASA, and aetiologies. No intraoperative complications (fractures) occurred with both stems.

Survival rate and functional score at least five year follow-up

The survival rate at five years for Symbol® stem in an unselected population was 95.9%. The three revisions appeared in the first 30 surgeries with one increased off-set, one aseptic stem loosening, and one septic loosening of cup and stem. Survival rate with the standard-length tapers Libra® was 93.3%. There was no significant difference in survival rate between the two groups.

Between groups, there was no significant difference in pre-operative or post-operative HHS or Oxford Scores at five year follow-up. For Libra®, median pre-operatively HHS and at five year follow-up were respectively 62.7 (SD, 14.3) and 97.9 (SD, 9.07). The median difference was −34.1 (SD = 18.42 ; CI95% = [−39.05; −31.9]; p<0.001). For Symbol®, the median pre-operatively HHS and at 5five years were respectively 61.6 (SD, 13.2) and 95.7 (SD, 12.1).

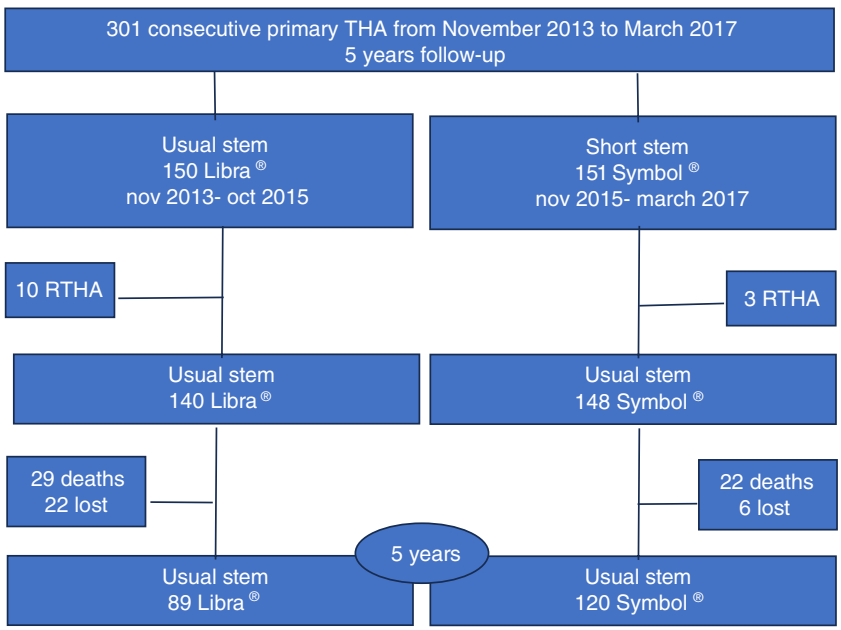

Fig. 2 Flow chart

Table 1 Demographic data of the cohorts

Stem	Total number of patients (%)	Female/male (%)	Average age at surgery and % of them with age > 80	Side	Average body mass index and % with BMI >30 (%)	Etiology (pre-operative diagnosis)
Symbol	148	49.6%	68 23.9%	Right 70 Left 78	26.8 26%	Arthrosis: 112 Neck fracture:15 Necrosis: 18 Other: 3
Libra	140	46.6%	71 25%	Right 65 Left 75	25.9 12.5%	Arthrosis: 109 Neck fracture: 11 Necrosis: 13 Other: 7

Table 2 Functional scores

	Number	Minimal	Maximum	Median
Pre-operative HHS Symbol®	148	0	80.3	50.7
Pre-operatively HHS Libra®	140	0	89.1	50.5
5-year FU Symbol HHS Symbol®	116	44	100	95.7
5-year FU HHS Libra®	82	42.9	100	97.9
5-year FU Oxford Score Symbol®	116	37	12	16.3
5-year FU Oxford Score Libra®	82	46	12	15

The median difference was −34.1 (SD = 13.2 ; CI95% = [−37.4; −32.45]; $p<0.001$) (Table 2).

Statistical analysis (Tables 3 and 4)

A multivariate linear regression was performed to assess the relationship between HHS and Oxford Score at five years post-operatively and the explanatory variables: age, BMI, ASA, and pre-operatively HHS.

For the Libra® stem, in a multivariate analysis (Table 3), none was associated with the value of HHS and Oxford Score at 5 years.

For the Symbol® stem, in a multivariate analysis, only an ASA score equal to 3 or 4 was significatively associated with lower values of Oxford Score and HHS at five years. The median HHS at five year follow-up for patients with Symbol® were respectively 97.9 (Q1 88.28; Q3 100.1), 95.7 (Q1 92.4; Q3 100.1), and 90.75 (Q1 74.8; Q3 93.78) for patients with ASA = 2, 1, and 3 (p=0.003).

Discussion

The primary endpoint of the study was to analyze the survival rate at five years for Symbol® stem in an unselected patient population. There was no difference between short-stem group and the standard-length stem group.

Similarly, our secondary endpoint showed no difference in functional scores at five year follow-up between the two groups and no influence of pre-operative individual parameters (age, BMI, ASA, and pre-operatively HHS) in the multivariate analysis. Only a pre-operative ASA score equal to 3 or 4 had worse functional results with the short stem than with the standard-length stem at five year follow-up.

Initially, short stems were developed to preserve bone and soft tissue in mini-invasive procedures and to allow rapid recovery for young patients [4]. The Symbol® stem was shaped with 200 scans to reproduce anatomy of the proximal femur to facilitate positioning of the stem and increase metaphyseal fill compared to a standard stem [5].

Table 3 Multi-variable analysis of the HHS and Oxford Score at 5 years with the Libra® stem

	HHS		Oxford score	
	Coefficient β	p-value	Coefficient β	p-value
Age	−0.196 [−0.52; 0.127]	0.23	0.00713 [−0.147; 0.161]	0.927
BMI	−0.41 [−1.12; 0.302]	0.254	0.141 [−0.198; 0.481]	0.409
ASA >2	−1.08 [−8.13; 5.96]	0.76	1.13 [−2.23; 4.49]	0.505
Pre-op HHS	0.0604 [−0.293; 0.172]	0.606	0.0203 [−0.0906; 0.131]	0.715

Table 4 Multi-variable analysis of the HHS and Oxford Score at 5 years with the Symbol® stem

	HHS		Oxford Score	
	Coefficient β	p-value	Coefficient β	p-value
Gender	1.58 [−5.76; 2.59]	0.454	0.883 [−1.34; 3.11]	0.432
BMI	0.234 [−0.208; 0.676]	0.296	−0.0453 [−0.279; 0.189]	0.702
ASA >2	−10.81 [−17.15; −4.47]	**0.00101**	4.62 [1.26; 7.97]	**0.00754**
Pre-op HHS	0.0847 [−0.0931; 0.262]	0.347	−0.0466 [−0.137; 0.0435]	0.307

In the literature, with recent interest in less invasive surgery through smaller incisions with mini-invasive posterior approach and anterior approach, shorter stems have been increasingly popularized and utilized to achieve femoral fixation [6]. We therefore compared the mid-term survival rate and post-operative HHS and Oxford Scores, for survival rate and functional outcome, between groups receiving standard-length stems and shorter stems. Results in the literature are similar with a good survival rate of short stem [7]. Metaphyseal-engaging short stems like Symbol® provide theoretical benefits compared to standard-length stems, including avoiding proximal-distal mismatch, decreasing proximal stress shielding, and limiting perioperative periprosthetic fractures. Several studies show that custom short-stem designs provide short-term fixation, specifically in patients younger than 60 years [8]. Worse functional results in patient with ASA score equal to 3 or 4 could be potentially explained by a worse metaphyseal. One explanation could be attributed to the existence of a bias with the HHS, potentially limited to evaluate and compare hip function between patient with ASA >2 or more. However, scores are intuitively based on patient report and are subject to patient reporting bias. Hence, any bias effect would be no greater in our study than in other studies using widely acknowledged function scoring systems. Another hypothesis could be the worse bone quality affected function in patients ASA 3 or 4. Osteoporotic bone exhibits diminished cellular and structural characteristics, potentially compromising ingrowth/outgrowth of the implant and secondary metaphyseal fixation of short stems. In this case, aseptic loosening could remain a concern solely in uncemented stems in diminished bone but in our cohort. However, no more short femoral components underwent revision for aseptic loosening, migration, subsidence, or osteolysis, compared to cemented stem or standard stems. In the current literature, this data is missing and no subsidence or loosening in short-stem implants was found but, in most instances, patients were selected with indications for the use of this short stem, namely patients aged of less than 60 years and good bone stock [8, 9]. Meding et al. [10] observed no difference in HHS and pain scores when stratifying patients based on Dorr classification. Dorr et al. [11] concluded increased incidence of thigh pain in patients with Dorr type C bone was secondary to delayed remodeling. As with any new use of standard stem or short stem, a learning curve is necessary [12]. Nevertheless, the frequency of various stem positioning may not predispose to subsidence, loosening, fracture, or be associated with negative outcomes in the literature if extensive metaphyseal fixation is achieved [13]. In all cases, the metaphyseal filling of this short stem must be rigorous and optimal, especially in cases of bone fragility, to avoid sinking of the stem. This requires a learning curve to learn how to "work" short stems. Short stems have the advantage compared to a standard stem to allow increasing the size of the stem and its metaphyseal filling without limitation by a too early distal diaphyseal blockage. In case of poor bone, the use of a short cemented stem remains a valid and interesting option, allowing stable metaphyseal fixation without risk of distal fracture and preserving bone during a less-invasive procedure [14–16].

Our study contains several limitations. Firstly, both stems differ completely in design, and Symbol® is not just a shorter version of the standard-length stem Libra®. Libra® is a straight femoral quadrangular stem with primary distal bone fixation and Symbol® is a stem with a proximal metaphyseal anchor. Secondly, the mid-term follow-up for this study was a limiting factor in terms of comparing differences in survivorship and functional outcomes and a study with a longer clinical follow-up will be interesting. Thirdly, although this was not the intent of this study, there was no specific analysis of radiographs with regard to positioning and sizing of stems, although studies have shown stem position is not correlated with increased incidence of early component failure and survival rate [13]. Fourthly, the data reflect a single surgeon's experience with a particular interest in short stems after November 2015 with a potential impact of the learning curve on the survivorship, as short stem was performed after using the standard-length stem, as previously discussed. However, the procedure for implanting short-stem devices was identical to that for inserting stems of conventional length. Thus, despite surgeon's preference and experience, the technique and outcomes can be expected to be replicable. Retrospective studies with a mid-term follow-up and evaluation of the durability of the implant, particularly in relation to radiographic stability and function scores, require long-term follow-up, generally more than ten years. While conventional uncemented THA has greater than 10-year follow-up in the literature, our study evaluates a newer stem design in a subset of the general unselected patient population. Longer follow-up is under way.

To conclude, despite these limitations, our experience with these two stem designs suggests that shorter stems are an equally efficient alternative to standard-length stems. Symbol stem in THA appears to be a safe and reliable alternative to a more traditional standard-length stem in an unselected patient population. While the shorter stems may make the procedure technically easier and more amenable to less invasive approaches, they do not appear to compromise either femoral fixation or mid-term clinical results and will likely continue to be utilized as many more surgeons and patients seek less invasive techniques for THA. A steep learning curve is mandatory as with any new prosthetic system. With growing interest in bone preservation techniques and in short stems [14–16], further future investigations through long-term durability in clinical practice and functional results of these "short stems" are needed to confirm this data and randomized prospective studies will be important in determining their continued use in THA in all patients.

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Gilles Estour: redaction
Robian Rassat: data collect
Alexandre Caubère: data analysis
Sonia Dubreuil: data collect

Data availability Not applicable.

Code availability Not applicable.

Declarations

Consent for publication Not applicable.

Informed consent Not applicable.

Conflict of interest Olivier Barbier: consulting for Arthrex and Dediène Santé. Gilles Estour: consulting for Dediène Santé. Robian Rassat, Alexandre Caubère, Sonia Dubreuil: no conflict of interest.

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