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ORIGINAL STUDY

Total hip arthroplasty using a modular "short-stem" femoral prosthesis vs. a standard prosthesis: a five-year follow-up study

Ramy Belhouane, Eric Havet, Antoine Gabrion, Massinissa Dehl, Yassine Bulaid, Patrice Mertl

From the Service de Chirurgie Orthopédique, CHU Amiens Sud, 80000, Amiens, France

The objective of this study was to compare the results and radiological stability of a short stem with those of a standard stem.
A series of 44 patients with a short stem Vitae® (Adler®) was compared to a control group of 33 patients who underwent the same procedure with a standard stem Hydra® (Adler®). Both cementless stems were modular. The surgical technique was identical and was performed by the same surgeon. The groups were comparable in terms of preoperative characteristics (age, sex, BMI, functional scores). The 5-year stem migration rate, its functional impact and risk factors for migration were was studied.
Mean subsidence was 2.2 mm + 1.7 in group 1 and 3.1 mm + 2.2 in group 2 (p = 0.08). Mean varus tilt was 2.7 ° ± 2.2 in group 1 and 0.5 ° ± 0.5 in group 2 (p <0.05 × 10- 5). Repeat surgery for painful migration was performed in one case in group 1. All functional scores were improved with no significant difference between the two groups.
Despite a higher radiological migration rate in the short stem group, functional results were comparable between the two groups, leading us to suspend the use of this short stem model.

Keywords: Total hip arthroplasty ; short stem ; migration ; modular stem ; cementless.

INTRODUCTION

Although modern total hip arthroplasty (THA) has been available for more than 60 years, this surgical procedure continues to be improved. Research and innovation in many different fields have significantly changed implant design. Increasing life expectancy is associated with a growing number of secondary THAs (mainly prompted by periprosthetic fractures or aseptic loosening of the femoral implant). The poor quality and quantity of the remaining bone at the time of repeat surgery often require the use of larger, more bulky implants to ensure sufficient mechanical stability. The use of bone-saving implants for

■ Ramy Belhouane, M.D.
■ Eric Havet, M.D., PhD.
■ Antoine Gabrion, M.D., PhD.
■ Massinissa Dehl, M.D.
■ Yassine Bulaid, M.D.
■ Patrice Mertl, M.D., PhD.
Service de Chirurgie Orthopédique, CHU Amiens Sud, 80000, Amiens, France.
Correspondence: Ramy Belhaouane. Service de Chirurgie Orthopédique, CHU Amiens Sud, 80000,Amiens, France. Phone : 0033610807781
E-mail : ramy.b@hotmail.fr

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primary surgery has therefore become a priority. One innovative approach involves the use of a short-stem femoral implant. Manufacturers have proposed various concepts for femoral implants, ranging from hip resurfacing to changes in stem size and the anchoring zone. Several studies have described a trend towards migration of short stems that could influence clinical outcomes or even lead to failure of this procedure *(30) (33)*.

In our orthopaedics department, we have chosen to use a short-stem implant that anchors with the metaphysis: Vitae® from Adler Ortho S.R.L., Cormano, Italy (now called Pulchra®). The primary objective of this study was to compare the migration of a short-stem implant (assessed radiologically) with that of a standard implant and to evaluate the respective functional outcomes.

The hypothesis was that the use of a short stem was not associated with a higher migration rate and did not affect the functional outcomes of total hip arthroplasty.

MATERIALS AND METHODS

This single-centre, single-surgeon study was conducted in two groups of patients who had undergone primary THA in our establishment between October 2011 and June 2013. All THAs were performed via Moore's posterior approach, according to the same surgical technique, with the same acetabular implants and the same friction couples (ceramic-ceramic). The two groups differed exclusively in terms of the length of the implant stem, with a short stem in one group (group 1) and a standard stem in the other group (group 2). The type of implant was chosen according to the availability of the material regardless of age or aethiology.

All patients were followed for five years. Forty-seven patients underwent THA with a short-stem implant and therefore constituted group 1. Two of these patients died and one was lost to follow-up; 44 patients (and 44 prostheses) were therefore included in the final analysis. Thirty-six patients underwent THA with a standard stem implant and constituted group 2. Two of these patients died, and one patient with revision of the acetabular cup was also excluded. Thirty-three patients (and 33 prostheses) were therefore included in the final analysis.

Group 1 comprised 34 cases of primary coxarthrosis and 10 cases of secondary coxarthrosis (Arlet and Ficat stage 4 avascular necrosis of the femoral head (n=5), protrusive dysplasia (n=2), sequelae of an acetabular fracture (n=1), Crowe grade 2 acetabular dysplasia (n=1) and psoriatic arthropathy (n=1)). Group 2 comprised 23 patients with primary coxarthrosis and 10 patients with secondary coxarthrosis (stage 4 avascular necrosis of the femoral head (n=2), protrusive dysplasia (n=6), sequelae of a Legg-Calve-Perthes disease (n=1) and grade 2 acetabular dysplasia (n=1)). There were no significant intergroup differences in terms of preoperative data (Table I), other than a significantly higher preoperative OHS-12 score in group 2.

All implants were obtained from Adler Ortho® S.R.L., Cormano, Italy. The short-stem Vitae® implant is a short, modular, straight, titanium alloy stem made by additive manufacturing, i.e. by superposing many thin layers of a metallic powder and sintering them with an electron beam. The stem has a non-coated, highly porous surface (Ti-por®). This metaphyseal-anchoring implant allows cementless THA. Stem length ranges from 78.4 to 93.6 mm. The standard Hydra® implant is also a modular, straight, titanium alloy stem, but is coated with a layer of hydroxyapatite. This metaphyseal-diaphyseal-anchoring implant also does not require the use of cement. Stem length ranges from 115 to 186 mm. The Fixa Ti-por® acetabular cup, made of titanium alloy using the same process as for the short-stem Vitae® implant, was used. Cup implantation does not require the use of cement. A Biolox Delta® ceramic composite femoral head was used. A modular, titanium alloy neck adaptor provided 27 different positions.

The stability of the femoral stem was assessed in terms of stem radiological migration after five years of follow-up. Axial migration (subsidence) and frontal migration (varus tilt) were measured by comparing X-rays obtained immediately after THA with those obtained at last follow-up (using OsiriX© software from Pixmeo, Bernex, Switzerland). Measurements were adjusted to the true diameter of the implant head, constituting the reference.

Table I. — Comparison of preoperative data, expressed as a ratio or as the mean ± SD (range)

Parameter	Short stem	Standard stem	p
Number of patients	44	33	
Gender ratio (H/F)	20/24	14/19	0.79**
Age (years)	62 ±8.2 (37-77)	64.6 ± 8.7 (33-78)	0.19*
Weight (kg)	75.1 ± 16.1 (40-129)	77.2 ± 12.4 (54-110)	0.53*
Height (cm)	168.7 ± 8.8 (142-189)	166.8 ± 8.8 (150-180)	0.33*
BMI	26.2 ± 4.5 (19-40.7)	27.7 ± 3.9 (21.1-40.9)	0.12*
Body side (R/L)	26/18	16/17	0.35**
Follow-up (months)	61.9 ± 4.9 (55-73)	63.2 ± 4.8 (55-71)	0.25*
Devane score	2(1), 7(2), 16(3), 17(4), 2(5)	0(1), 7(2), 15(3), 9(4), 2(5)	0.64***
Pre-op PMA score	10.8 ± 2.1 (6-16)	10.2 ±2.4 (5-15)	0.29*
Pre-op HHS	53.5 ± 13.4 (30-90)	52.9 ± 16.4 (25-89)	0.84*
Pre-op OHS	32.7 ±8.1 (16-50)	38.4 ± 10.2 (18-55)	0.01*
Dorr femur morphology	13A, 24B, 7C	8A, 21B, 4C	0.76***

*= Student's t test, **= Chi-squared test, ***= Fisher's test.

Height (H) was defined as the distance between the top of the greater trochanter and the distal end of the stem. Angle (α) was that formed between the anatomical axis of the femoral diaphysis and the axis of the stem. These measurements were always performed by the same observer using the same methodology. Stem subsidence and varus tilt were defined as the change in height H (ΔH) and angle α (Δα) between the immediate postoperative period and last follow-up, respectively. As proposed in the Agora Roentgenographic Assessment *(6) (5)*, migration was considered insignificant for ΔH and Δα values less than 2 mm or 2°, moderate for values of 2-5 mm or 2-5°, and severe for values of more than 5 mm or 5°.

The influence of the initial stem position on stem migration was studied in group 1 only. For this purpose, three possible positions were defined. In position 1, the stem was in contact with both cortices at its distal end or in contact with the calcar femorale and the lateral femoral cortex. In position 2, the stem was in contact with the calcar femorale and the medial femoral cortex at its distal end. In position 3, the stem was neither in position 1 nor in position 2, and presented pure cancellous bone contact.

Five-year complication rates and clinical outcomes (based on the Postel-Merle d'Aubigné (PMA) score, the Harris Hip Score (HHS) and the 12-item Oxford Hip Score (OHS) recorded at last follow-up) were compared.

The study was registered with the National Data Protection Commission and was approved by an independent ethics committee.

Informed consent: Informed consent was obtained from all participants included in the study.

Statistical analyses

Quantitative variables were compared with Student's t test, chi-square test, Fisher's test and analysis of variance (ANOVA). Correlations were assessed by calculating Pearson's rho ([0.75 to 1] = strong correlation; [0.25 to 0.75] = moderate correlation; [0 to 0.25] = weak correlation). The limit of statistical significance was $p<0.05$.

RESULTS

Radiological results

Mean ± SD (range) subsidence was 2.2 mm ± 1.7 (0-7) in group 1 and 3.1 mm ± 2.2 (0-8) in group 2. The between-group difference was not statistically significant ($p=0.08$ on Student's t test) (Figure 1).

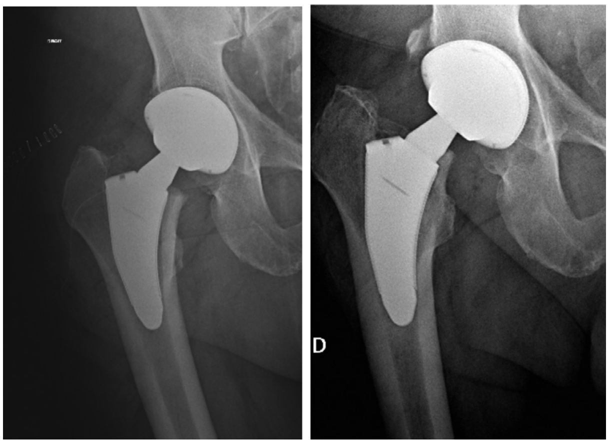

Fig. 1. — X-rays of a short-stem implant immediately after primary THA and 5 years later, showing subsidence of the stem

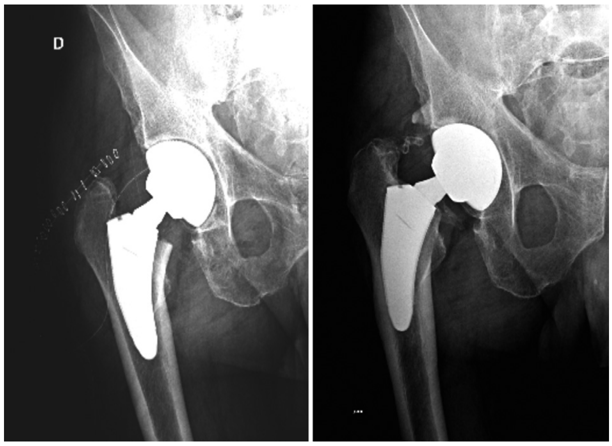

Fig. 2. — X-rays of a short-stem THA immediately after primary THA and d 5 years later, showing varus tilt of the stem

Table II. — Distribution of the patients by migration category

	Short stem		Standard stem		p
	n	%	n	%	
Migration*					
Not significant	13	30.23	13	39.39	0.48
Moderate	19	44.18	15	45.45	
Severe	11	25.58	5	15.15	
Subsidence **					
Not significant	25	58.13	13	39.39	0.15
Moderate	16	37.20	15	45.45	
Severe	2	4.65	5	15.15	
Varus tilt **					
Not significant	22	51.16	33	100	<0.05 10^{-4}
Moderate	12	27.90	0	0	
Severe	9	20.93	0	0	

* = Chi-squared test ** = Fisher's test

Mean ± SD (range) varus tilt was 2.7 ± 2.2 (0-7.7) in group 1 and 0.5 ± 0.5 (0-2) in group 2, with a statistically significant between-group difference (p<0.05.10-5 on Student's t test) (Figure 2).
Analysis of migration categories did not reveal any significant between-group difference, despite a greater number of cases of severe migration in group 1. Subgroup analysis of migration classes (subsidence or varus tilt) revealed a significantly higher proportion of cases with severe varus tilt in group 1 (Table II).

Analysis of the type of migration with respect to the initial position of the short stem revealed significantly greater migration for stems with pure cancellous bone contact (position 3) (Table III).

Functional outcomes

The two groups did not differ significantly in terms of any of the functional outcomes. (Table IV).

No correlations were observed between postoperative functional scores and radiological migration of the implants (Pearson's rho: <0.25) (Table V).

The patients' preoperative data (age, weight, height, BMI, gender or Dorr femur type) had no significant impact on radiological migration of the implants (ΔH

Table III. — Influence of the short stem's initial position on subsequent migration

	Not significant		Moderate		Severe		p*
	n	%	n	%	n	%	
Migration							
Position 1	8	61.5	4	21	0	0	0.001
Position 2	2	15.3	1	5.2	1	9	
Position 3	3	23	14	73.6	10	91	
Subsidence							
Position 1	9	36	3	18.7	0	0	0.10
Position 2	3	12	0	0	1	50	
Position 3	13	52	13	81.2	1	50	
Varus tilt							
Position 1	9	40.9	3	25	0	0	0.06
Position 2	3	13.6	1	8.3	0	0	
Position 3	10	45.4	8	66.6	9	100	

* = Fisher's test

Table IV. — Functional outcomes expressed as the mean ± SD (range)

Parameter	Short stem	Standard stem	P*
PMA	17.6 ± 0.7 (15-18)	17.7 ± 0.5 (15-18)	0.46
HHS	96.4 ± 6.5 (67-100)	95.2 ± 11.8 (37-100)	0.60
OHS	13.5 ± 3.1 (12-29)	13.8 ± 5.7 (12-44)	0.77

*= Student's t test

Table V. — Correlations between the postoperative functional scores and radiological migration of the implants (Pearson's rho coefficient)

		Short stem	Standard stem
PMA	ΔH	-0,20	0,23
	Δα	0,17	-0,12
HHS	ΔH	-0,22	0,17
	Δα	0,13	-0,24
OHS	ΔH	0,21	-0,16
	Δα	-0,13	0,18

and Δα) in either of the two groups (Pearson's rho: <0.25; p>0.05 on ANOVA) (Table VI).

Complications

Only one revision of THA was observed in group 1 (replacement of the stem due to painful axial migration one year after the first operation) in a 62-year-old retired, non-dependent, obese, relatively inactive patient (weight: 129 kg; height: 1.78 m; body mass index (BMI): 40.7; Dorr type A femur morphology) with primary coxarthrosis. Five mm of stem subsidence was observed within six weeks of the primary THA in the absence of varus tilt. This axial migration was painful and caused the patient to limp due to the difference in leg length. After 1 year of follow-up, the subsidence had increased by a further 2 mm and was associated with 1° varus tilt and a peri-prosthetic radiolucent

Table VI. — Influence of the patients' preoperative data on the radiological migration of the implants

		Short stem	Standard stem
Age	ΔH	-0,15*	0,13*
	Δα	0,17*	0,21*
Weight	ΔH	0,16*	-0,06*
	Δα	-0,06*	-0,03*
Height	ΔH	0,09*	0,20*
	Δα	0,004*	0,02*
BMI	ΔH	0,13*	-0,24*
	Δα	-0,11*	-0,05*
Gender	ΔH	0,86**	0,27**
	Δα	0,11**	0,94**
Dorr	ΔH	0,46**	0,16**
	Δα	0,87**	0,26**

line. The presence of secondary osteointegration was confirmed at the time of revision (requiring femorotomy). No postoperative complications were observed and the final functional outcome was satisfactory.

DISCUSSION

This was a single-centre, single-surgeon cohort study, ensuring that surgical procedures and postoperative assessments were perfectly reproducible. The constraints associated with the study's retrospective design were limited by the standardized, prospective, computerized collection of clinical data in our department. The lack of randomization and group matching does not appear to have influenced the methodology or the results, inasmuch as the two groups were very similar in terms of preoperative characteristics, although similar characteristics cannot replace randomization. The two groups only differed in terms of the type of femoral implant stem. This study design eliminated most sources of bias and allowed us to focus on the short-stem concept. Apart from the difference in stem length, the standard Hydra® implant has a hydroxyapatite coating (to ensure subsequent stability). The short-stem Vitae® implant lacks a hydroxyapatite coating but does have a rough, microporous surface that contributes to primary stability and secondary stability as a result of osteointegration.

The primary analysis revealed poor stability (primarily varus tilt) in the short stem group.

Migration was observed in 27.3% of patients in the group 1 (vs. 15.2% in the group 2), corresponding to the revision prompted by painful subsidence of a short-stem implant and 11 cases of severe migration. These cases of severe migration were essentially due to varus tilt of the stem in group 1. Preoperative data did not appear to have any impact on this parameter.

The results of this study showed that the most stable short stems were those with bicortical contact at the distal metaphyseal-diaphyseal support zone and those with cortical contact at the calcar femorale and lateral femoral cortex at the distal end of the stem. In contrast, stems implanted with simple cancellous bone contact (position 3) were more likely to migrate because cancellous bone anchorage alone does not provide permanent, long-lasting stability. In cases with only cancellous bone contact, migration appeared to begin early, during the first six weeks after THA.

Stem migration was confirmed with both types of stems, in terms of both axial migration and varus tilt. Axial migration was observed in both groups and can be explained by undersizing of the stems and the absence of a collar in this type of stem design. A collar would have provided more stable support at the calcar femorale to prevent stem subsidence. Manufacture of a modular stem with a collar would be technically difficult.

The lesser degree of varus tilt in the standard stem group can probably be explained by the fact that the distal end of the stem “catheterises” the femoral shaft and counteracts the moment of varus tilt. In the short stem group, these forces appear to be lowest when the stem is in contact with both cortices or in contact with the calcar femorale and the lateral femoral cortex.

Despite the presence of migration, functional outcomes were improved in both groups and the results of short stem implants were comparable to those of coated standard stems *(25)*. Five-years radiological stem migration did not appear to influence the patient’s functional outcome.

Freitag et al. *(12)* studied the risk factors for failure of the short-stem Fitmore Hip System® (Zimmer Orthopedics, Warsaw, IN, USA) in a series of 72 THAs with two years of follow-up. This study did not observe any significant influence of BMI, gender or femoral offset on radiological migration of the implant. However, a trend towards greater migration was observed in women and patients with a BMI >30.

In a series of 1,092 THAs (including seven revisions performed for stem failure), Gruner et al. *(13)* stated that the short-stem Metha® implant was contraindicated in cases of coxa vara and high dysplastic femoral neck antetorsion. Wide and short femoral necks, a deep stem position below the femoral osteotomy and implant undersizing were factors predisposing to THA failure due to migration and aseptic loosening. Gruner et al. recommended selecting patients under the age of 70 with primary osteoarthritis, avascular head necrosis and intraoperative confirmation of adequate bone quality.

In a series of 1,953 THAs with the short-stem Metha® implant, Von Lewinski et al. *(22)* reported 11 revisions for aseptic loosening due to major stem migration. These authors considered that stem undersizing, a varus position and the absence of contact with the lateral femoral cortex in a short neck were risk factors for failure by migration. Braun et al. *(2)* identified the same risk factors in a study of 50 patients using the same stem.

Mantelli et al. reported the preliminary results of a study of 287 short-stem Vitae® at two years of follow-up, with five cases of varus tilt greater than 2mm *(23)*.

The present study compared two groups of patients differing only in terms of the type of stem, whereas other studies have included patients with different cups and femoral head implants, different surgical approaches and different surgeons. We therefore compared our results with those reported in the literature (Table VII). Although published results concern stems with a range of different shapes (compared to Vitae®), the functional results of the present study were among the best.

Migration has been reported in several series and was sometimes responsible for revisional surgery. In a review of 49 publications, Van Oldenrijk et al. found that the implant survival rate ranged from 62% to 100%, depending on the study. The various published studies sometimes concerned implants with very different stems, notably in terms of the degree of bone-sparing, metaphyseal filling, anchoring mode and support site. Some researchers have tried to classify short stems *(29) (9) (10) (19)*. However, depending on the proposed classification, some stems in the same family have different geometries and biomechanical properties. In contrast, other stems are difficult to classify because they may present characteristics of more than one family. None of the proposed classifications has yet provided satisfactory definitions of the various short stems.

The long-term outcomes following severe stem migration are subject of debate. Major migration may be predictive of a poor prognosis, although osteointegration may occur after migration (as in the case of revision in our study). The patients included in the present study continue to be closely monitored in order to describe their longer-term outcomes.

In the literature, short-stem implants have primarily been used for bone-sparing primary THA in relatively young patients. As a precaution, our team has decided to temporarily suspend the use of this implant.

Table VI. — Functional and/or radiological results from 26 publications on short-stems. NR=not reported

Author	Stem	Number of patients	Mean age (years)	BMI	Follow-up (years)	Pre-op score	Post-op score	Migration	Revision
Gruner et al.(13)	Metha Aesculap, Braun	110	60 (41-72)	27.1	4	HHS: 55.8	HHS: 97.1 ±9,5	NR	0
	Metha Aesculap, Braun	50	54 (27-69)	27 (20-36)	2.4	NR	HHS: 95 (68-100)	7 cases (3- 10 mm)	1
Jahnke et al. (16)	Metha Aesculap, Braun	40	55.4 (27-77)	26.9 (18-36.7)	1	HHS: 57.4	HHS: 96.7	NR	0
Wittenberg et al. (36)	Metha Aesculap, Braun	204	60 (27-73)	27 (16-47)	4.9	HHS: 50 (22-86)	HHS: 97 (46-100)	7 cases <5 mm 1 cases 5-10 mm	9
Synder et al. (34)	Metha Aesculap, Braun	36	50.4 (21-65)	NR	1	HHS: 56.2 (30-86)	HHS: 94.1 (55-100)	0	0
Thorey et al. (35)	Metha Aesculap, Braun	151	55.7 ±9.8	NR	5.8	HHS: 46±17	HHS: 90 ±5	NR	2
Schmidutz et al. (32)	Metha Aesculap, Braun	74	55	27 ± 4	2.7	NR	NR	0.7 mm (0.3-1.1)	NR
Floerkemeier et al. (11)	Metha Aesculap, Braun ONFH	64	49.4 (17.3–67.1)	NR	2.8	HHS: 41.4 (19–75)	HHS: 90.6 (39–100)	1 case (4 mm)	0
	Metha Aesculap, Braun Primary oxarthrosis	59	59.3	NR	2.5	HHS: 43.0	HHS: 43.0	NR	0
Brinkmann et al. (4)	Metha Aesculap, Braun	24	58.7 (43-70)	27.4 (19-39)	1	NR	HHS: 96.2	1.96 mm (0–7)	0
	Nanos Smith & Nephew	26	59.7 (48-70)	27.1 (21-33)	1	NR	HHS: 96.5	2.04 mm (0–10)	0
Amenabar (1)	Nanos Smith & Nephew	147	63	NR	1	HHS: 53 (51-56)	HHS: 91 (89-93)	3 cases (4-6-7 mm)	0
Kaipel et al. (17)	Nanos Smith & Nephew	50	64 (40-81)	30.2 22.3-45)	2	HHS: 47.9	HHS: 98.1	5 cases >1.5 mm	0
Ettinger et al. (7)	Nanos Smith & Nephew	65	63±8.3	NR	5.2	HHS: 47.3 ±12.2	HHS: 97.6 ±0,6	NR	0
McCalden et al. (24)	SMF Smith & Nephew	20	62.6	30.7	2	HHS: 51.4	HHS: 90.2	0.942 mm (0-5.8) 0.9° (0.4-5.9)	1
Gustke et al. (14)	Fitmore Zimmer	500	67 (19-96)	NR	1.3	NR	NR	34 (2 -8.7 mm)	0

Freitag et al. (12)	Fitmore Zimmer	72	54 (22–75)	29 (21–51)	2	NR	NR	1.0 mm ±1.4 0.01° ±1.39	NR
Morrey et al. (28)	Mayo Zimmer	159	50.9	74.6	6.2	HHS: 66.3	HHS: 90.4	8 cases<2 mm 12 ases>2mm	3
Felez et al. (8)	Mayo Zimmer	160	63.4 (42-83)	NR	4.7	NR	NR	NR	2
Molli et al. (26)	Taperloc icroplasty Biomet	269	63 (27–91)	30.1 (19-60)	2.4	HHS: 49.9	HHS: 83.1	NR	1
Kim et al. (20)	Proxima Depuy <65 years	100	43.9 (31–50)	28.3 25.5–30.8)	7.5	HHS: 43 (17–51)	HHS: 95 (85–100)	1 case < 1 mm	0
	Proxima Depuy >65 years	100	78.9 (66–91)	30.2 28.1–32)	7.6	HHS: 36 (10–55)	HHS: 91 (61–100)	1 case < 1 mm	0
Salemyr et al. (31)	Proxima Depuy	26	62±5	27±4	2	HHS: 56 (29–68)	HHS: 95	1.71 mm (0.39-6)	1
Briem et al. (3)	CFP Link	155	59.3 (27–77)	26.5 18.5–35)	6.2	NR	NR	NR	1
Kress et al. (21)	CFP Link	38	59 (36-68)	NR	7	HHS: 42	HHS: 92	NR	1
Kendoff et al. (18)	CFP Link	117	63.8 (33-83)	NR	11.2	HHS: 53	HHS: 93 (53-98)	NR	4
Hutt et al. (15)	CFP Link	67	52 (13–69)	NR	9.3	HHS: 50 (27–77)	HHS: 91 (49-100)	NR	0
Morales de Cano et al. (27)	GTS stem Biomet	80	64.8 (43–78)	NR	1.3	PMA: 10 (8–14)	PMA: 17.4 (12-18)	5 cases (<5°)	0
Our study	Vitae Adler	44	62 (37-77)	26.2 (19-40.7)	5	HHS: 53.5 (30-90) PMA: 10.8 (6-16)	HHS: 96.4 (67-100) PMA: 17.6 (15-18)	2.2 mm (0-7) 2.7° (0-7.7)	1

CONCLUSION

Our experience with the short-stem Vitae® implant yielded satisfactory functional outcomes, despite a significant proportion of cases with severe radiological varus tilt (relative to a standard stem). With a follow-up of five-years, one case of failure (due to stem migration) requiring revision was observed in this series, corresponding to 2.2% of the study population.

Risk factors for failure and patient profiles in which a short-stem implant would be indicated could not be determined due to the small sample size of this study. Subsequent research should determine whether stem undersizing is a cause of migratory failure. The results of the present study have prompted us to reserve short-stem implants for non-obese patients with good bone quality, in whom implantation of a standard stem is impossible (due to a small femur).

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