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ORIGINAL PAPER

Total hip replacement with a collarless polished cemented anatomic stem: clinical and gait analysis results at ten years follow-up

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Abstract
Purpose The aim of this study was to determine outcomes of total hip replacement (THR) with the Lemania cemented femoral stem.
Methods A total of 78 THR patients were followed and compared to 17 "fit", healthy, elderly and 72 "frail" elderly subjects without THR, using clinical outcome measures and a portable, in-field gait analysis device at five and ten years follow-up.
Results Forty-one patients (53 %), mean age 83.4 years, available at ten years follow-up, reported very good to excellent satisfaction. Mean Harris Hip and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores were 81.2 and 10.5 points, respectively, with excellent radiological preservation of proximal femur bone stock. Spatial and temporal gait parameters were close to the fit group and better than the frail group.
Conclusions Lemania THR demonstrated very good, stable clinical and radiological results at ten years in an older patient group, comparable to other cemented systems for primary THR. Gait analysis confirmed good walking performance in a real-life environment.

Keywords Total hip replacement · Cemented stem · Anatomic femoral stem · Gait analysis · Outcome · Geriatric population

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Introduction

Total hip replacement (THR) is an established surgical treatment for advanced hip osteoarthritis, with a low complication rate and survival rates of 94 % at 10 years and 78–87 % at 25 years [1]. Different stem philosophies, surface finishes, cementing and surgery techniques, and a wide choice of implants are available.

Encouraging short-term results prompted widespread use of several cemented prostheses, but long-term results proved less than satisfactory [2, 3]. A clinical need and economic demand to improve implants has encouraged the development of a less expensive implant with an equal or higher survival rate. The Lemania™ femoral stem (Symbios, Yverdon-les-Bains, Switzerland), introduced in 1999, proposes a biomechanical advantage and is produced at 25 % lower cost than equivalent cemented stems. The smooth, polished, collarless and symmetrical stainless steel stem has a unique design that fills most of the proximal femur metaphysis and better disperses loads to bone [4]. Outcomes with the Lemania stem have not yet been reported.

Traditional outcome measures to assess THR include the Harris Hip Score (HHS) [5], the Western Ontario and

McMaster Universities Osteoarthritis Index (WOMAC) [6] and general quality of life questionnaires such as the EuroQol in five dimensions (EQ-5D) [7]. These scores correlate poorly with the real walking performance of patients, which can be assessed objectively with gait analysis [8]. Most gait analysis techniques are expensive, complicated and require a gait laboratory with specially trained staff or interfere with the patient's gait [9]. Hence, lighter, portable, easy-to-use, ambulatory gait recording systems have been developed [10].

We determined subjective and objective outcomes of THR with the cemented Lemania stem, using traditional outcome measures and a portable, in-field gait analysis device at five and ten years follow-up.

Materials and methods

In this prospective cohort study, osteoarthritis patients aged ≥65 years requiring THR were recruited at a large, urban hospital from March 1999 to October 2000. Patients provided informed consent prior to study enrolment. Gait performance was compared to two reference populations: (1) "fit elderly"—17 selected individuals (mean age 77.5 years, range 71–88) with no health problems and (2) "frail elderly"—72 patients (mean age 82.0 years, range 63–98) hospitalised at a rehabilitation centre for three weeks for health problems unrelated to the lower limb, who performed the gait trial prior to discharge. The Research Ethics Board of our institution approved this study.

Primary THR for primary or secondary coxarthrosis was performed by a senior surgeon using a standardised operative technique. Patients received the collarless cemented Lemania stem and the Hilock™ (Symbios, Yverdon-les-Bains, Switzerland) press-fit cup using a posterolateral approach. The femoral diaphysis was washed under pressure with physiological serum after implantation of the cement stopper (Cemstop™, Teknimed, France) using the OrthoLav™ system (Stryker, Kalamazoo, MI, USA). Retrograde stem cementation was performed under drain aspiration with gentamicin-impregnated cement AKZ™ (Howmedica, Mahwah, NJ, USA). Patients were mobilised to a bedside seat on the first post-operative day and began walking with crutches, without weight-bearing restrictions, on the second day. Patients received physical therapy for one week and walked with crutches for six weeks.

Clinical follow-up Patients were evaluated by an independent observer before and one, five and ten years after THR. Preoperative HHS and WOMAC scores were calculated. Clinical examinations included physical examination, documentation of complications and HHS, WOMAC and EQ-5D questionnaires. Pain and stiffness in the operated limb were evaluated using visual analogue scales (VAS). Patients also completed a satisfaction questionnaire.

Radiological follow-up Radiological assessment after each follow-up visit included anteroposterior and axial view radiographs of the pelvis. All radiological analyses were performed by the same independent trained observer. Cup inclination and anteversion, caput-collum-diaphyseal (CCD) angle and prosthesis neck anteversion were calculated. The femur was analysed for osteolysis zones, defined as newly developed radiolucent lines >2 mm at the cement-bone interface. Stem subsidence was measured as a vertical increase of >2 mm of radiolucency created by distal migration of the prosthesis shoulder from any overlapping cement in Gruen zone 1. Calcar bone resorption, diaphyseal cortical hypertrophy and fractures of the cement mantle were assessed. The modified Brooker classification was used to describe heterotopic ossifications [11].

Objective gait analysis Objective gait analysis at five and ten years after surgery used the Physilog® ambulatory in-field system (BioAGM, La Tour-de-Peilz, Switzerland). A lightweight (300 g) portable recorder was placed on the waist belt, with four miniature gyroscopes (ADXRS150, Analog Devices Inc., Munich, Germany) attached to each calf and thigh with Velcro. This system is easy to use and shows good agreement with a gait analysis laboratory reference system and the HHS [10].

We measured lower limb movement while patients walked 30 metres in a corridor, at a self-selected normal speed. Two walking trials were recorded and averaged for analysis. Sensor signals were digitised and stored by the Physilog recorder for offline 2D gait analysis [10].

Statistical analysis Non-parametric tests were used due to the asymmetrical distribution of most variables. The Wilcoxon signed rank test was used for paired comparison (i.e. same patient at different times). The Wilcoxon rank sum test was used for unpaired comparison (i.e. reference population versus patients). A p value <0.05 was considered significant.

Results

Eighty-four patients received a Lemania THR. In the first year, four patients died for reasons unrelated to the surgery, one was lost to follow-up and one declined to participate retroactively. The mean age at surgery of the 78 remaining patients (74 % women) was 75.6 years (range 62–91).

We reviewed 39 patients (72 % women) clinically and radiologically at five years (range 5.1–7.0) follow-up (Fig. 1). Of these patients, 22 (28 %) had died for reasons

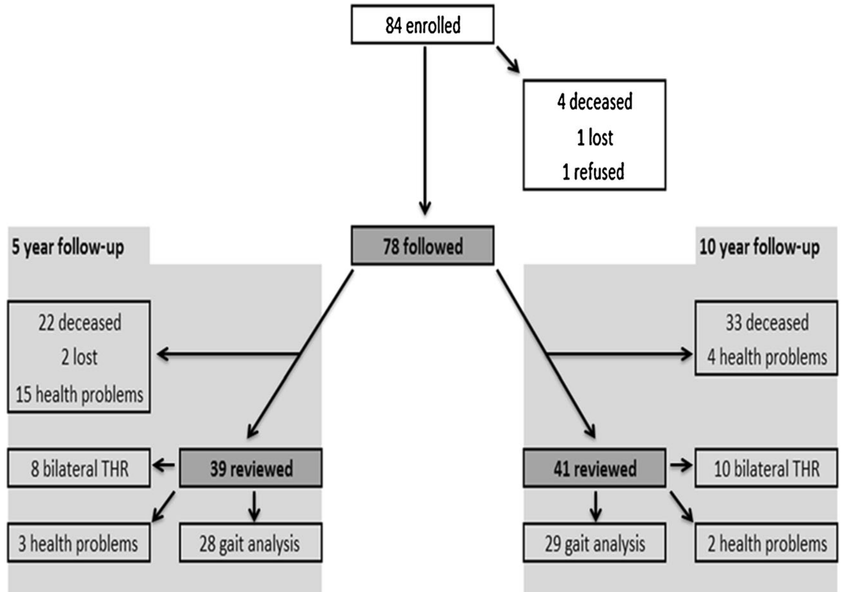

Fig. 1 Flow chart presenting the examined patients and patients lost to follow-up during the study

unrelated to the THR, two (3 %) were lost to follow-up and 15 (19 %) were not examined due to health reasons unrelated to the surgery. Gait was analysed in 28 patients with a mean age of 79.2 years (range 67–96). Patients who received a contralateral THR during the follow-up period or could not perform the walking trials due to health reasons unrelated to the THR were excluded from gait analysis. At ten years (range 10.8–11.8) follow-up, 41 patients (81 % women) were reviewed clinically and radiologically. Gait was analysed in 29 patients with a mean age of 83.4 years (range 72–93) (Fig. 1).

Table 1 Clinical outcomes following THR

Outcome measure	Preoperative ($n=78$)	5 years follow-up ($n=39$)	10 years follow-up ($n=41$)	p value[a]
WOMAC				
Total score, mean (range)	63.0 (31–94)	4.9 (0–23)	10.5 (0–50)	$p<0.001$
Pain subscore, mean (range)	17.3 (10–20)	0.8 (0–6)	0.7 (0–8)	
HHS				
Total score, mean (range)	43.8 (24–56)	84.7 (43–100)	81.2 (49–100)	$p<0.16$
Distance walked subscore, mean (range)	4.2 (2–5)	8.7 (5–11)	8.1 (0–11)	
Pain subscore, mean (range)	10.9 (10–20)	40.1 (10–44)	40.3 (10–44)	
EQ-5D				
VAS, mean (range)		87.5 (75–95)	74.5 (40–100)	$p=0.003$
Level 1 (no problems), %				
Mobility		67	50	
Self-care		92	86	
Usual (daily) activities		69	71	
Pain/discomfort		87	82	
Anxiety/depression		100	82	
Level 2 (some problems), %				
Mobility		33	50	
Self-care		8	11	
Usual (daily) activities		31	27	
Pain/discomfort		13	18	
Anxiety/depression		0	18	

[a] Wilcoxon signed rank test, testing the difference between the variable at 5 and 10 years follow-up

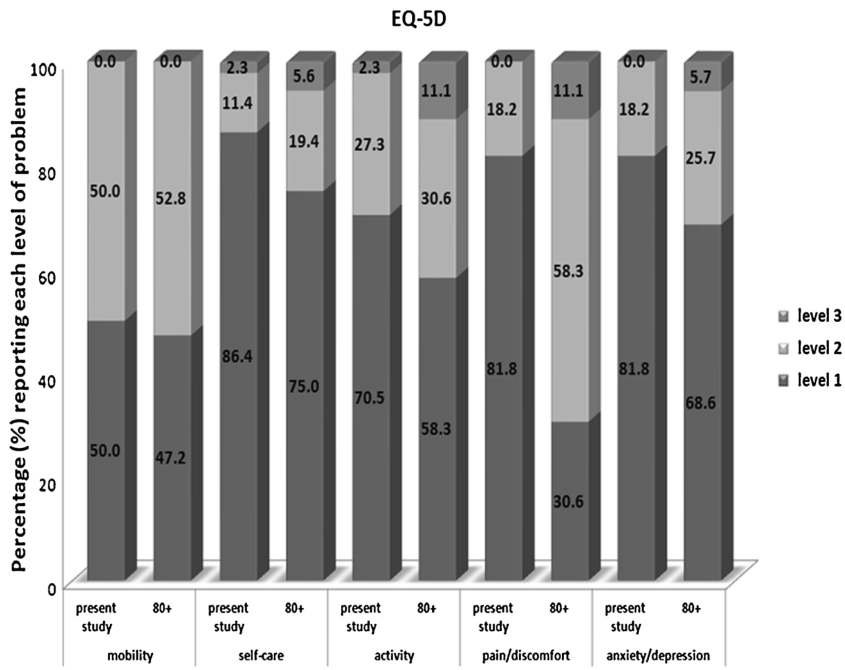

Fig. 2 The EQ-5D score at 10 years follow-up, compared to the reference population of people age 80 years and older (80+) (EQ-5D norms table for national population [7]). Values are percentages

Clinical results The EQ-5D, HHS and WOMAC results are summarised in Table 1. The difference between five and ten years follow-up was statistically significant for the WOMAC total score and EQ-5D VAS score, with better scores at five years follow-up.

For the EQ-5D, most patients reported no problems (level 1) for the various domains, some reported some problems (level 2) and one patient (2.3 %) reported level 3 problems for self-care and usual activity. The EQ-5D scores are compared to EQ-5D norm scores in the general population ≥80 years [7] in Fig. 2.

Total HHS are shown in Fig. 3. The mean walked distance was a maximum of 500 metres pre-operatively (4.2 points, range 2–5) and improved to >500 m at five years (8.7 points, range 5—11) and ten years (8.2 points, range 0–11) follow-up. The difference between preoperative and five years follow-up was significant ($p<0.05$), but between five and ten years follow-up was not ($p=0.16$). At ten years follow-up, 34 % of THR were rated excellent, and 22 % were rated good.

At ten years follow-up, 95 % of patients were satisfied or very satisfied with the surgery. Pain relief was excellent: 34 patients (83 %) had no pain in the operated hip, five (12 %) had

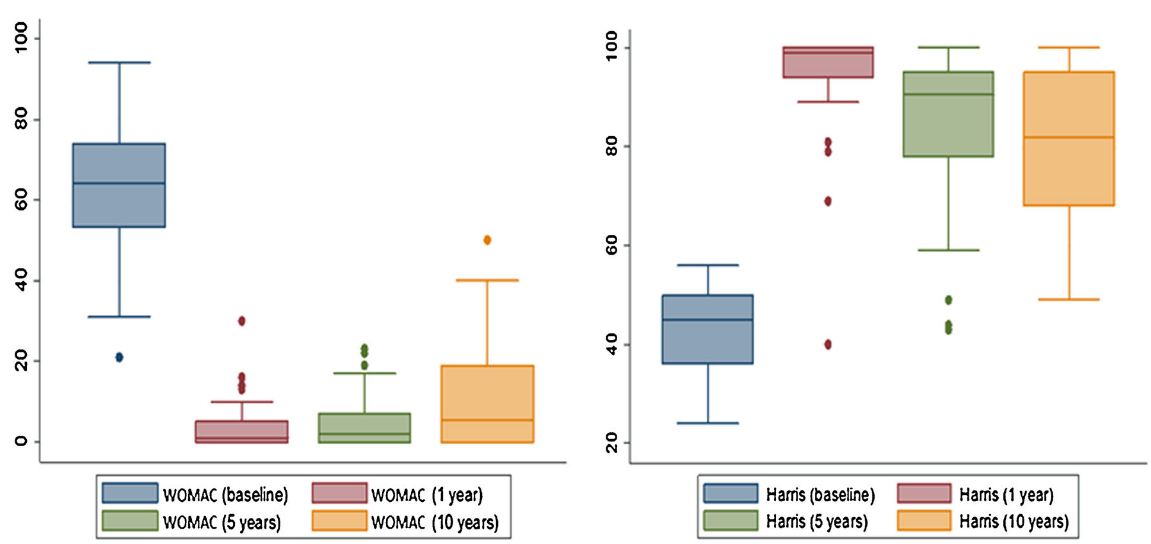

Fig. 3 Evolution of WOMAC and HHS during follow-up

Table 2 Spatial and temporal gait parameters

Variable	Reference group, fit elderly	Patients, 5 years follow-up	Patients, 10 years follow-up	Reference group, frail elderly
Cadence (steps/min)	112.63±10.04	102.77±11.05	99.09±11.88	75.63±14.78
Stance (%)	59.02±2.09	61.52±2.49	62.48±2.45	67.79±5.41
Double support (%)	18.03±4.18	23.03±4.97	24.96±4.91	36.06±10.55
Stride length (m)	1.28±0.11	1.13±0.18	1.00±0.15	0.81±0.17
Speed (m/s)	1.20±0.16	0.97±0.20	0.83±0.15	0.52±0.17
Shank (°)	70.57±4.07	65.83±7.95	58.99±6.49	47.80±9.15
Thigh (°)	42.32±4.41	41.82±5.92	34.24±5.20	26.65±5.86
Knee (°)	52.29±5.03	53.85±6.71	46.39±6.40	35.34±7.84

Double support and stance are expressed as percentage of gait cycle time. Significant differences were observed between each group (Wilcoxon p value < 0.001)

occasional mild pain (VAS=2 or 3) and one (2 %) complained of occasional moderate pain (VAS=5).

Radiological results At ten years follow-up, mean cup inclination was 49.9° (range 36–65°), and mean cup anteversion was 29.2° (range 12–46°). The mean CCD angle was 132.4° (range 123–140°), and mean anteversion of the stem neck was 10.1° (range −4 to 38°).

Radiolucent lines >2 mm were found around the stem in 11 cases (27 %). Stem subsidence occurred in four cases, of which one presented with stem subsidence >20 mm, a distal cement fracture and radiolucent lines at the stem-cement interface. This woman had few symptoms (VAS pain=0, VAS stiffness=0) and a good clinical outcome with total WOMAC score of 24 points. There were no cases of calcar resorption greater than grade I and five cases (12 %) of cortical hypertrophy (one patient in Gruen zone 3, three patients in zone 5 and one patient in zones 3 and 5). Heterotopic ossifications were identified in seven (17 %) patients—six with Brooker grade I and one with Brooker grade III. All patients with the above-described radiological changes were asymptomatic.

Gait analysis Mean spatial and temporal gait parameters at five and ten years follow-up and for the fit elderly and frail elderly reference populations are summarised in Table 2. There was a significant difference between all groups for each parameter ($p < 0.001$). A significant deterioration of every gait parameter was observed between five and ten years follow-up. With advancing age, THR patients walked with slower cadence and speed and shortened stride length. Single and double stance phases increased with advancing age. Range of motion (ROM) for each limb segment also decreased with age.

Discussion

Clinical outcome measures and gait analysis results were very good at five and ten years following THR with the cemented Lemania stem. Gait analysis was performed while patients walked freely for 30 metres in a corridor, and the results were compared to reference populations representing two extremes—a fit elderly and a frail elderly population. No other study on outcomes with this anatomic femoral stem has been published to date.

Table 3 Comparison of HHS after THR, at long-term follow-up, in the literature

Authors	Stem	Follow-up (years)	HHS pre-op	HHS at final follow-up
This study	Lemania	9.7	43.8 (24–56)	81.2 (49–100)
Bjørgul et al. [13]	Charnley	10	48.3	89.8
Chandran et al. [22]	Charnley	14	23.4 (13–42)	89.1 ±1.18
Chiu et al. [27]	Exeter	12.8	39.8 (20–62)	82.3 (42–92)
Hulleberg et al. [28]	Charnley	13		83 (29–100)
Lachiewicz and Messick [23]	Cemented Zimmer	10	44 (0–70)	86 (30–100)
Nieuwenhuijse et al. [16]	Exeter	9.4	31±19	73±23
Stucinskas et al. [24]	Müller	16		78±16.3
Riede et al. [14]	Müller	10.3		87.3 (55–100)
Williams et al. [25]	Exeter	8.9		82 (14–100)
Yates et al. [26]	Collarless polished	11	39 (20–61)	86 (47–100)

Values are mean (range) in points or mean ± SD

Table 4 Long-term evolution of the HHS following THR in the literature

	Before THR	1 year	2 years	5 years	10 years	15 years
This study	43.8	96.2		84.7	81.2	
Bjørgul et al. [13]	48.3	90.2	92.7	93.9	89.8	
Chandran et al. [22]	23.4	93.6		93		89.1
Riede et al. [14]					87.3	82.1

Values are mean in points

Ten years following THR, the EQ-5D score was excellent, with a mean VAS of 74.5 points, compared to 58 points in the age-matched healthy reference population [7]. Our study's patients reported fewer difficulties for each dimension: 82 % presented with no pain versus 31 % of the reference population, and 71 % reported no difficulty in usual activities versus 58 % of the reference population. HHS and WOMAC scores improved significantly compared to baseline (Fig. 3). The magnitude of HHS improvement was comparable to that reported for other prostheses with similar follow-up (Table 3). Both HHS and WOMAC scores declined slowly during the follow-up period (Fig. 3). Patients remained pain free over the long term, despite a gradual functional decline. Other studies have noted a gradual decline in HHS following THR (Table 4), at an average of 0.7 points per year with no medical complications [12]. Deterioration of functional scores appears to correspond to a decline in general health due to aging. The use of instruments other than the HHS to assess activity level and walking ability in THR patients has been recommended [13, 14].

The Lemania stem demonstrated good radiological results at ten years follow-up, with radiolucent lines at the cement-bone interface in 11 patients (27 %), all asymptomatic. Linear radiolucency and isolated bone lysis at the cement-bone interface have been reported in up to 30 % of cases at long-term follow-up [14] and do not necessarily indicate loosening [15]. We found stem subsidence in four asymptomatic patients, which is often the case in this type of prosthesis design [16]. This finding validates the design of the Lemania stem to optimally fill the proximal metaphysis and improve proximal load transfer to the bone.

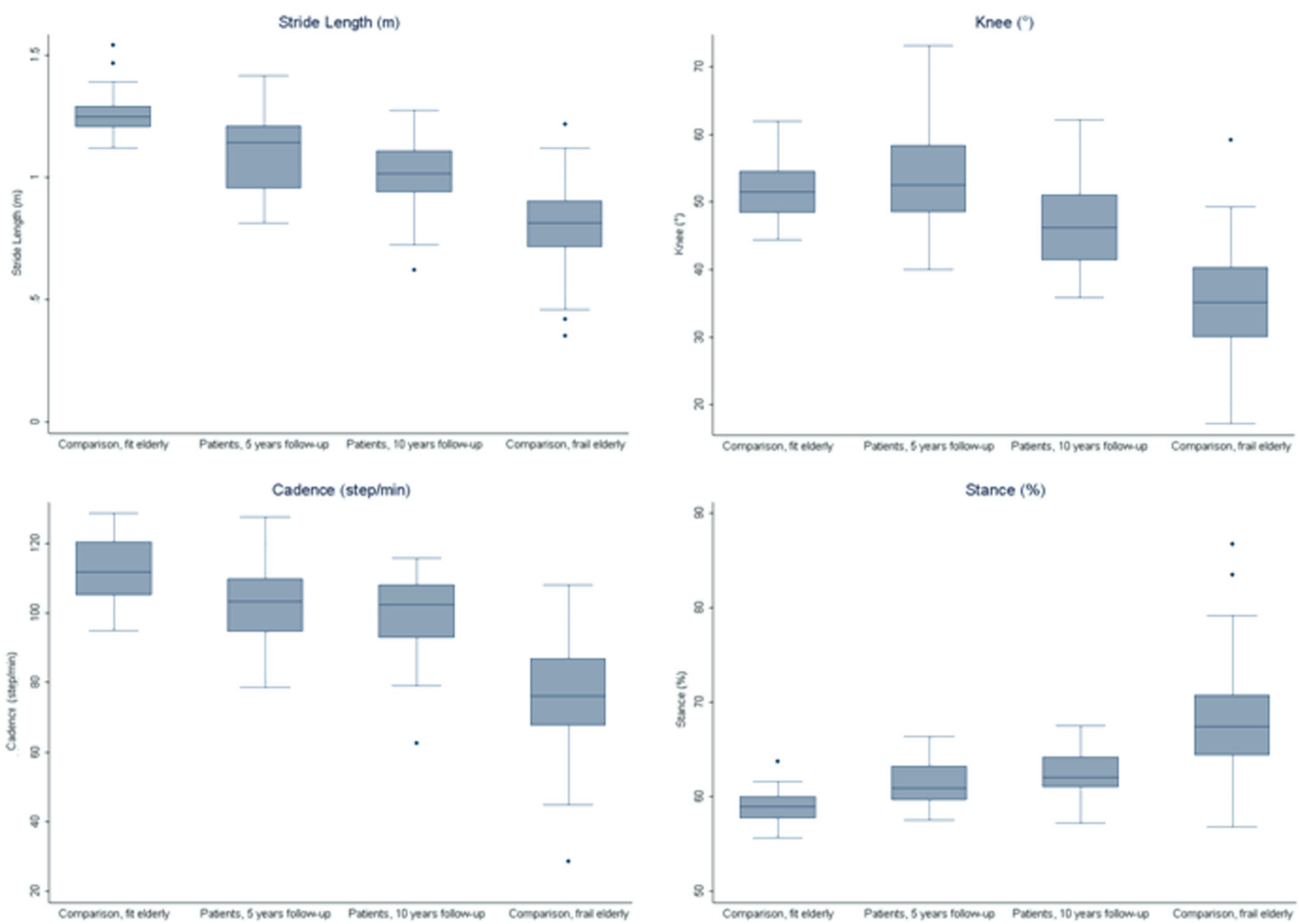

Fig. 4 Comparison of chosen gait parameters in our study

Table 5 Comparison of chosen gait parameters to other studies

Authors (gait method)	Stem	Group	Follow-up	Age	Cadence (steps/min)	Stance (%)	Stride (m)	Speed (m/s)	ROM thigh (°)	ROM knee (°)
This study (corridor free walking)	Lemania	THR	9.7	83.3	**99.09**	**62.48**	**1.00**	**0.83**	**34.2**	**46.4**
		FRAIL		82.0	75.63	67.79	0.81	0.52	26.7	35.3
		FIT		77.5	112.6	59.02	1.28	1.20	42.32	52.3
Bennett et al. [20, 21] (gait lab with Vicon cameras)	X-press cemented	THR	10	84	110.9	64.10	**0.88**	**0.82**	**30.4**	**46.7**
		CON		64	117.2	60.90	1.37	1.34	45.9	57.7
Kyriazis and Rigas [9] (conductive walkway)	Uncemented	THR	10	60	**110.2**	**68.90**	**1.22**	**1.12**		
		CON		60	105.2	73.10	1.55	1.36		

Boldface indicates statistical difference between THR group and control group. Values for follow-up and age are mean in years

THR total hip replacement group, *FRAIL* our reference population of 72 elderly frail patients, *FIT* our reference population of fit patients, *CON* control group, *ROM* range of motion

Objective gait analysis is useful for locomotor function evaluation after THR. Most studies evaluated gait at short-term follow-up, with contradictory findings. Petersen et al. [17] compared operated and non-operated hips at 12 weeks post-operatively and reported an asymmetric gait pattern, with significantly less power produced by muscles around the operated hip. Nantel and colleagues [18] observed a return to normal walking one to four years after THR, whereas Perron et al. [19] failed to show normal gait at short-term follow-up. Kyriazis and Rigas [9] found significant differences in gait at ten years follow-up in THR patients and controls, suggesting that patients who have undergone THR do not return to the same normal gait pattern as healthy, age-matched controls. We found significant differences between the THR and reference groups in every analysed temporal and spatial parameter at five and ten years follow-up, with significant deterioration of every gait parameter between five and ten years (Fig. 4). Our study's patients had better gait performance than the frail elderly, but never achieved the level of the fit elderly patients. The differences were small and likely difficult to elucidate by physical examination only. However, objective gait analysis demonstrated statistically significant differences and confirmed its utility as a complement to traditional evaluation methods.

Three studies analysed gait parameters of THR patients at a follow-up of at least ten years (Table 5) [9, 20, 21]. None had patients walking freely in a corridor (without cameras or specific walkways) as in our study. The observed decreases in cadence, stride length, speed and all ROM from five to ten years follow-up in our study are similar to those reported by Bennett et al. [20, 21]. However, THR patients in our study walked faster and with a greater stride length (Table 5). They also had a better thigh ROM, despite a similar mean age. In contrast, our patients had a worse gait pattern than that reported by Kyriazis and Rigas [9], with slower speed, slower cadence and shorter stride length (Table 5). Comparison of these studies is difficult, due to the substantially younger patient population in the study by Kyriazis and Rigas (60 years versus 83 years in our cohort). Our good clinical and radiological results suggest that the deterioration in gait pattern over time is related to advanced age rather than THR.

A strength of this study is that gait analysis was performed over a relatively long distance of 30 metres, with two walking trials, which allowed recording of real walking performance and minimised the effect of better initial gait values produced by a rested patient. Bennett et al. [20, 21] performed their gait analysis at one self-selected speed on a walkway with six cameras. Kyriazis and Rigas [9] used a conductive walkway. More age-matched controlled trials with a standardised gait analysis are required for a better understanding of long-term changes in gait patterns after THR and to improve comparison of results.

In conclusion, THR with the Lemania stem demonstrated good, stable clinical and radiological results at ten years follow-up in a relatively old patient group. Our results are comparable to those of primary THR with other cemented systems such as Müller or Exeter. Patients demonstrated good walking performance ten years following Lemania THR. Temporal and spatial gait parameters were better than those of frail, age-matched patients and close to those of a fit, age-matched population, as measured in a real-life environment. Clinical outcome scores and gait parameters decrease progressively in patients ≥80 years of age, likely due to the effect of advancing age rather than THR.

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Conflict of interest B. Jolles is a consultant for Symbios Orthopédie SA. The remaining authors declare that they have no conflict of interest.

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