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HIP ARTHROPLASTY

Blood loss in primary total hip arthroplasty with a short versus conventional cementless stem: a retrospective cohort study

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Abstract
Introduction To evaluate the impact of short cementless stem on several clinical and radiographic outcomes, with particular focus on blood loss, in comparison with conventional cementless stem in total hip arthroplasty (THA).
Materials and methods Patients undergoing THA with GTS short stem or CLS conventional stem were included. Clinical data were retrospectively collected including preoperative and postoperative day 1 value for haemoglobin (HB); rate of postoperative blood transfusions; intraoperative bone infractions; stem alignment; 5-year follow-up Harris Hip Score (HHS) and rate of stem revision at 5 years of follow-up of the short and conventional cementless stem.
Results GTS and CLS stem group included 374 and 321 patients, respectively. The mean difference between the preoperative and postoperative day 1 HB value was 3.98 g/dL (SD 1.12) and 3.67 g/dL (SD 1.19) in the GTS and CLS group, respectively, which correspond to a crude effect (β) of 0.32 (95% CI 0.15; 0.49) and adjusted effect of 0.11 (95% CI −0.08; 0.3). GTS group reported a significantly higher number of patients with excellent results in terms of HHS ($p=0.001$). The rate of intraoperative bone infractions was 1.6% and 0.3% in the GTS and CLS group, respectively ($p=0.013$). At radiographic assessment, the rate of varus position of the stem was 14% in the GTS group and 6% in the CLS group ($p<0.0001$). The rate of stem revision at 5 years of follow-up was 0.8% and 0.4% in the GTS and CLS group, respectively ($p=0.63$).
Conclusions GTS short stem was not associated with a clinically significant lower blood loss in the immediately postoperative period. Unadjusted exploratory analyses show that GTS stem provides the same results of CLS stem in terms of HHS and rate of stem revision at 5 years of follow-up.

Keywords Blood loss · Total hip arthroplasty · Uncemented · Short stem · Conventional stem

Introduction

Total hip arthroplasty (THA) with conventional cementless stems has been widely recognized as reliable and effective procedure for the management of hip diseases in both old and young people [1, 2].

Although the long-term survival rate of the cementless stems has been estimated around 94% in patients with more than 65 years, it decreases at 78% in patients between 55 and 65 years [3]. Therefore, revision surgery likely occurs once in a lifetime, and young patients could undergo multiple revisions. Several implants with conservative designs have been produced, including neck-preserving stems, metaphyseal implants, and short stems [4–11]. Recently, Khanuja et al. [12] classified short stems according with fixation principles and location of proximal loading. The authors distinguished four categories: femoral neck fixation (type I), calcar loading (type II), lateral flare and calcar loading (type III), and shortened tapered stems (type IV). All designs aim to preserve the bone in the trochanteric region, achieve a more physiological loading in the proximal femur to reduce the risk of stress shielding, and avoid a long stem into the diaphysis preventing impingement with the femoral cortex and thigh pain [13, 14].

Two recent meta-analyses of randomized controlled trials showed that short stems provide the same clinical and

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radiographic outcomes as conventional implants, and are associated with lower risk of post-operative thigh pain and superior bone remodelling [15, 16]. Moreover, some authors demonstrated that short and ultra-short stems provide the same excellent fixation of conventional cementless stems at 2 years of follow-up [17, 18].

The cementless Global Tissue Sparing (GTS) Primary Hip Stem (ZimmerBiomet) is a shortened tapered conventional stem (type IV according to Khanuja et al.) that aims to preserve the bone stock of the greater trochanter and to limit the invasion of the femoral diaphysis. For this reason, it was designed reducing the trochanteric shoulder and shortening the stem. In a biomechanical study [19], GTS stem demonstrated a comparable rotational stability to conventional CLS stem (ZimmerBiomet), even though the reduced longitudinal length and trochanteric shoulder. To our knowledge, only two studies with short-term follow-up investigated GTS stem clinical and radiographic results [9, 20] without any comparison with conventional stems. Moreover, only few studies evaluated the blood loss in primary THA with a short stem compared to a conventional stem [21, 22]. Therefore, further evidences are required to determine whether a shortened cementless stem provides similar clinical and radiographic results, and revision rate as a conventional cementless stem at mid-term follow-up.

Assuming that the short cementless stem would cause a lower bone invasivity, in this study we aim at evaluating its impact on several clinical and radiographic outcomes, with particular focus on blood loss, in comparison with conventional cementless stem.

Materials and methods

In this retrospective cohort study, we included all patients undergoing primary THA with GTS short stem or CLS conventional stem in Humanitas Research Hospital from January 2010 to December 2010. Patients with bilateral procedure in the same time or in two stage, infection, tumor, pathologic fractures, or undergoing revision THA procedures were excluded.

All patients underwent hip replacement with a standardized operative technique through a posterolateral approach [23], and received prophylactic antibiotics and routine postoperative thromboembolic prophylaxis with low molecular weight heparin. According to clinical practice, all patients underwent clinical and radiographic examination before and immediately after surgery, and 1, 3, 6, and 12 months from surgery. Subsequently, all patients were examined once per year. For each patient, all clinical data were retrospectively collected from medical records of hospital stay and follow-up consultations by one orthopaedic surgeon.

The exposure of interest was the type of stem: short stem (GTS) versus conventional stem (CLS). The stem size of GTS ranged between −6 to +6, while the size of CLS ranged from 5 to 20. Both groups included unselected patients. No selection criteria were applied to decide the type of implanted stem. The primary endpoint of the study was the difference between the preoperative value and the value recorded on day 1 postoperatively for haemoglobin (HB). The blood loss was expressed by the difference between the preoperative value and the value recorded on day 1 postoperatively for HB in patients without blood transfusion. No patients received postoperative blood transfusion the day of surgery.

The secondary endpoints included perioperative results such as the rate of postoperative blood transfusions, the intraoperative bone infractions and the stem alignment, and mid-term results such as the 5-year follow-up Harris Hip Score (HHS) [24] and the rate of stem revision at 5 years of follow-up of the short and conventional cementless stem. The HHS was retrospectively collected from follow-up consultations.

The other following data were gathered from the medical records: gender (male or female), preoperative diagnosis (osteoarthritis, osteoarthritis secondary to hip dysplasia, osteoarthritis post-trauma, femoral head avascular necrosis, femoral neck fracture, osteoarthritis secondary to slipped capital femoral epiphysis, or disarthrodesis of the hip), coagulopathies (yes or no), preoperative American Society of Anesthesiology (ASA) score (classes from I to V) [25], preoperative antiaggregant or anticoagulant therapy (yes or no), body mass index (BMI) (categorized in two classes: not overweight, BMI < 25, and overweight, BMI ≥ 25), age at surgery (years), preoperative HHS (from 0 to 100 points).

All patients had conventional radiographs in anteroposterior (AP) view of the pelvis and axial view of the hip in both preoperative and postoperative evaluations. One orthopaedic surgeon retrospectively reviewed the preoperative x-rays to confirm the diagnosis and to categorize the type of femur according to Dorr classification [26]. Type A is characterized by thick cortices beginning at the distal end of the lesser trochanter and a narrow diaphyseal canal leading to a funnel shape femur. Type B is characterized by proximal bone loss and widening of the diaphyseal canal. Type C is characterized by significant reduction of the cortical thickness with a wide intramedullary canal leading to a femur with a stove pipe shape.

In the postoperative AP view radiographs, the bone invasivity in the proximal femur was retrospectively measured by one orthopaedic surgeon. The invasion of the metaphyseal region was expressed in percentage with the following ratio: length in millimetres of the transverse section of the prosthesis in the metaphyseal region/length in millimetres of the line connecting the superior limit of the lesser trochanter with the lateral edge of the great trochanter (Fig. 1). The invasion of the femoral shaft was expressed in percentage with the following ratio: length in millimetres of the longitudinal axis of the prosthesis from the inferior limit of the lesser trochanter to the tip of the stem/length in millimetres of the line connecting the tip of the great trochanter with the tip of the stem (Fig. 1). In the postoperative AP view radiographs, the varus/valgus positioning was also retrospectively evaluated by one orthopaedic surgeon and defined with an angle between the longitudinal stem axis and the longitudinal femoral axis greater than 3° [9].

Statistical analysis

Continuous variables were expressed as mean and standard deviation (SD). Categorical variables were expressed as proportion and percentage.

We compared the two groups for all the baseline features such as gender, age, BMI, preoperative diagnosis classification, type of femur according to Dorr classification, ASA, coagulopathies, preoperative antiaggregant or anticoagulant therapy, and preoperative HHS. Continuous variables were assessed with two-tailed Student's t test or Mann–Whitney test, whereas categorical variables were assessed with the Chi squared test, with Fisher correction when necessary.

The primary endpoint was defined as the difference between the preoperative value and the day 1 postoperative value of HB. The effect of the exposure of interest (GTS versus CLS stem) on the primary endpoint has been estimated by applying univariate and multiple linear regression model. Although no selection criteria were applied to decide a priori the type of implanted stem, we considered as potential confounders for the primary endpoint all those outcome risk factors that might have affected the choice of the stem type, namely age, BMI, ASA, coagulopathies and preoperative use of antiaggregants or anticoagulants. This will allow to estimate the effect of the stem type on the blood loss accounting for the difference in the potential confounders distribution between the two exposure groups. All these variables have been included in the model as categorical variables except for the age. ASA was categorized in three classes: (1) I (reference); (2) II; (3) III and IV. Both coagulopathies and preoperative use of antiaggregants or anticoagulants were categorized as present or absent. The variables preoperative diagnosis and type of femur according to Dorr classification were not included in the model, because were not supposed to affect the primary endpoint.

The effect of the exposure of interest on the secondary endpoints has been also evaluated. In particular the comparison of the rate of postoperative blood transfusions, the intraoperative bone infractions, the stem alignment, the 5-year follow-up HHS and the rate of stem revision at 5 years of follow-up were assessed with the Chi squared test, with Fisher correction when necessary.

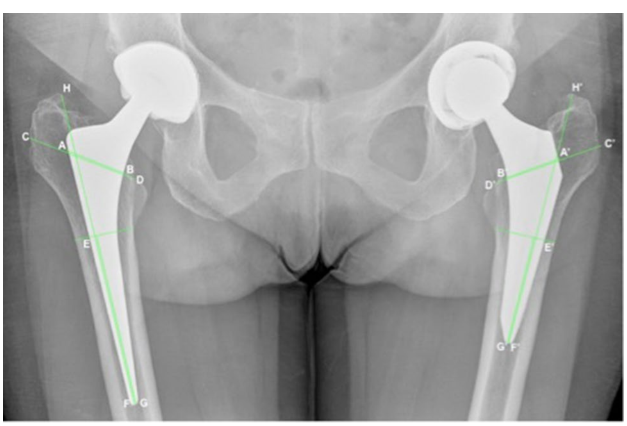

Fig. 1 X-ray, anterior–posterior view of the pelvis. Measurements of bone invasivity in metaphiseal region and femoral shaft with GTS and CLS stem. The invasion of the metaphiseal region is expressed in percentage with the ratio AB/CD in CLS stem and A'B'/C'D' in GTS stem. The invasion of the femoral shaft is expressed in percentage with the ratio EF/GH in CLS stem and E'F'/G'H' in GTS stem

Ethical approval

The present retrospective cohort study was performed with medical records of patients included in a registry of orthopaedic surgical procedures approved by the Ethical Committee of Humanitas Research Hospital and in strict accordance with the Helsinki Declaration.

Source of funding

No external funding was received for this study.

Results

The GTS stem group included 374 patients, of whom 5 died and 9 were lost to follow-up, while in the CLS stem group included 321 patients, of whom 48 died and 5 were lost to follow-up. In both groups, no deaths were related to the procedure. Thus, 360 patients in the GTS group and 268 in the CLS group were available for clinical assessment at a follow-up period of minimum 5 years. The primary endpoint and the secondary endpoints collected in the immediate postoperative period were measured using the whole sample. The baseline features of both groups are reported in Table 1. In the group of CLS stem number of females, mean age of patients, and number of ASA III patients were significantly higher. On the other hand, there was no difference between the two groups in terms of preoperative mean HB value.

The mean bone invasivity was lower in the short stem group both in the metaphyseal region (44.6% in the GTS

Table 1 Baseline features of patients in GTS and CLS stem groups

	GTS (n = 374)	CLS (n = 321)	p value
Gender N (%)			< 0.0001
Male	196 (53%)	112 (35%)	
Female	178 (47%)	209 (65%)	
Age mean (SD)	58 (12.7)	70 (9.6)	< 0.0001
BMI N (%)			0.068
Normal	118 (32%)	96 (30%)	
Overweight	256 (68%)	225 (70%)	
Diagnosis N (%)			0.003
Osteoarthritis	316 (86%)	275 (85%)	
Osteoarthritis secondary to hip dysplasia	30 (8%)	20 (7%)	
Osteoarthritis post-trauma	20 (5%)	10 (3%)	
FHAV	5 (1%)	5 (1%)	
Femoral neck fracture	0	9 (3%)	
Osteoarthritis secondary to SCFE	3 (1%)	0	
Disarthrodesis of the hip	0	2 (1%)	
Type of femur N (%)			0.029
Type A	52 (14%)	45 (14%)	
Type B	310 (83%)	251 (78%)	
Type C	12 (3%)	25 (8%)	
ANSA score (%)			< 0.0001
I	48 (13%)	14 (4%)	
II	310 (83%)	257 (80%)	
III	16 (4%)	49 (15%)	
IV	0	1 (1%)	
Coagulopathies N (%)			0.82
Yes	10 (3%)	8 (2%)	
No	364 (97%)	313 (98%)	
Antiaggregant/anticoagulant therapy N (%)			< 0.0001
Yes	30 (8%)	71 (22%)	
No	344 (92%)	250 (78%)	
Preoperative HHS mean (SD)	46.52 (6.27)	46.67 (6.04)	< 0.0001
Preoperative HB g/dL mean (SD)	14.60 (1.33)	14.02 (1.35)	0.57

BMI: body mass index; ASA: American Society of Anesthesiology; HHS: Harris Hip Score; HB: haemoglobin; FHAV: Femoral Head Avascular Necrosis; SCFE: Slipped Capital Femoral Epiphysis

group and 57.77% in the CLS group) and in the femoral shaft (42.14% in the GTS group and 56.97% in the CLS group). Figures 2, 3 show that the metaphyseal and femoral shaft bone invasivity and, therefore, the ratio bone-prosthesis remain fairly constant with increasing sizes in both groups.

The mean difference between the preoperative and postoperative day 1 HB value was 3.98 g/dL (SD 1.12) in the GTS group and 3.67 g/dL (SD 1.19) in the CLS group, which correspond to a crude effect (β) of 0.32 (95% CI 0.15; 0.49) (Table 2). When adjusting for the potential confounders this effect lowered to 0.11 (95% CI −0.08; 0.3), mainly driven by the confounding effect of the age.

The effect on the secondary endpoints is reported in Table 3. In the GTS group, 6 patients had an intraoperative bone infraction of the calcar zone, 1 patient in the CLS group. In all cases, the bone infraction was managed with a screw or cerclage wiring.

The rate of stem revision at 5 years of follow-up was 0.8% in GTS group and 0.4% in the CLS group (p = 0.63). The GTS group reported a significantly higher number of patients with excellent results in terms of HHS. Because of

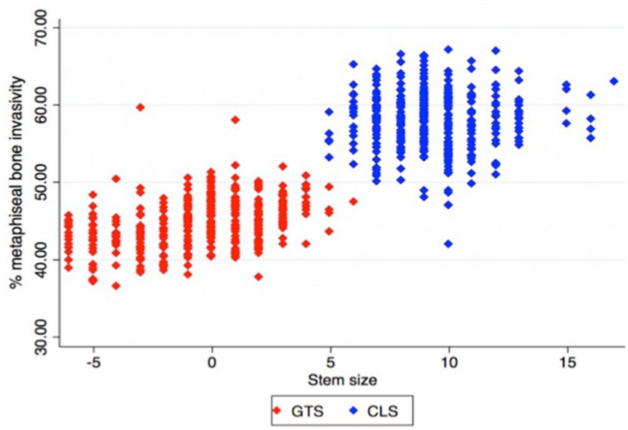

Fig. 2 Scatter plot of the metaphiseal bone invasivity according the stem size in the GTS and CLS groups

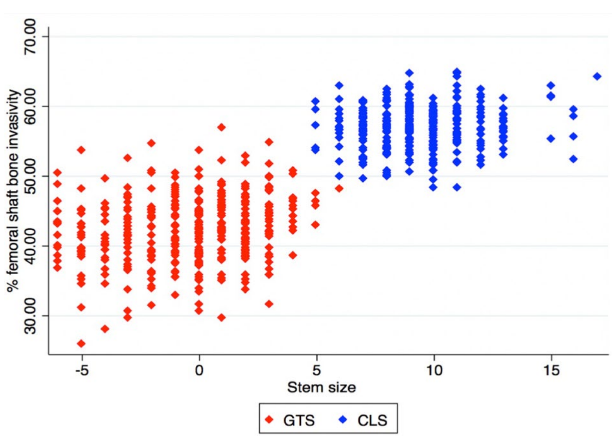

Fig. 3 Scatter plot of the femoral shaft bone invasivity according the stem size in the GTS and CLS groups

death or lost to follow-up, 14 patients in GTS group and 53 patients in CLS group were not available for the assessment of these secondary endpoints. On the other hand, the rate of varus position of the stem was higher in the GTS group compared with the CLS group (14% versus 6%).

Discussion

The main finding of the present study was that the GTS stem was not associated with a clinically significant lower blood loss in terms of difference between the preoperative and postoperative day 1 value of HB, despite it provides a significantly lower bone invasivity in both metaphyseal region and femoral shaft when compared to CLS conventional stem.

In terms of secondary outcomes, the GTS stem provided better clinical results in terms of HHS value with a rate of stem revision similar to CLS stem at 5 years of follow-up. On the other hand, the GTS stem was associated with higher rate of varus alignment and intraoperative bone infractions. However, these are crude estimates likely affected by confounding bias, that should be interpreted with caution.

Although the GTS stem was associated with a slightly higher blood loss in terms of higher reduction of postoperative day 1 value of HB when compared with CLS stem, the multiple regression analysis showed that this effect disappeared when adjusted for the potential confounders. The age was the main variable to drive this confounding effect. In this respect, we reported that older patients had lower blood loss, and these patients were more represented in the CLS group. In a previous study, Yu et al. compared a short stem versus a conventional stem in patients older than 70 years showing no difference between the two groups in terms of average estimated blood loss and average HB at discharge [21]. On the other hand, Hochreiter et al. demonstrated that both blood loss and blood transfusion rates were lower in patients undergoing short stem THA compared with those managed with straight stem THA [22]. Because of the significant variability in terms of design among the conservative stems, the results of the present study are not be applicable to all short stems. The lack of significant difference in terms of postoperative blood loss between the two groups could be explained by the comparison between a shortened tapered stem with a straight conventional stem implanted with the same posterolateral approach. In this respect, other short stems such as type I and II prosthesis according to Khanuja et al. could allow less invasive approach and less soft-tissue damage resulting in a significant reduction of blood loss compared with conventional stems.

Varus or valgus alignment of the stem has been reported in studies investigating short stems, with a rate ranging from 4% to 51% [20, 27–30]. We reported a significantly higher rate of varus position with the GTS than CLS stem (14% versus 6%), even if it was a slightly varus alignment ranging between 3° and 7°. Moreover, a short stem aims to preserve the proximal femoral anatomy; therefore, it is usually aligned with the metaepiphysis [31]. In patients with a varus alignment of the metaepiphysis respect to the femoral shaft, the stem can be positioned in varus position. On the other hands, the conventional straight stem needs to be aligned with the femoral shaft to prevent cortical fractures. However, it can results in grater loss of trochanteric bone stock, particularly in patients with a varus metaepiphysis.

In literature, intraoperative periprothesic fracture associated with short stem is another complication that occurs with a mean incidence of 1.4% and up to 7% [14]. Morales de Cano et al. [9] reported a rate of 1.2% with the GTS design. In our study, we only reported intraoperative bone infractions of the calcar zone without significant difference between the two groups.

Table 2 Association between type of stem and difference between preoperative and postoperative day 1 HB

Delta HB1	Crude effect (β)	95% CI	Adjusted effect (adjusted β)	95% CI
Type of stem				
GTS versus CLS	0.32	0.15; 0.49	0.11	− 0.08; 0.3
Age				
	–	–	− 0.01	− 0.017; − 0.002
BMI				
Overweight versus Ref*	–	–	− 0.38	− 0.56; − 0.19
ASA				
Class II versus Ref**	–	–	− 0.14	− 0.46; 0.17
Classes III–IV versus Ref**	–	–	− 0.43	− 0.86; 0.07
Antiaggregant/anticoagulant therapy				
	–	–	− 0.3	− 0.56; − 0.04
Coagulopathies				
	–	–	− 0.005	− 0.53; 0.53

Delta HB1 difference between preoperative and postoperative day 1 HB; *BMI* body mass index, *ASA* American Society of Anesthesiology

Ref*: normal weight class of BMI; Ref**: Class I of ASA

Table 3 Effect of type of stem on the secondary endpoints

	GTS	CLS	*p* value
Postoperative blood transfusions N/tot (%)	129/374 (34%)	126/321 (39%)	0.15
Intraoperative bone infractions N/tot (%)	6/374 (1.6%)	1/321 (0.3%)	0.013
Stem alignment N/tot (%)			< 0.0001
Normal	319/374 (85%)	288/321 (90%)	
Varus	52/374 (14%)	20/321 (6%)	
Valgus	3/374 (1%)	13/321 (4%)	
5-year FU HHS N/tot (%)			0.001
Poor (< 70)	6/360 (2%)	12/268 (4%)	
Fair (70–79)	11/360 (3%)	8/268 (3%)	
Good (80–89)	32/360 (9%)	50/268 (19%)	
Excellent (90–100)	311/360 (86%)	198/268 (74%)	
Stem revision at 5-year FU N/tot (%)	3/360 (0.8)	1/268 (0.4)	0.63

HHS harris hip score, *FU* follow-up

Finally, we found that GTS and CLS stems have a similar rate of stem revision at 5 years of follow-up, but the short stem is associated with a better clinical results in terms of patient reported outcome. These findings are consistent with previous studies investigating the clinical and radiographic results of several short stem designs [14, 15].

We are aware that the present study is affected by some limitations. First of all, it is a retrospective cohort study and all clinical data were retrospectively collected from medical records of hospital stay and follow-up consultations. Second limitation of the study is represented by the length of the follow-up. Although a minimum follow-up of 5 years allows us to study the osteointegration of the stems, comparative studies with longer follow-up are required to demonstrate that GTS stem can provide the same clinical and radiographic results of clinically well-established uncemented stems in the long term. Third, although no selection criteria were applied to decide a priori the type of implanted stem, the baseline features of the population in the two groups differed because of the retrospective nature of the study. We account for these differences treating the baseline features that might have affected the choice of the stem type, such as age, BMI, ASA, coagulopathies and preoperative use of antiaggregants or anticoagulants, as potential confounders fitting multivariable linear regression models. However, we acknowledge that residual confounding due to other unknown or unmeasured factors, such as the preferred choice of the surgeon, may be present. Fourth, we were not able to perform a survival analysis to investigate the stem revision rate due to the small number of events. In the crude comparison we observed no significant difference in terms of the rate of stem revisions between the two groups at 5 years of follow-up. However, the interpretation of this finding should take into account that the number of patients not available for this endpoint was higher in the CLS group than that of GTS group (53 versus 14) and most of all that confounding might affect this result. In the future, we aim to include a longer follow-up and to perform adjusted regression analyses to minimize bias associated with the assessment of secondary endpoints.

In conclusion, the GTS short stem was not associated with a clinically significant lower blood loss in the immediately postoperative period, despite it provides a significantly lower bone invasivity in the proximal femur than CLS conventional stem. Moreover, unadjusted exploratory analyses show that GTS stem provides the same results of the CLS stem in terms of HHS value and rate of stem revision at 5 years of follow-up.

Funding No external funding was received for this study.

Complaince with ethical standards

Conflict of interest Mattia Loppini received research grant from Italian Ministry of Health (GR-2018-12367275), financial support for attending symposia and educational programs from Zimmer Biomet. He is also Scientific Director of Livio Sciutto Foundation Biomedical Research in Orthopaedics – ONLUS. Guido Grappiolo received honoraria for speaking at symposia, financial support for attending symposia and educational programs from Zimmer Biomet, and royalties from Zimmer Biomet and Innomed. Antonello Della Rocca received financial support for attending symposia and educational programs from Zimmer Biomet. Davide Ferrentino and Costanza Pizzi have no conflict of interest.

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