High Rates of Satisfaction and Return to Dance in Current or Former Professional Ballet Dancers After Total Hip Arthroplasty With a Muscle-Sparing Direct Anterior Approach Using Custom Femoral Stems

Alexis Nogier,*†‡ MSc, MD, Idriss Tourabaly,†‡ MSc, MD, Sonia Ramos-Pascual,§‖ MEng, PhD, Mo Saffarini,§ MEng, MBA, FRSM, Elodie Baraduc,‡ DC, Xavière Barreau,¶ MD, and Cyril Courtin,* MD

Investigation performed at Service de Chirurgie Orthopédique, Clinique Malsains Nollet, Ramsay Santé, Paris, France and at Service de Chirurgie Orthopédique, Clinique Trenel, Sainte-Colombe, France

Background: Professional ballet dancers have high expectations after total hip arthroplasty (THA), particularly if they intend to resume dancing as performers or teachers.

Purpose: To report clinical outcomes and return to dance after THA with a muscle-sparing direct anterior approach using a custom femoral stem in a cohort of current or former professional ballet dancers.

Study Design: Case series; Level of evidence, 4.

Methods: Twenty-three patients (26 hips) were included, that identified as current or former professional ballet dancers, from a consecutive series of 1699 hips that underwent primary THA by 1 of 2 surgeons. Both surgeons routinely implanted custom femoral stems using a muscle-sparing direct anterior approach in active and/or high-demand patients. All patients completed a questionnaire postoperatively that assessed dance capabilities, the visual analog scale (VAS) for hip pain (0-10), the VAS for satisfaction with surgery (0-10), the Oxford Hip Score (OHS), and the Forgotten Joint Score (FJS).

Results: The initial cohort comprised 19 women and 4 men, with a mean age of 50.5 ± 14.9 years and a mean 38.0 ± 14.4 years of dance experience. One patient underwent revision THA for a leg-length discrepancy, leaving 22 patients (25 hips) with a mean follow-up of 3.4 ± 1.4 years. The mean VAS satisfaction score was 9.8 ± 0.6, and the mean VAS pain score was 0.5 ± 1.0. The postoperative OHS and FJS were 46 ± 2 and 92 ± 15, respectively. Overall, 16 patients resumed ballet at 5.1 ± 3.9 months, 3 resumed other types of dance, and 3 did not resume any type of dance. None of the 6 patients who did not resume ballet indicated pain in the operated hip as the reason for stopping.

Conclusion: In current or former professional ballet dancers, THA by a muscle-sparing direct anterior approach using a custom femoral stem yielded excellent clinical outcomes at a minimum of 2 years, with the highest satisfaction score of 10 points reported for 88% of hips and 72% of hips being totally pain free. Furthermore, 73% of patients resumed ballet, and 86% resumed dance in general.

Keywords: total hip arthroplasty; custom femoral stem; professional ballet dancer; direct anterior approach; clinical outcomes

Professional dancers spend many hours training during their childhood and early adulthood,[3,7] exposing their lower limbs to intense repetitive loading and extreme range of motion (ROM). The prevalence of joint injuries in professional dancers is greater than in the general population, which could make them more susceptible to requiring arthroplasty at a younger age.[2,9,21]

In contrast to the general population, professional dancers have high expectations after total hip arthroplasty (THA), particularly ballet dancers, for whom the recuperation of ROM can be of paramount importance.[19] Custom femoral stems may be advantageous over off-the-shelf

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stems because they facilitate an accurate restoration of 3-dimensional (3D) extramedullary hip architecture, notably femoral offset and femoral anteversion, which can improve ROM; furthermore, they maximize metaphyseal fit and fill, thereby increasing both rotational and axial stability.[20] In addition, a recent systematic review showed that custom stems provide good clinical outcomes, low complication rates, and excellent survival.[16]

In our experience, ballet dancers are reluctant to undergo THA if they know of peers who had disappointing outcomes. This may explain why there are only 4 published studies presenting the outcomes of dancers after THA, which further indicate the rarity of this type of surgery for this high-demand population. It is also possible that very few dancers need THA, making it difficult to study a large-sized cohort. Buyls et al[4] reported pain relief and return to dance in 9 dancers, without specifying the THA surgical approach used; however, most were disappointed with the prolonged rehabilitation period. Komiyama et al[12] reported on 2 recreational dancers who underwent surgery via a posterolateral approach and were satisfied with their ability to return to dance, with both able to perform complex ranges of hip movements and activity-dependent kinematics. Mizoguchi et al[14] reported on an experienced jazz dance instructor who underwent simultaneous bilateral THA using a transtrochanteric approach and the tailored postoperative physical therapy program that she followed. Morio et al[15] reported on a retired professional ballet dancer who underwent bilateral THA and was able to regain most of her prearthritic ROM, being able to perform the split position.

For the past decade, we have routinely implanted a custom femoral stem by a muscle-sparing direct anterior approach in all active and/or high-demand patients requiring THA. The purpose of the present study was to report clinical outcomes and return to dance after THA by a muscle-sparing direct anterior approach using a custom femoral stem in a cohort of current or former professional ballet dancers.

METHODS

We retrospectively reviewed the records of 1699 consecutive hips that underwent primary THA, operated under the care of 2 senior surgeons (A.N., I.T.) between June 1, 2014, and October 31, 2019. Patients were included in the study if they had undergone primary THA by a direct anterior approach using custom femoral stems. Patients were excluded from the study if they were neither current nor former professional ballet dancers. During this time period, the surgeons systematically implanted a custom femoral stem by a muscle-sparing direct anterior approach in all active and/or high-demand patients (1207 hips); otherwise, they implanted a standard femoral stem also by a muscle-sparing direct anterior approach in inactive and/or elderly patients (492 hips). All patients were asked to indicate their current profession and sports activities. A total of 60 patients (69 hips; 4.1%) indicated dance as a profession or sports activity, of which 23 patients (26 hips; 1.5%) were current or former professional ballet dancers (Figure 1). The protocol for this study received institutional review board approval, and the study patients provided informed consent for their data to be used for research and publication purposes.

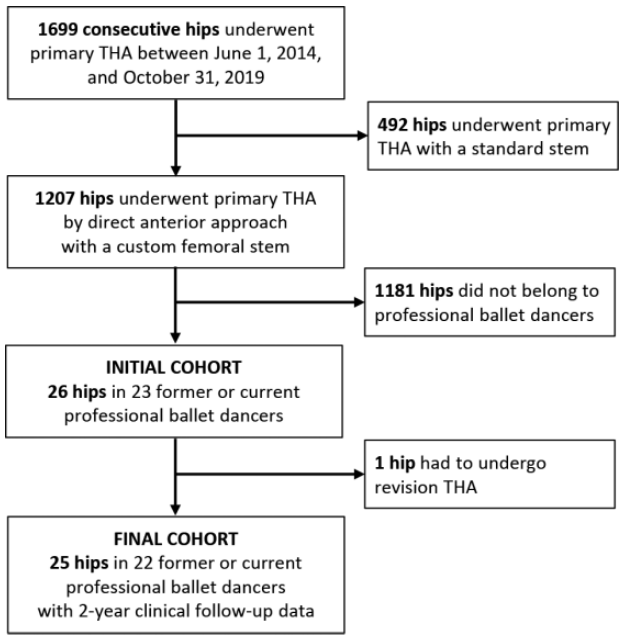

Figure 1. Flowchart of the patient inclusion process. THA, total hip arthroplasty.

Preoperative Planning

Preoperative planning was performed using computed tomography (CT) to assess hip morphology in all patients scheduled to receive a custom femoral stem. The design of

‖Address correspondence to Sonia Ramos-Pascual, MEng, PhD, ReSurg, Rue Saint-Jean 22, 1260 Nyon, Switzerland (email: journals@resurg.com).
*Service de Chirurgie Orthopédique, Clinique Trenel, Sainte-Colombe, France.
†Service de Chirurgie Orthopédique, Clinique Maussins Nollet, Ramsay Santé, Paris, France.
‡Clinique Nollet, Paris, France.
§ReSurg, Nyon, Switzerland.
¶Service de Médecine de la Danse, Opéra National de Paris, Paris, France.
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Ethical approval for this study was obtained from Ramsay Santé (No. COS-RGDS-2022-02-001-NOGIER-A).

TABLE 1
Characteristics of Custom Stems Used in Study Patients[a]

	Fixation Type	
	Cementless	Cemented
Proximal geometry	Metaphyseal engaging	Metaphyseal engaging
Length	Standard	Standard
Material	Titanium alloy	Stainless steel
Coating	Proximal two-thirds with hydroxyapatite coating	None
Management strategy		
Femoral offset	Reproduce native (prearthritic) femoral offset in primary OA; otherwise, correct deformity	Reproduce native (prearthritic) femoral offset in primary OA; otherwise, correct deformity
Femoral anteversion	Reproduce native (prearthritic) femoral anteversion	Reproduce native (prearthritic) femoral anteversion

[a]Characteristics are listed according to the classification recommended by Nogier et al.[16] OA, osteoarthritis.

all custom stems (Symbios) was based on preoperative CT, which were fine-tuned by the surgeon to ensure that they matched patient anatomy and corrected architectural hip deformities.

Surgical Technique

All the procedures were performed using a muscle-sparing direct anterior approach (Hueter or modified Hueter[17]), without the release of any muscles or ligaments, including the external rotators. The patient was placed under general or spinal anesthesia in the supine position on a traction table. Femoral head-neck resection was performed at the level designated during preoperative planning to ensure stem stability. The femur was prepared using a curette and then using a single custom stainless-steel broach. Capsulotomy with anatomic repair was generally performed, except in cases of capsular retraction. None of the cases had abductor, tensor fasciae latae, piriformis, or external rotator release.

The characteristics of custom stems are described according to the classification recommended in a recent systematic review[16] (Table 1). The acetabular cup was an off-the-shelf cementless hemispheric April cup (Symbios) with a ceramic-on-ceramic bearing for 23 hips, a custom-made cementless hemispheric April cup (Symbios) with a ceramic-on-polyethylene bearing designed to lateralize the center of rotation for 2 hips, and an off-the-shelf dual-mobility Serenity cup (Symbios) with a metal-on-polyethylene bearing for 1 hip, which corresponded to the only patient aged >70 years at index THA. The femoral head size was 28 mm for 2 hips, 32 mm for 19 hips, and 36 mm for 5 hips.

Postoperative Management and Rehabilitation Protocol

Immediately after surgery, partial weightbearing with the use of crutches was allowed. Within the first 4 weeks, passive rehabilitation was started progressively to recover full ROM in all directions; if needed, pain was managed with massages, ice treatment, analgesics, and ultrasound/Tecar therapy. Soon afterward, active nonweightbearing rehabilitation was initiated, adapted to the level of pain; this included cardiovascular training on cycling machines as well as muscle strengthening and full-body conditioning (hip, foot, ankle, core, and upper limbs if needed). After 4 to 6 weeks, active progressive weightbearing rehabilitation was started for global strengthening and proprioception. After 8 weeks, functional training specific to ballet was initiated, including static positions (*relevé*, *dégagé*, *plié*, *reprise de la barre*) and teaching. After 16 weeks, active dancing, including turning and jumping, as well as performing were allowed if the following criteria were met: (1) pain free; (2) symmetric ROM (with no limitations); (3) symmetric isokinetic muscle strength (maximum 15% difference in dynamometer measurements between ipsilateral and contralateral sides) and good muscular balance of the psoas, gluteus maximus, abductors, adductors, internal rotators, and external rotators; and (4) good alignment of the lower limbs during dance movements.

Postoperative Assessment

At a minimum follow-up of 2 years, patients were asked to complete a dance-specific questionnaire, comprising a modified version of the questionnaire developed by Ukwuani et al.[22] Additionally, patients were clinically evaluated using the Oxford Hip Score (OHS; 0 = worst, 48 = best), Forgotten Joint Score (FJS; 0 = worst, 100 = best), Short Form–12 (SF-12; 0 = worst, 100 = best), and University of California, Los Angeles activity score (1 = worst, 10 = best). Pain in both hips and satisfaction with surgery were evaluated with a visual analog scale (VAS; 0 = no pain/very dissatisfied; 10 = very severe pain/very satisfied).

Statistical Analysis

Descriptive statistics were used to summarize the data. The Kruskal-Wallis test was performed to compare the data among patients who returned to ballet at the same or higher level versus those who returned to ballet at a lower level versus those who did not return, while the Wilcoxon rank-sum test was performed to compare patients who returned to the same or higher level versus those who returned to a lower level. Univariable linear regression

analysis was performed to determine the associations of 3 continuous outcomes (postoperative OHS, postoperative FJS, and time to return to dance) and 1 categorical outcome (return to dance) with 9 independent variables (sex, age, body mass index, indication for surgery, operated side, femoral head size, years of dance experience, hours per week of dance practice before surgery, and ability to dance at usual pace before surgery). Multivariable linear regression analysis was performed after backward selection of pertinent variables using the Akaike information criterion.[1] The variable "years of dance experience" was not included in the Akaike information criterion method because of its strong collinearity with the variable "age" ($R = 0.81$; $P < .01$). Statistical analyses were conducted using R version 3.6.1 (R Foundation for Statistical Computing). P values $<.05$ were considered statistically significant.

RESULTS

The initial cohort of 23 current or former professional ballet dancers (26 hips) comprised 19 women and 4 men, with a mean age of 50.5 ± 14.9 years (range, 15-82 years) at index THA, and 19 of 23 patients aged ≤60 years (Table 2). Their mean dance experience was 38.0 ± 14.4 years (range, 12-66 years), and they practiced dance for 29.5 ± 19.4 h/wk (range, 6-80 h/wk). Reasons for surgery were primary osteoarthritis (OA) in 8 hips, secondary OA due to dysplasia in 16 hips (all classified as Crowe grade 1), secondary OA due to Perthes disease in 1 hip, and severe chondral lesion in 1 hip. Overall, 23 hips received titanium-alloy hydroxyapatite-coated cementless stems, while 3 hips received smooth stainless-steel cemented stems because of poor-quality bone and/or osteoporosis. All stems had a fit-and-fill design, which was equal for cementless and cemented stems, although cemented stems were slightly smaller to leave space for a thin cement mantle. Only 1 of the ballet dancers reported articular noise after index THA during extreme exercising (hyperextension in supine position with hips in full external rotation and abduction) but not while dancing.

TABLE 2
Demographics and Dance Characteristics of Initial Cohort (n = 23)[a]

	Value
Age at surgery, y	50.5 ± 14.9 (15.1-82.3)
Body mass index	20.7 ± 2.9 (16.2-25.6)
Dance experience before surgery, y	38.0 ± 14.4 (12.0-66.0)
Dance practice before surgery, h/wk	29.5 ± 19.4 (6.0-80.0)
Range of motion, deg	
Flexion	90 ± 31 (40-150)
Abduction	39 ± 30 (0-110)
Adduction	17 ± 13 (0-40)
External rotation	35 ± 29 (0-80)
Internal rotation	10 ± 12 (0-40)
Type/position of dancer (not mutually exclusive)	
Dance school	7 (30.4)
Professional classical dance company	11 (47.8)
Soloist	6 (26.1)
Dance conservatory	4 (17.4)
Corps de ballet[b]	3 (13.0)
Other	7 (30.4)
Female sex	19 (82.6)
Bilateral hip replacement	3 (13.0)
Ability to dance at usual pace before surgery	
Unchanged	0 (0.0)
Reduced training load/hours	10 (43.5)
Stopped dancing completely	13 (56.5)
Reason for reducing/stopping dance before surgery (not mutually exclusive)	
Pain or discomfort	22 (95.7)
Loss of interest	1 (4.3)
Lack of resources	1 (4.3)
Other	2 (8.7)

[a]Data are reported as mean ± SD (range) or n (%).
[b]Permanent part of a ballet company that often works as a backdrop for principal dancers.

Complications

There were 3 complications (11.5%) in this series, one of which required implant removal, but there were no cases of dislocation. The patient who required implant removal was aged 49 years at index THA and underwent head and cup revision after 6 months because of a severe leg-length discrepancy and was thus excluded from the final cohort (patient did not return to ballet after revision THA). The other 2 patients reported psoas-related pain: the first patient at 5 months, with the surgeon performing CT, which revealed iliopsoas impingement against preexisting osteophytes. The patient received physical therapy, balneotherapy, and corticosteroid infiltration. At a follow-up of 2.3 years, this patient was satisfied with surgery (VAS = 8), with an OHS of 48 and an FJS of 100, despite some residual pain in the operated hip (VAS = 4). The second patient reported persistent pain at 24 months, and thus, the surgeon performed CT, which revealed iliopsoas bursitis. The patient received corticosteroid infiltration. At a follow-up of 2.9 years, this patient was satisfied with surgery (VAS = 8), with an OHS of 45 and an FJS of 85, despite slight residual pain in the operated hip (VAS = 2).

Clinical and Functional Outcomes

The final cohort comprised 22 current or former professional ballet dancers (25 hips) who were clinically assessed at a mean follow-up of 3.4 ± 1.4 years (Table 3). VAS scores for satisfaction with surgery were 10 points in 22 hips, 9 points in 1 hip, and 8 points in 2 hips, while VAS scores for pain in the operated hip were 0 points in 19 hips, 1 point in 2 hips, 2 points in 3 hips, and 4 points in 1 hip. There were no significant differences in clinical or functional outcomes among patients who returned to ballet at the same or higher level versus those who returned to ballet at a lower level versus those who did not return ($P > .05$) (Table 4). However, it is worth noting that trends may appear to be nonsignificant because of insufficient

subgroup sizes (type II error); for instance, the SF-12 physical component score was worst for the patients who returned to a lower level ($P = .057$), and the SF-12 mental component score was best for the patients who returned to the same or higher level ($P = .338$). There were no significant differences in outcomes between patients who received cementless versus cemented custom stems ($P > .10$).

TABLE 3
Clinical and Functional Outcomes of Final Cohort (n = 22)[a]

	Value
Follow-up, y	3.4 ± 1.4 (2-6)
Oxford Hip Score	46 ± 2 (39-48)
Forgotten Joint Score	92 ± 15 (38-100)
SF-12 physical component score	93 ± 6.5 (75-100)
SF-12 mental component score	92 ± 7.7 (75-100)
UCLA score	9.5 ± 0.8 (7-10)
VAS pain score	0.5 ± 1.0 (0-4)
VAS satisfaction score	9.8 ± 0.6 (8-10)
Range of motion, deg	
Flexion	132 ± 17 (100-160)
Abduction	72 ± 20 (40-90)
Adduction	27 ± 9 (15-40)
External rotation	65 ± 16 (40-90)
Internal rotation	24 ± 15 (5-70)
Return to ballet	
Did not return	6 (27.3)
Returned to lower level[b]	7 (31.8)
Returned to same level[b]	4 (18.2)
Returned to higher level[b]	5 (22.7)
Time to return,[c] mo	5.1 ± 3.9 (1-14)
Dance practice,[c] h/wk	20.0 ± 19.4 (1-80)

[a]Data are reported as mean ± SD (range) or n (%). SF-12, Short Form–12; UCLA, University of California, Los Angeles; VAS, visual analog scale.
[b]Compared with before symptoms started.
[c]Data for 16 patients who returned to ballet after hip replacement.

Return to Dance

Of the 22 patients in the final cohort, 16 (72.7%) resumed ballet after THA, 3 (13.6%) returned to other types of dance, and 3 (13.6%) did not return to any type of dance (Table 5). All 6 patients who did not return to ballet indicated "loss of interest" as one of the reasons, 2 patients also indicated "fear of getting hurt," 1 patient also indicated "pain or discomfort in the contralateral hip," and 1 patient also indicated "loss of pleasure." It is important to note that for the 6 patients who did not return to ballet after surgery, none indicated the reason to be "pain or discomfort in the operated hip," and hours per week of dance practice were more than double for patients who returned to ballet at their previous level or better compared to those who returned to ballet at a lower level (26.4 ± 23.3 vs 11.9 ± 9.0 h/wk, respectively), although the difference was nonsignificant ($P = .135$) possibly because of insufficient subgroup sizes (type II error) (Table 4).

Regression Analyses

Univariable analysis revealed that the postoperative OHS improved with age ($\beta = 0.1$; $P = .005$) and dance experience ($\beta = 0.1$; $P = .021$), while backward selection for multivariable analysis identified no pertinent variables regarding the OHS (Table 6). Univariable analysis also revealed that the postoperative FJS improved with

TABLE 4
Clinical and Functional Outcomes Stratified by Return to Ballet (n = 22)[a]

	Returned to Same or Higher Level (n = 9)	Returned to Lower Level (n = 7)	Did Not Return (n = 6)	P[b]
Follow-up, y	3.3 ± 1.3 (2-5)	3.0 ± 1.5 (2-6)	4.1 ± 1.5 (2-6)	.321
Oxford Hip Score	45.8 ± 3.0 (39-48)	46.1 ± 2.5 (42-48)	46.7 ± 1.5 (45-48)	.872
Forgotten Joint Score	87.7 ± 21.4 (38-100)	94.6 ± 9.2 (75-100)	96.9 ± 5.9 (85-100)	.769
SF-12 physical component score	92.1 ± 8.2 (75-100)	86.9 ± 7.4 (75-96)	96.5 ± 4.1 (92-100)	.057
SF-12 mental component score	94.4 ± 8.1 (75-100)	91.4 ± 5.6 (85-100)	93.3 ± 5.2 (85-100)	.338
UCLA score	9.9 ± 0.3 (9-10)	9.6 ± 0.5 (9-10)	9.0 ± 1.3 (7-10)	.177
VAS pain score	0.4 ± 0.9 (0-2)	0.9 ± 1.5 (0-4)	0.3 ± 0.8 (0-2)	.622
VAS satisfaction score	9.9 ± 0.3 (9-10)	9.7 ± 0.8 (8-10)	9.7 ± 0.8 (8-10)	.919
Range of motion, deg				
Flexion	134 ± 12 (120-160)	134 ± 22 (100-160)	124 ± 13 (110-140)	.441
Abduction	73 ± 20 (50-90)	74 ± 21 (40-90)	68 ± 22 (40-90)	.870
Adduction	26 ± 10 (15-40)	29 ± 9 (20-40)	27 ± 8 (20-40)	.719
External rotation	63 ± 11 (50-80)	71 ± 16 (40-90)	66 ± 22 (40-85)	.514
Internal rotation	21 ± 12 (5-40)	28 ± 20 (10-70)	25 ± 15 (10-45)	.812
Time to return,[c] mo	6.0 ± 5.1 (1-14)	4.0 ± 1.2 (3-6)	—	.870
Dance practice,[c] h/wk	26.4 ± 23.3 (5-80)	11.9 ± 9.0 (1-26)	—	.135

[a]Data are reported as mean ± SD (range). SF-12, Short Form–12; UCLA, University of California, Los Angeles; VAS, visual analog scale. Dashes indicate not applicable.
[b]The Kruskal-Wallis test was performed to compare the 3 groups, while the Wilcoxon rank-sum test was performed to compare patients who returned to the same or higher level versus those who returned to a lower level; note that trends may appear as nonsignificant because of insufficient subgroup sizes (type II error).
[c]Data for patients who returned to ballet after hip replacement.

TABLE 5
Characteristics of Patients in Final Cohort Who Did Not Return to Dance After Surgery (n = 6)[a]

	Patient 1	Patient 2	Patient 3[b]	Patient 4	Patient 5	Patient 6
Age at surgery, y	52	69	59	61	46	64
Sex	Female	Female	Female	Male	Female	Female
Operated side	Bilateral	Bilateral	Left	Left	Right	Left
Indication for surgery	Secondary OA due to dysplasia	Secondary OA due to dysplasia	Primary OA	Primary OA	Secondary OA due to dysplasia	Secondary OA due to dysplasia
Dance experience, y	50	65	42	40	25	32
Dance practice, h/wk	6	36	13	12	12	70
Ability to dance at usual pace before surgery	Stopped dancing completely	Stopped dancing completely	Reduced training load/hours	Stopped dancing completely	Stopped dancing completely	Stopped dancing completely
Reason for reducing/stopping dance before surgery	Pain or discomfort, other	Pain or discomfort	Pain or discomfort	Pain or discomfort	Pain or discomfort, loss of interest	Other
Any dancing after surgery	None	Ballroom dancing	Contemporary dancing	Salsa, tango, ballroom dancing	None	None
Reason for stopping ballet after surgery	Loss of interest	Loss of interest	Loss of interest, fear of getting hurt	Loss of interest, fear of getting hurt	Contralateral hip pain/ discomfort, loss of interest, loss of pleasure	Loss of interest
Postoperative outcomes						
Oxford Hip Score	48	48	45	46	45	48
Forgotten Joint Score	100	100	85	100	96	100
VAS pain score	0	0	2	0	0	0
VAS satisfaction score	10	10	8	10	10	10

[a]OA, osteoarthritis; VAS, visual analog scale.
[b]This patient had iliopsoas bursitis, treated by corticosteroid infiltration.

TABLE 6
Factors Associated With Clinical Outcomes and Return to Ballet[a]

	Oxford Hip Score (n = 22)		Forgotten Joint Score (n = 22)		Return to Ballet (n = 22)		Time to Return (n = 16)	
	β[b] (95% CI)	*P*	β[b] (95% CI)	*P*	OR (95% CI)	*P*	β[b] (95% CI)	*P*
Age at surgery	0.1 (0.0 to 0.2)	.005	0.4 (0.0 to 0.9)	.035	0.94 (0.8 to 1.0)	.147	–0.2 (–0.3 to –0.1)	.005
Body mass index	0.2 (–0.1 to 0.6)	.198	1.9 (–0.3 to 4.0)	.081	0.68 (0.4 to 1.0)	.063	0.2 (–0.5 to 1.0)	.484
Male sex	–0.2 (–3.0 to 2.7)	.904	9.3 (–7.9 to 26.4)	.273	1.15 (0.1 to 26.4)	.910	5.2 (0.4 to 9.9)	.034
Operated side: left	0.3 (–2.0 to 2.5)	.816	–4.7 (–18.2 to 8.8)	.475	0.50 (0.1 to 3.4)	.488	1.5 (–2.8 to 5.8)	.464
Dance experience before surgery	0.1 (0.0 to 0.2)	.021	0.3 (–0.1 to 0.8)	.136	0.97 (0.9 to 1.0)	.470	–0.1 (–0.3 to 0.0)	.027
Dance practice before surgery (h/wk)	0.0 (0.0 to 0.1)	.610	0.0 (–0.4 to 0.4)	.999	1.02 (1.0 to 1.1)	.451	0.0 (–0.2 to 0.1)	.480
Indication for surgery								
Secondary OA due to dysplasia	Reference		Reference		Reference		Reference	
Primary OA	–0.4 (–2.3 to 1.5)	.665	–6.4 (–14.9 to 2.1)	.134	1.11 (0.2 to 10.1)	.919	–2.7 (–7.1 to 1.7)	.212
Secondary OA due to Perthes disease[c]	—		—		—		—	
Severe chondral lesion[c]	—		—		—		—	
Ability to dance at usual pace before surgery								
Unchanged[c]	—		—		—		—	
Reduced training load/hours	Reference		Reference		Reference		Reference	
Stopped dancing completely	0.4 (–1.8 to 2.6)	.686	2.2 (–11.5 to 15.8)	.746	0.16 (0.0 to 1.3)	.123	3.0 (–0.9 to 7.0)	.122
Femoral head size								
28 mm[c]	—		—		—		—	
32 mm	Reference		Reference		Reference		Reference	
36 mm	–0.6 (–3.3 to 2.1)	.650	8.2 (–8.1 to 24.5)	.304	1.82 (0.2 to 40.6)	.630	4.2 (–0.1 to 8.5)	.057

[a] Dashes indicate not applicable. OA, osteoarthritis, OR, odds ratio.
[b]Expected difference.
[c]Subgroup excluded from regression analysis because it comprised <5 patients.

age (β = 0.4; *P* = .035), while backward selection for multivariable analysis identified no pertinent variables regarding the FJS.

Univariable analysis revealed no significant associations between return to ballet and any of the independent variables, but the likelihood of return to ballet tended to

decrease with age (odds ratio [OR], 0.94; $P = .147$), with body mass index (OR, 0.68; $P = .063$), and for patients who completely stopped dancing before surgery (OR, 0.16; $P = .123$) (Table 6). Backward selection for multivariable analysis identified no pertinent variables regarding return to ballet. Univariable analysis also revealed that time to return to ballet was significantly greater for male participants ($\beta = 5.2$ months; $P = .034$), while it decreased with age ($\beta = –0.2$ months per year of age; $P = .005$) and dance experience ($\beta = –0.1$ months per year of experience; $P = .027$). Backward selection for multivariable analysis identified no pertinent variables regarding time to return to dance.

DISCUSSION

The most important findings of this study are that in current or former professional ballet dancers, THA performed by a muscle-sparing direct anterior approach using custom femoral stems yielded excellent clinical outcomes at a minimum follow-up of 2 years. Notably, the highest satisfaction score of 10 points was reported for 88% of the hips, while satisfaction scores between 8 and 9 points were reported for the remaining 12%. Moreover, 72% of the operated hips were totally pain free, while the remaining 28% had some residual pain with 1 to 4 points. Finally, 73% of patients resumed ballet, and 86% resumed dance in general. It is important to note that for 27% of patients who did not return to ballet after surgery, none indicated the reason to be pain or discomfort in the operated hip.

The present case series differs from the typical cohort scheduled for THA in terms of patient age, hip morphology, ROM, and level of activity. Most patients (83%) were 60 years or less at index THA, and the majority (62%) had some degree of developmental hip dysplasia, a common condition in the ballet population.[8] All patients had at least 12 years of dance experience and practiced dance for at least 6 h/wk before their hip injury or surgery. It is interesting to note that some dancers in the present series sought medical consultation at the end stage of OA with severely impaired ROM. In our experience, ballet dancers are reluctant to undergo THA if they know of peers who had disappointing outcomes. Ballet dancers might therefore wait a long time before deciding to undergo THA, sometimes deferring surgery until their performing career is over. This could explain the wide age range (15-82 years) of patients in the present study. Although univariable analysis revealed age to be significantly associated with the postoperative OHS ($\beta = 0.1$; $P = .005$), the postoperative FJS ($\beta = 0.4$; $P = .035$), and time to return to ballet ($\beta = –0.2$ per year; $P = .005$), multivariable analysis did not confirm these associations.

A previous case series on 9 active dancers and dance teachers after THA, for which the surgical approach was not specified, reported frequent disappointment with the speed of postoperative rehabilitation, even though it was objectively normal and often faster compared to that in nondancers.[4] The authors postulated that disappointment could be caused by dancers' high demands and expectations, in view of the favorable results of THA in the general population, which is considerably older and less active. The findings of the present study are in contrast to this previous report, as all patients were satisfied or very satisfied with their surgery, and only 14% did not return to dance but specified that this was not because of pain or discomfort in the operated hip. For those patients who returned to ballet, a statistically significant association was found between age and time to return to dance, with older patients returning to dance faster, possibly because their level and/or intensity was lower than that of younger patients.

A recent meta-analysis by Magan et al[13] investigated return to sports after THA. From 11 eligible studies on 2297 patients, the authors reported an overall adjusted return-to-sports rate of 84% (95% CI, 71%-94%) at the end of the follow-up period, which ranged between 4 and 48 months. Interestingly, the authors found that postoperatively, there was a shift away from high-impact sports, with more patients turning to lower impact sports compared to their preinjury level of sporting function. Furthermore, a recent study by Ukwuani et al[22] investigated return to dance after hip arthroscopic surgery for femoroacetabular impingement in competitive, intermediate, and recreational dancers. The authors reported that 62 of 64 patients (97%) returned to dance at an average of 7 ± 3 months; 40 dancers (63%) returned to a better level of participation, 20 (31%) to the same level, and 2 (3%) to a lower level. Nonetheless, there was a decrease in the number of hours of dance (from 11.5 ± 8.2 to 9.0 ± 7.3 h/wk; $P = .041$). In the present study, there was also a decrease in the number of hours of dance practice (from 29.5 ± 19.4 to 20.0 ± 19.4 h/wk), but compared to Ukwuani et al,[22] the rate of return to ballet was lower (73%), although the time to return was shorter (5.1 ± 3.9 months). Furthermore, in the present study, 5 dancers (23%) returned to a better level, 4 (18%) to the same level, and 7 (32%) to a lower level, with patients who returned to ballet at the same or better level dancing for more than double the number of hours compared to those who returned to ballet at a lower level (26.4 ± 23.3 vs 11.9 ± 9.0 h/wk, respectively). It is important to note that recovery after THA is harder than that after hip arthroscopic surgery.

The use of a muscle-sparing technique (without the release of any muscles or ligaments) and/or the use of custom stems in the present case series could have contributed to the favorable outcomes and satisfaction in a cohort of high-demand patients. While one recent systematic review found no substantial differences in hip morphology among dancers versus nondancers,[16] another recent systematic review found that ballet dancers more frequently display pincer morphology rather than cam deformity.[5] The present cohort of professional ballet dancers who underwent THA had a high prevalence of developmental hip dysplasia. The use of custom stems likely facilitated the accurate restoration of 3D extramedullary hip architecture and the optimization of ROM, as suggested in a recent systematic review that showed that custom stems provide good clinical outcomes, low complication rates, and excellent survival.[16] It is interesting to note that there were no significant differences in clinical and functional outcomes between cementless and cemented stems, although there was a considerable difference in subgroup sizes (23 vs 3 hips,

respectively). The role of bearing surfaces on long-term wear could not be investigated in the present study, as results were only available at 2 years of follow-up. However, a recent network meta-analysis investigated wear rates at 10 years after THA and reported that ceramic or metal on conventional polyethylene had significantly higher wear rates than ceramic on ceramic and ceramic on highly cross-linked polyethylene,[24] which may suggest that either of these 2 bearing surfaces could be appropriate for patients undergoing high-impact activities.

Ultimately, 2 decades ago, custom stems were more than twice as expensive as off-the-shelf stems, without accounting for the cost of preoperative CT.[18,23] The cost of custom stems is decreasing as production processes become more efficient and manufacturers attain "economies of scale"; in fact, a study from 2020 reported that custom stems were only about 30% more expensive than off-the-shelf stems.[10] Furthermore, possible advantages of custom stems may be short-term savings in hospital inventory, the logistics and sterilization of instruments, and the potential to reduce long-term expenditure on reoperations and revisions, as the cost of revision THA is significantly greater than that of primary THA.[6,11]

Limitations

The current study has several limitations by virtue of its retrospective design. First, the motivation to return to ballet after THA was not recorded; thus, it remains unclear whether patients who did not return to dance were intending or expecting to do so when they opted to undergo THA. Second, this study included both current and former professional ballet dancers; thus, these findings cannot be generalized or extrapolated to active professional ballet dancers. Third, there was no comparative group of dancers who underwent surgery with off-the-shelf stems or using another surgical approach. We believe that young high-demand patients benefit from the combination of custom stems implanted by a muscle-sparing direct anterior approach (without the release of any muscles or ligaments), as this results in an accurate restoration of 3D hip anatomy (leg length, femoral anteversion, femoral offset) as well as the least soft tissue damage. Nonetheless, it is not possible to assess the relative contributions of the anterior approach versus those of the custom stems in the results reported. Fourth, the lack of preoperative clinical scores did not permit us to examine net improvements. Fifth, clinical outcomes were only collected at one time point postoperatively, which makes it difficult to assess changes in scores over time, and radiographic outcomes were not collected. Finally, the study presents satisfactory clinical scores at $\geq$2 years, suggesting good implant fixation; however, no long-term survival data were available to assess potential long-term wear in this young and active population.

CONCLUSION

In current or former professional ballet dancers, THA performed by a muscle-sparing direct anterior approach using custom femoral stems yielded excellent clinical outcomes at a minimum follow-up of 2 years, with the highest satisfaction score of 10 points reported for 88% of hips and 72% of hips being totally pain free. Furthermore, 73% of patients resumed ballet, and 86% resumed dance in general. None of the patients who did not resume ballet indicated pain or discomfort in the operated hip to be the reason for stopping.

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